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Performance of ramp and pitfall traps for arthropods and non-target vertebrates in Californian oak woodland and chaparral habitats

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Abstract. Selection of tools for monitoring epigeal arthropods may be limited by site characteristics and the need to reduce risk of vertebrate bycatch. We designed a ramp trap for sampling surface-active arthropod diversity and compared its effectiveness with pitfall traps. Paired transects of ten ramp and ten pitfall traps were laid out in five sites at the Hopland Research and Extension Center in California. We identified and enumerated the ground-dwelling arthropods in the samples, with an emphasis on beetles and spiders, and compared trap types using t-tests and NMDS. There was no significant difference in abundance and diversity between ramp and pitfall traps for beetles or spiders; however, there were significantly more millipedes caught by pitfall traps. The NMDS analysis of beetle assemblages distinguished between trap types; however, differences were not significant for spider assemblages. The ramp traps were more difficult to fabricate and transport because of their complexity and bulk, but they were easier and faster to setup, more resistant to disturbance, and resulted in less vertebrate bycatch. Ramp traps are a useful tool to be used alongside or as an alternative to pitfall traps.

Keywords. Sampling methods, Carabidae, Tenebrionidae, Staphylinidae, Araneae, ground-dwelling arthropods, capture efficiency.

Introduction

Pitfall trapping is a long-recognized collecting method that is effective for studying diverse assemblages of ground-dwelling arthropods (Bury et al. 1987, Work et al. 2002, Brown & Matthews 2016, Spence & Niemela 2017, Hoekman et al. 2017). The advantages of this technique over simple hand collecting include continuous sampling over extended periods of time, studying multiple sites simultaneously, having a readily quantifiable amount of collecting effort, and sampling done independent of sampler's skill or bias for particular taxa (Bostanian et al. 1983). There is substantial variation in how pitfall traps are designed and employed in the field (Brown & Matthews 2016). Numerous studies have tested different pitfall trap designs in search of the most efficient traps at capturing the greatest number of individuals and maximizing the breadth of species diversity sampled (Luff 1975, Lange et al. 2011, Siewers et al. 2014). For example, uncovered round pitfall traps yielded the highest abundance of catches (Spence & Niemela 2017), and increasing size of pitfall trap diameter yielded diminishing returns since smaller traps captured disproportionately more arthropods (Work et al. 2002). In this same vein of research, we would like to find more efficient ways of capturing arthropods while minimizing disturbance and impact on non-target organisms.

Despite their efficacy, pitfall traps cannot be used in many situations, such as where soil disturbance is not permitted, where substrate is mostly rock, or when the trap needs to be placed in a difficult to reach crevice. Installing pitfall traps can also be difficult in shallow or very wet soil. Pitfall trapping is not desirable when unwanted capture of small mammals, amphibians, and other vertebrates is a concern (Pearce et al. 2005). Ramp traps are an appealing alternative to pitfalls, as they require no digging and deployment causes minimal disturbance to the environment. Multiple ramp trap designs exist that are inexpensive, durable, easy to install, and capture a wide diversity of arthropods (Bostanian et al. 1983, Bouchard et al. 2000).

Pitfall traps can capture arthropods from all directions, whereas ramp traps can only capture arthropods in the directions that the ramps are facing, and this could influence catch rates (Bouchard et al. 2000). The expectation would be a reduction in take for ramp traps; however, the literature indicates otherwise in the few cases where pitfall and ramp traps have been compared. Different ramp trap designs have been shown to yield higher catches of large carabids (Bostanian et al. 1983), wandering spiders (Patrick & Hansen 2013), and two different species of pest weevils (Reddy et al. 2009, 2011). Ramp traps may also capture fewer non-target vertebrates (Pearce et al. 2005). Although ramp traps are effective at capturing some groups, no study has directly compared pitfall and ramp traps across diverse assemblages of arthropods, nor has any research been done on ramp trap performance across a variety of habitats.

Our study was designed using a duration and trapping effort that would be typical for a relatively short field trip or for a rapid site characterization project. The traps are relatively light-duty and differ from long-term trap systems that typically employ larger traps, anchoring hardware, and deeply dug in PVC tube sleeves. We specifically compared the efficacy of pitfall and ramp traps for capturing a wide variety of ground-dwelling arthropods that are targeted using pitfall traps, with an emphasis on spiders and beetles. Trap effectiveness was measured in terms of both total number of target individuals and the diversity of taxa caught. We also quantified vertebrate bycatch. We discuss qualitative aspects of the two trap types including durability of traps, trap disturbance events, and ease of use.

