Investigating optimal pit fall trap rim circumference for sampling surface dwelling arthropods in a desert habitat

Abstract

Pitfall trapping is one of the most extensively used methods for sampling surface foraging arthropods in ecological monitoring and biodiversity studies. Despite variations in trap design influencing catch rate and species composition, there is no standardisation protocol associated with pitfall trapping. Larger traps are known to increase catch rate and species richness sampled, but also increase handling and processing time and have been found to enhance the positive body size bias towards larger species. Many studies have investigated how trap size influences the size bias and trapping efficiency but studies focussed on optimal rim circumference are few. This study consisted of a single short sampling period, investigating the role of rim circumference in sampling surface dwelling arthropods in an Emirati desert environment. Four rim circumferences (22, 27, 35 and 45 cm) were assessed across four sites (4 sizes, 20 replicates, 80 traps) on their diversity estimates and catch mean body length. To assess the strength of any catch body size bias, body length was compared between the pitfall size classes using one way ANOVAs and no consistent significant overrepresentation of larger bodied species in larger traps was found. Three criteria were then considered in choosing optimal rim circumference; handling/processing time, ability to maximise species diversity and ethical consideration. The results suggest the second largest trap size was optimal. For the same number of traps and handling time, the 35 cm size class caught the highest number of species (>4) out of all of the

other traps (<4). Moreover, larger traps may increase the potential for trapping non-target species, further justifying the second largest circumference as the optimum.

Introduction

Arthropods represent more than 80% of global species richness (Wilson, 1992), carry out indispensable roles in ecosystems such as pollination and nutrient cycling (Mattson and Addy 1975), and show quick responses to ecological changes. For these reasons, they are commonly used as indicator species. In addition, certain arthropod species have been used in studies to identify the impacts of anthropogenic activities, such as agriculture (Eyre et al. 1989), urbanization (Niemelä and Spence, 1991) and climate change (Parmesan, 1996).

The ability to accurately monitor and detect changes in biodiversity is critical due to such increasing anthropogenic impacts (Work et al., 2002). However, the usefulness of scientific results depends on sampling techniques and their biases, thus, sampling methods must be studied to ensure they can provide true ecological samples (Southwood, 1994). In addition, to make comparisons between studies, biases in sampling methods must be understood and standardised where possible (Spence and Niemelä, 1994).

The most basic prerequisite for obtaining reliable results in scientific studies is using appropriate methodology (Elphick, 2008). Pitfall traps are the most widely used ecological survey method for sampling surface dwelling arthropods, they were found to have been used in almost 90% of field studies involving ground beetles between 2008 and 2010 (Spence and Niemelä, 1994). The excessive use of pitfall trapping has been justified because of the methods ease of use, low cost, and ability to collect large data sets in short periods of time (Spence and Niemelä, 1994). However, pitfall trapping has been criticized since the 1960s (Knapp and Ruzicka, 2012) and several biases associated with the method have been identified. Studies have found that trap material, shape, preservative and bait type can influence the number and type of species collected (Luff, 1975, Curtis, 1980 and Digweed et al., 1995). Catches obtained by pitfall traps have been compared with catches obtained from alternative sampling techniques and biases associated with pitfall traps have been identified, for example, sex ratios are clearly biased in some taxonomical groups and large bodied species are significantly overrepresented in pitfall traps (Spence and Niemelä, 1994; Arneberg and Andersen, 2003).

Pitfall traps provide an activity density (Southwood, 1994), hence, sampling biases associated with pitfall traps depend on factors that change the locomotory activity of a specimen, such as its body mass and ambient temperature, in addition to the population density of the species in an area (Halsall and Wratten, 1988; Mommertz et al., 1996; Lang, 2000; Perner and Schueler, 2004; Woodcock, 2005). Spence and Niemelä (1994) and Arneberg and Anderson (2003) compared numbers of arthropods caught by pitfalls with those counted in quadrats and found that larger species were more abundant in pitfall data and there is increasing evidence that this could be due to increasing activity linked to body mass.

Luff (1975) compared the capture rate and retaining efficiency of pitfall traps of different diameters and materials for carabid beetles and found that traps with larger diameters caught a larger total number of beetles than smaller traps, however, the study identified a positive catch size bias towards larger beetles in larger traps. He suggested that this was because large beetles were more able to escape from small traps and smaller beetles were more able to escape from larger traps. This conclusion implies that the body-size catch bias towards larger species is stronger when pitfalls have a larger diameter, further implying that the body size-catch bias can be reduced when using pitfalls with a smaller diameter. However, although small traps decrease handling and processing time, they often catch fewer arthropods and compromise the retaining efficiency of the trap (Luff, 1975) overall. However, rim circumference may be more important than pitfall diameter. Luff (1975) explained the 'perimeter model' as the likelihood of an animal falling into a pitfall trap depending on 'the probability of it arriving at any point on the perimeter of that trap, which will depend on the length of that perimeter. Circumference will therefore determine the expected catch of a circular trap'.

This study aims to determine the optimal rim circumference which minimises the size bias associated with larger traps, whilst maximising species diversity estimates. To answer the question of which class of rim circumference maximises species diversity and yields estimates closest to the true diversity of an area, quadrat estimates and estimates from pitfall traps of varying rim circumference were compared. Spence and Niemelä (1994) tested the extent to which quadrat sampling measured true densities by using marked beetles in three body sizes, they recorded a 96% re-capture rate. Hence, quadrats are considered to have minor biases with respect to arthropod body size. In this study, quadrats were used to produce representative estimates of species diversity, to test how accurately pitfall traps of different rim circumferences can estimate species diversity of an area. In addition, how rim circumference affects the catch size bias that is positive towards larger bodied arthropods in larger pitfall traps, was investigated by estimating the body length of each specimen trapped. The optimum rim circumference will be be selected depending on the relationship found between circumference and mean body length and ability of producing diversity estimates similar to the representative quadrat samples.

Methodology

Study sites

The study areas consisted of four desert habitats across the Dubai Desert Conservation Reserve in the United Arab Emirates. The first habitat was a slightly vegetated area near an artificial lake on the reserve (a). The second was an uneven, dry dune area (b). On the third day, a Ghaff forest grove was sampled which was relatively vegetated and shaded (c). The fourth and last site studied was a flat gravel plain habitat (d).

Methods

Data collection began on the 9th of February 2019 at 7.30 am and was completed on the 12th of February 2019 at 3 pm. Due to a sandstorm which buried most of the pitfall traps on the fifth day, data from that day could not be used. In each area, five pitfall traps of four different rim circumferences (22 cm, 27 cm, 35 cm, 43 cm) were arranged along four transects parallel to each other and positioned 3 metres apart.