Materials and Methods

Study Site. Hopland Research and Extension Center (HREC) in Mendocino County, California, was the study site. This field research facility owned by the University of California is home to diverse and well-studied plant and animal communities. HREC has a total area of 5358 acres ranging in elevation from 150 to over 900 m and is subject to typical Mediterranean climate patterns. Summers are hot and dry (June through September), and winters have mild temperatures and are when most rain falls (October to May). Rainfall drives plant growth, limiting the growing season to the November through April period (Anonymous 2018).

We chose five locations to place traps (Fig. 1) that are located in the HREC zones designated on station maps as “pasture S1”, “James II”, “James III”, and “orchard”:

Site 1. 39°01’30”N/123°05’29”W; HREC pasture S1, 485 m elevation. This area has a relatively closed canopy. It is dominated by Douglas-fir (Pinaceae: *Pseudotsuga menziesii menziesi* Francoi), madrone (Ericaceae: *Arbutus menziesii* Pursh), and oak (Fagaceae: *Quercus* spp.). There was little herbaceous understory but a substantial number of seedling trees. It had a deep layer of leaf litter and abundant deadfall wood. The soil was mesic and somewhat gravelly.

Site 2. 39°01’43”N/123°05’38”W; HREC, James II, 460 m elevation. This area has a relatively closed canopy. It is dominated by madrone with a few oak and very few

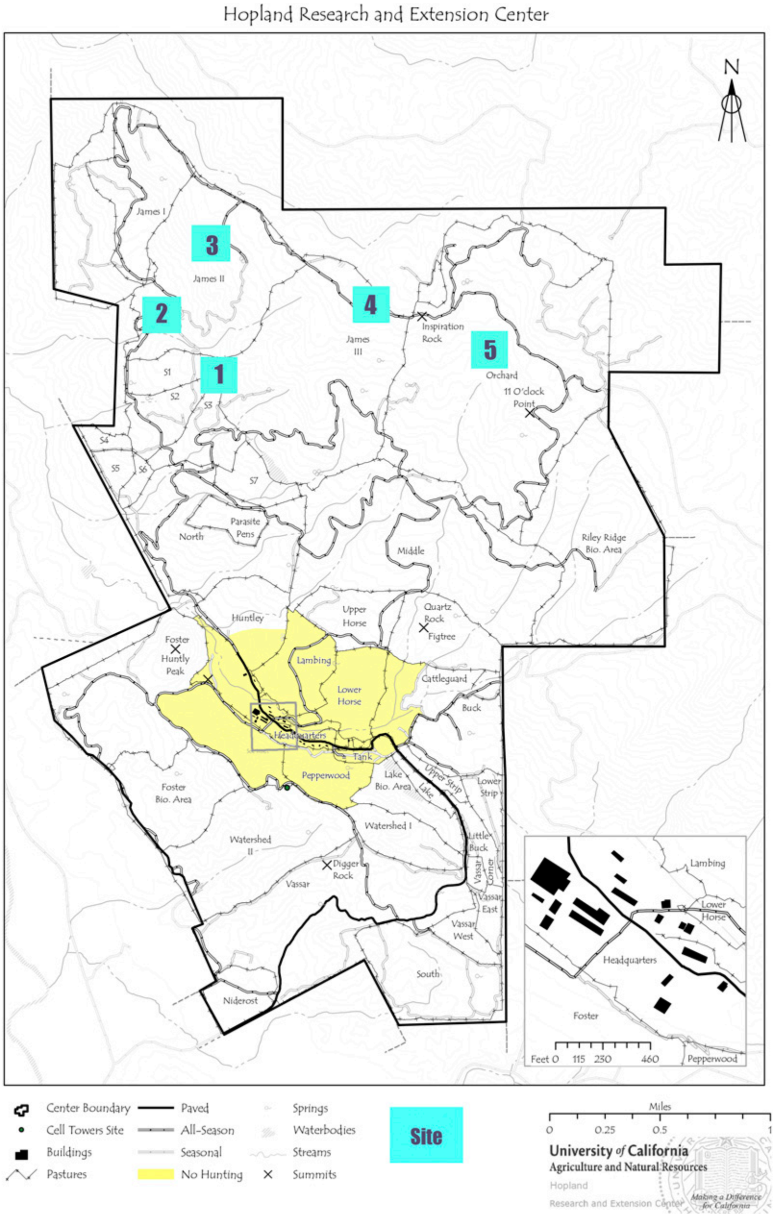

Figure 1. Map of Hopland Research and Extension Center, Hopland, California (Mendocino County). Sample sites are shown in blue. Sites were chosen to represent a variety of habitats at HREC.

Douglas-fir. There was little herbaceous understory and a shallow layer of leaf litter. The soil was relatively dry and had a significant gravel content.

Site 3. 39°01’57”N/123°05’17”W; HREC, James II, 677 m elevation. This area has a relatively open canopy in part but was mostly open pasture. The dominant tree is oak. There was significant herbaceous growth, primarily grasses. Most of the area was lacking leaf litter. The soil was very wet as an active spring was emergent in the site. The soil was heavy with clay.

Site 4. 39°01’43”N/123°04’36”W; HREC, James III, 808 m elevation. A chaparral habitat with a dense stand of MacNab cypress (Cupressaceae: *Cupressus macnabiana* Murray), surrounded by chamise (Rosaceae: *Adenostoma fasciculatum* Hook & Arn), and manzanita (Ericaceae: *Arctostaphylos* spp.). The dry, rocky soil had few herbaceous plants and was a mosaic of bare soil and piles of leaf litter.

Site 5. 39°01’41”N/123°04’02”W; HREC, Orchard, 800 m, elevation. This area has a very open canopy, mostly open pasture. The dominant tree is scattered oaks. There was significant herbaceous growth, primarily grasses. Most of the area was lacking leaf litter. There was some scattered woody deadfall present. The soil was relatively wet and rich in organic material.

Trap Construction. For pitfall traps we used standard 16 oz. polyethylene terephthalate (PET) cups, also called “red party cups.” The diameter of the opening was 95 mm and the cup height 121 mm. Rain covers were constructed out of white polypropylene lids with three 40-mm screws to act as supports. The screws held the rain cover above the trap and anchored it into the ground snugly around the cup.

The ramp traps (Fig. 2a) were constructed as a modified version of the design used by Bouchard et al. (2000). The plastic containers were empty micropipette tip boxes measuring 120 × 82 × 50 mm (L × W × H) and with a snap on, hinged lid. A 2.5 × 10.0-mm notch was cut on each side of the box to receive the ramps (Fig. 2b). Ramps were made from standard 5 × 7-in galvanized shingle flashing commonly available in hardware stores. Edges were bent upward to form a 13.0-mm barrier on the sides and a 5.0-mm flap bent outward at the end of each upward edge. The outward bent flaps are used to secure the ramp in the notch in the container. The top surface of the ramp was spray painted with galvanized metal primer and then brush painted with brown,

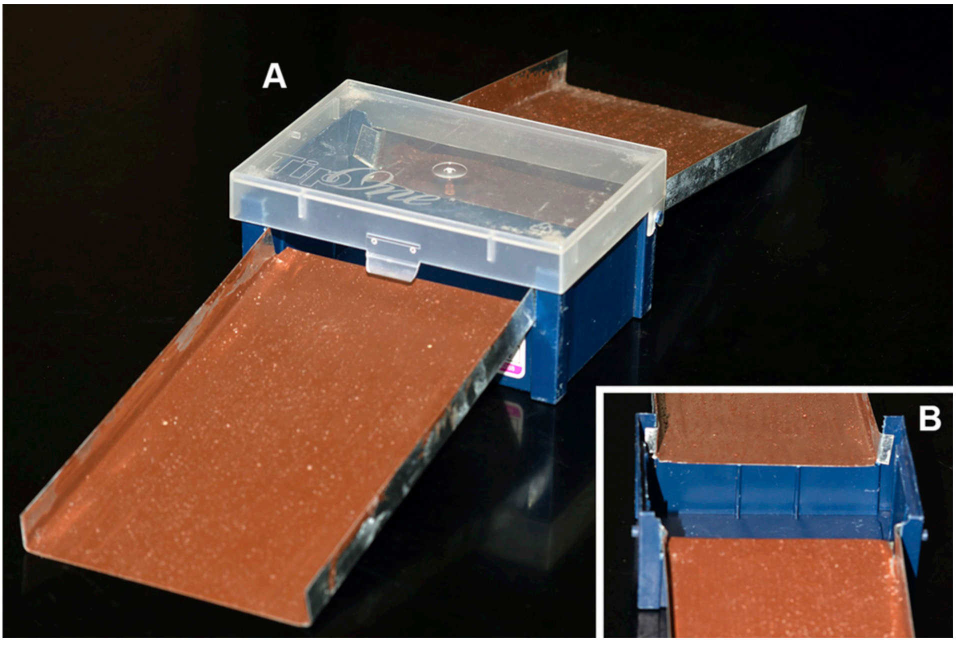

Figure 2. Assembled ramp trap with (A) lid on and (B) lid off to show notches cut into VWR pipette-tip box to receive ramp ends. During deployment, fluid is filled to approximately 2 cm.

exterior metal paint mixed with clean sand. When the lid is snapped into place the gap between ramp and lid was 15 mm (Fig. 2b).

Other than the specific materials, the only significant differences between our trap design and that of Bouchard et al. (2000) were the shape and dimensions of the ramps. Our ramps were rectangular, while theirs formed an isosceles trapezoid. The effective end-width for a ramp is similar in both traps, 100 mm for ours versus 115 mm for theirs, and by using a parallel form no additional cutting of the galvanized shingle flashing was required. The ramp length, 177 mm, was intermediate between their large and small traps.

Trap Placement and Sampling Protocols. The effort level in our study is thought to be typical of a seasonal collecting field trip or a rapid site characterization. The traps are relatively light-duty, portable, and smaller than those typically used in long-term trap studies (Hoekman et al. 2017). Traps were deployed on 19 March 2016 and final samples taken 9 April 2016. All sites except Site 4 had two lines of ten traps each with 5 m between lines and between traps. Within lines, traps alternated between ramp and pitfall and left and right. At Site 4 (McNab cypress), the terrain and plant cover were too irregular and impenetrable to arrange traps in parallel lines. At this site traps were paired and placed 5 m apart but in several short series within the habitat. Pitfall traps were buried to be flush to the ground. Approximately 80 ml of 100% propylene glycol was poured into each trap to act as killing agent and preservative. Ramp traps were alternated between facing parallel and perpendicular to the line of traps, and the ramp entry ends were placed flush to the ground or within the leaf litter layer.

All traps were serviced and propylene glycol replaced after one week in both trap types and final samples collected 14 days later. All samples for each trap type at each site were pooled for the 21-day period.

Sample Sorting and Taxa Included. This study was timed so that the final trap collection coincided with a 2016 Hopland Bioblitz event, and many Bioblitz volunteers, under the supervision of K.W.W., helped sort samples to broad categories of ‘Beetle,’ ‘Spider,’ and ‘Other.’ We then took the semi-sorted samples and identified target groups as follows: beetles to species, or when not possible to apply a species name, morphospecies; spiders to family; and other arthropods (e.g., Mutillids, Opiliones, etc.) to order or lowest level possible given our expertise. This study primarily considers the effects of pitfall trap design choice on beetles and spiders, which are abundant within pitfall trap collections. Although ants are ground-dwelling and readily collected in pitfalls, we did not include them because nest location and the disturbance caused by digging can strongly bias trap catches (Greenslade 1973, Pendola & New 2007). Collembola were very numerous in traps but were excluded because the sample handling protocol was not designed to preserve the integrity of small soft-bodied arthropods. Taxa that are not primarily ground-dwelling and/or thought to be incidental bycatch (e.g., moths, flies, bees) were also excluded from analysis.

Analysis. We compared the effect of pitfall and ramp trap design on beetle and spider riches and abundance using paired t-tests. In addition, paired t-tests were used to assess effect of trap design on the abundance of select arthropod taxa: Dermaptera, Opiliones, Diplopoda, Chilopoda, and Archaeognatha. When data did not meet the statistical assumptions of a parametric test, Wilcoxon signed ranks test was used in lieu of a parametric analysis. Only these groups were collected with sufficient regularity to allow for statistical analysis.

To determine differences by trap type for the assemblage captured for beetles and spiders, we used non-metric multidimensional scaling (NMDS, Kruskal 1964). We conducted the analysis on two transformations of the data. First, we conducted a presence-absence ordination by site to determine if the two trap types detected the presence of species equally. Second, we conducted an abundance-weighted ordination on the relative-abundance transformed data by site to determine if trap type captured different frequencies of beetles and spiders. We performed NMDS using function metaMDS in the Vegan package (Oksanen et al. 2018) using the Bray-Curtis distance metric in R (R Development Core Team 2017) and tested up to three axes with real data. Using stress as the goodness-of-fit measure, we determined that two axes represented the community structure well and the final NMDS was performed with up to 250 runs with real data or a scale factor gradient minimum of $1x10^{-7}$, whichever criteria was met first. Results were centered, principle components rotated, and the ordination axes were scaled into half-change units; taxon scores were calculated with weighted averaging (Oksanen et al. 2018). We correlated species fits and tested for significance of trap type and habitat on the ordination structure using permutation tests (N=999) via function envfit in Vegan.

Results and Discussion

Beetles. Beetles in the samples totaled 809 individuals representing 53 species in 11 families (Table 1). Overall, neither pitfalls (433 individuals, 31 species) nor ramp traps (336 individuals, 49 species) captured significantly more individual beetles (paired sample t-test, two-tail P=0.63), and there was little difference in the diversity of species (paired sample t-test, two-tail P=0.19). For all sites, the traps largely overlapped in which kinds of beetles were caught. About half (27) of the beetle species were collected in both ramp and pitfall traps. However, a few commonly sampled beetle species were notably different in pitfall versus ramp trap samples. There are seven species that are represented in the samples by ten or more individuals and that had an absolute (±) proportional difference of more than 0.50. Of these seven species, five (*Phloeodes plicatus* (LeConte, 1866), Staphylinidae sp. D (Mycetoporini), Staphylinidae sp. C (Xantholinini), *Catops* sp, and *Promecognathus crassus* LeConte, 1868) were found more abundantly in pitfall traps, primarily from traps in sites 1 and 2. These two sites are both areas with a relatively closed canopy that are dominated by Douglas fir, madrone, and oaks. These five species were also taken in many ramp traps, but at a much lower rate. The two species collected predominantly in ramp traps (Staphylinidae sp. F (Aleocharine) and *Ptinus* sp. 1) were collected across habitats in ramps (except *Ptinus* sp. 1 was absent from the chaparral site 4), but very few or no specimens of these species were taken in pitfall traps. *Phloeodes plicatus* and *P. crassus* are both relatively large-sized beetles incapable of flying, which could potentially contribute to their reduced occurrence in ramp traps.

Ramp traps noticeably added to the overall taxa richness caught; 22 species were only taken in the ramps, while only four were exclusively taken in pitfall traps. Ramp trap samples had many more rare taxa or species represented by few individuals; 27 species were represented by less than three individuals each in ramp traps and only ten species were represented by less than three in pitfalls. These species were uncommon or rare in the ramps (1–5 individuals). Of the rare species in the ramp traps, 12 species were staphylinid morpho-species (in some cases identified down to genus or subfamily), and most of those were in Site 3 (open wet pasture). Only four species were captured exclusively in pitfalls, three of those with only one specimen each. *Zarhipis integripennis* LeConte, 1874 (Phengodidae) is the only exception, with nine individuals exclusively from pitfalls in sites 1 and 2.

We used NMDS analysis to look at the subtler trends in the data, such as how particular species or habitats may have influenced the results. The NMDS ordination of beetle species using presence-absence indicated little difference in species sampled by the two trap types (Fig. 3a; habitat r^2=0.126, p=0.376). However, Site 4 (Macnab cypress) visibly separated from the other sites for both trap types on the ordination and habitat (r^2=0.752, p=0.015) was significant in permutation tests. *Dacne californica* (Horn, 1870) (Erotylidae) (p=0.006) and *Eleodes* (*Blapylis*) sp. (Tenebrionidae) (p=0.028) were correlated with NMDS axes in the direction of Site 4. The two-axis solution resulted in a final stress of 0.09 (non-metric R^2 = 0.991, final stability = $1x10^{-7}$).

The NMDS ordination of beetle species using relative abundance indicates different beetle species assemblages between the trap types (Fig. 3b; r^2=0.283, p=0.040) but not habitat (r^2=0.482, p=0.405). Compared to the presence-absence ordination, there is more spread along NMDS2 with ramp traps on the positive half characterized by Aleocharine sp. E (Staphylinidae) (p=0.023) and Aleocharine sp. F (Staphylinidae) (p=0.007). Pitfall traps occurred on the negative half of NMDS2 and were characterized by *Dyslobus* sp. (Curculionidae) (p=0.024) and *Phloeodes plicatus* (Leconte, 1859) (Tenebrionidae) (p=0.004) except for PF5 (open oak pasture). The PF4 (Macnab cypress) sample is separate from the rest of the ordination in the positive direction of NMDS1, primarily characterized by *Eleodes* (*Blapylis*) sp. (p=0.010) and *D. californica* (p=0.004). The two-axis solution resulted in a final stress of 0.07 (non-metric R^2 = 0.994, final stability = $1x10^{-7}$). The NMDS analysis indicates that the differences between trap types were mostly due to a small number of species that characterized each trap type, and that Site 4 (Macnab cypress) differed the most from the other sites.

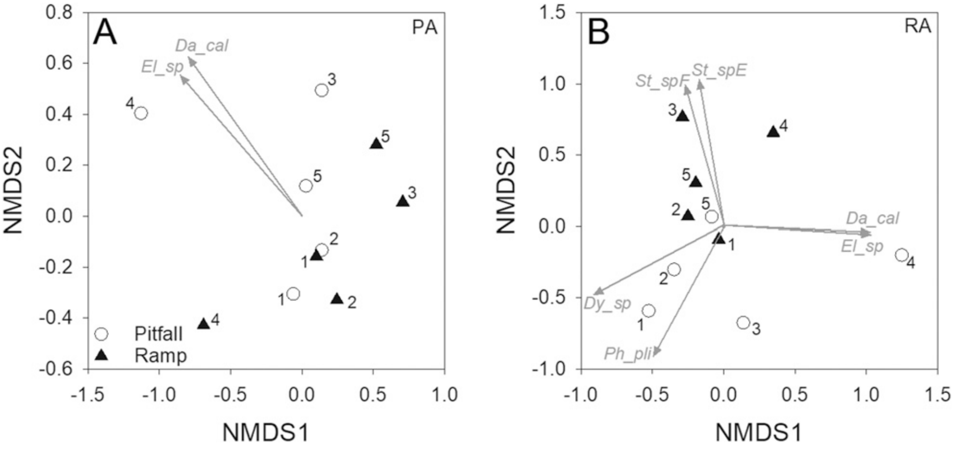

Figure 3. NMDS ordination of beetle assemblages for (A) presence-absence and (B) relative abundance. Points on the graph that are closer to each other are more similar in assemblage. The vectors represent species that accounted for most of the dissimilarity between points. The species are *Dacne californica* (Da_cal), *Eleodes (Blapylis)* sp. (El_sp), *Dyslobus* sp. (Dys_sp), *Phloeodes plicatus* (Ph_pli), Staphylinidae sp. F (St_spF), and Staphylinidae sp. E (St_spE).

Spiders. Spiders in the samples totaled 1584 individual spiders representing 19 spider families (Table 1). Pitfalls and ramp traps collected similar numbers of individual spiders (778 in pitfalls, 806 in ramp traps, paired sample t-test, two-tail P=0.83) and spider families (18 in pitfalls, 16 in ramp traps). Of the 19 spider families observed, 14 were present in both pitfall and ramp trap samples. Pitfall trap samples included 18 of the 19 families, missing only the Clubionidae (Table 2). Ramp traps failed to sample four families found in pitfalls: Agelenidae, Filistatidae, Antrodiaetidae, and Nemesiidae (Table 2).

Pitfall traps detected four spider families that ramp traps did not, three of which are ground-dwelling. The only spider family that the pitfall traps failed to detect was the Clubionidae, a family of arboreal hunters more often found by beating or sweeping vegetation. Of the four families found more abundantly in ramp traps, three build aerial snares and are usually found by beating or sweeping vegetation or by visual search.

The NMDS ordination of spiders using presence-absence resulted in little difference between sites with neither habitat (Fig. 4a; r^2=0.1939, p=0.226) nor trap type (r^2=0.1939, p=0.181) as significant variables. Site scores on the NMDS axes were tightly clustered near the origin and only Amaurobiidae (p=0.007) was significantly negatively correlated with NMDS2. The two-axis solution resulted in a final stress of 0.10 (non-metric R^2 = 0.988, final stability = $1x10^{-7}$).

The NMDS ordination of spiders using relative abundance resulted in more spread in the site positions than the presence-absence ordination, with only habitat (Fig. 4b; r^2=0.8103, p=0.011) as a significant variable (trap type r^2=0.0603, p=0.579). Visually, sites were positioned in pairs except for Site 3 and Site 5; however, there was no clear separation. Sites along NMDS1 were positively correlated with Filistatidae (p= 0.037) and Lycosidae (p=0.001) and negatively correlated with Amaurobiidae (p=0.004) and Thomisidae (p=0.039). Sites along NMDS2 were positively correlated with Linyphiidae (p=0.003) and negatively correlated with Corinnidae (p=0.016) and to a lesser extent with Thomisidae (p=0.039). The two-axis solution resulted in a final stress of 0.07 (non-metric R^2 = 0.994, final stability = $1x10^{-7}$). The NMDS analysis indicates that both trap types capture spider families equally well when considering the abundance-weighted catch.

Table 1. Abundance and richness totals and metrics for ramp and pitfall traps. Total abundance and total richness are combined for both ramp and pitfall traps. Positive values for the proportional difference indicate that ramp traps had more individuals. Paired tests include both T-tests (T) or Wilcoxon signed rank test (W) with significance (*) indicated when p <0.05. Paired t-tests are not included for richness for groups not identified at least to family level.

	Abundance			Richness		
Group	Total abundance	Proportional difference	Paired test (p)	Total richness	Proportional difference	Paired test (p)
Beetles	809	-0.1	0.63^{T}	53 spp.	0.35	0.19T
Spiders	1584	0.02	0.83^{T}	19 families	-0.11	0.07T
Dermaptera	114	0.26	0.37^{W}	-	-	-
Opiliones	231	-0.52	0.26^{T}	--	-	-
Diplopoda	175	-0.58	0.04^{T*}	--	-	-
Chilopoda	44	-0.59	0.06^{T}	--	-	-
Archaeognatha	72	-0.17	0.37^{W}	--	-	-

For all statistical tests, N=5 and df=4.

Table 2. Abundance counts for spider families by trap type. None of the differences are statistically significant.

Spider family	Pitfalls	Ramps
Agelenidae	6	0
Amaurobiidae	101	59
Antrodiaetidae	1	0
Araneidae	2	9
Clubionidae	0	5
Corinnidae	56	72
Cybaeidae	29	24
Cyrtaucheniidae	1	1
Dictynidae	36	25
Filistatidae	2	0
Gnaphosidae	192	174
Linyphiidae	34	133
Liocranidae	20	18
Lycosidae	185	96
Nemesiidae	6	0
Salticidae	7	23
Theridiidae	4	11
Thomisidae	82	155
Zoropsidae	14	1

Site to Site and Habitat Specific Comparisons. The NMDS analyses (Figs. 3, 4) indicate that site generally influenced catch independently of trap type. Site 4 (Macnab cypress) differed the most from the other sites, regardless of trap type. These differences could be explained by the unique flora of the chaparral habitat. Sites 1 and 2 are both closed canopy forest, and as expected, they came out closest together on the NMDS analyses.

Vertebrate Bycatch. Pitfall traps caught more individual vertebrates than ramp traps did (34:13) and also more species (4:1). Pitfall traps captured two species of amphibian and two species of lizard, while ramp traps only caught juvenile California slender salamanders (*Batrachoseps attenuatus* Eschscholtz, 1833). Notably, no mammals were caught in the study. Our results are consistent with Pearce et al. (2005), and ramp traps appear to be the better choice for minimizing impact on vertebrate populations.

Anecdotal Results. Although not part of this study, one of us (K.W.W.) has deployed these and other styles of ramp traps in several habitats in California (unpublished data), the Great Basin National Park (Will et al. 2017), and in the Pilbara region of Western Australia (unpublished data). In all cases, the qualitative performance of the traps are consistent with the quantitative results presented here. Additionally, in one case, ramp traps in a shoreline riparian habitat were found floating with samples intact when an unexpected flood occurred. Pitfalls in the same situation were lost because of the flooding.

Cost and Construction Effort. In terms of costs and construction, simple cup and rain shield traps are considerably cheaper and easier. Although the ramp trap containers are free for most laboratory scientists (micropipette tip boxes are a common waste product in most laboratories), the galvanized steel flashing, primer, and paint add

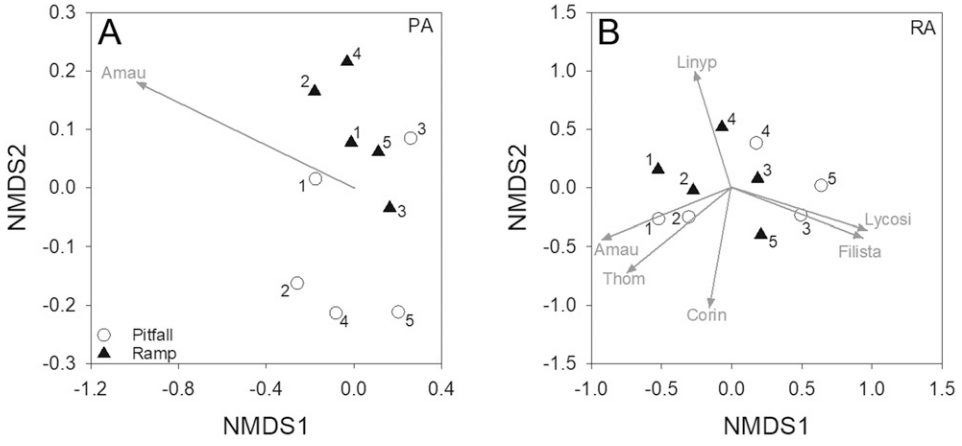

Figure 4. NMDS ordination of spider assemblages for (A) presence-absence and (B) relative abundance. Points on the graph that are closer to each other are more similar in assemblage. The vectors represent families that accounted for most of the dissimilarity between points. The families are Amaurobiidae (Amau), Thomisidae (Thom), Corinnidae (Corin), Linyphiidae (Linyp), Filistatidae (Filista), and Lycosidae (Lycosi).

notably to the costs. Additionally, the cutting of the container and fabrication and sand-painting of ramps also involves significant effort. In our case, we made cutting and bending jigs for container modification and ramp fabrication, respectively. This sped up production significantly and allowed a group of students to more quickly make the 100 identical ramp traps for this study. The ramp traps used for this study have been used in multiple studies, and they are quite durable. Each ramp trap took ~1.5 minutes to construct, not including time for the paint to dry. It took 10–15 seconds to construct each rain cover for the pitfall traps.

Packing and Transportation. Travel and field conditions often constrain what can be packed into a vehicle or shipped. Therefore, efficient use of space is a significant consideration. Cups and rain shields pack smaller and are lighter. Cups nest and, when packed, allow 100 cups to occupy a very small space. Ramps, particularly the steel material we used, are much heavier and, with the container, required several medium-size boxes for transport.

Ease-of-Setup. Although the ramp traps were heavier and bulkier than the pitfall traps, they were consistently set up much more quickly in all soil types as they required no digging. In some areas, we found the soil to be exceptionally rocky and installing pitfalls very time consuming. The total footprint of the pitfall is small (95 mm dia.) compared to the ramp trap (fully assembled 40 mm × 125 mm). Therefore, where the surface was irregular or sloping, it was easier to locate a position for the pitfall trap. Setup was about 5–10 minutes for each pitfall trap, except at Site 4 where digging in the dry soil could take up to 30 minutes. Setup was about two minutes for each ramp trap.

Trap Disturbance. Two pitfall traps and no ramp traps were disturbed to the point that their samples were lost during the month of deployment. Noticeable disturbances, i.e., the rim of the cups was no longer flush with the soil surface or ramps knocked out of place, were recorded for 23 pitfall traps but only two ramp traps. There was no evidence in these cases that the samples were affected by any of the disturbances.

These disturbances were likely due to rain and soil saturation that can force cups out of the ground. The bulk of the disturbed traps were in Site 2 (open wet pasture) and Site 4 (Macnab cypress). If disturbance from rain and flooding is a concern, ramp traps may be the superior option.

Summary

Ramp traps were as effective as pitfall traps in capturing most arthropods. If the sampling goal is to acquire a snapshot of arthropod diversity, ramp traps and pitfall traps perform equally well. For beetles, ramp traps are a useful addition in that they can increase total number of species caught, and assemblage differed somewhat by trap type. For spiders, there was no statistically significant bias between trap types. Ramp traps did capture significantly fewer millipedes and near-significantly fewer centipedes, but no other taxa showed a significant bias.

Ramp traps resulted in less vertebrate bycatch, were quicker and easier to setup, and were more resistant to disturbance. They are more difficult and expensive, however, to fabricate, pack and transport. The decision to use ramp traps instead of pitfall traps will depend on whether the costs outweigh the benefits for each situation.

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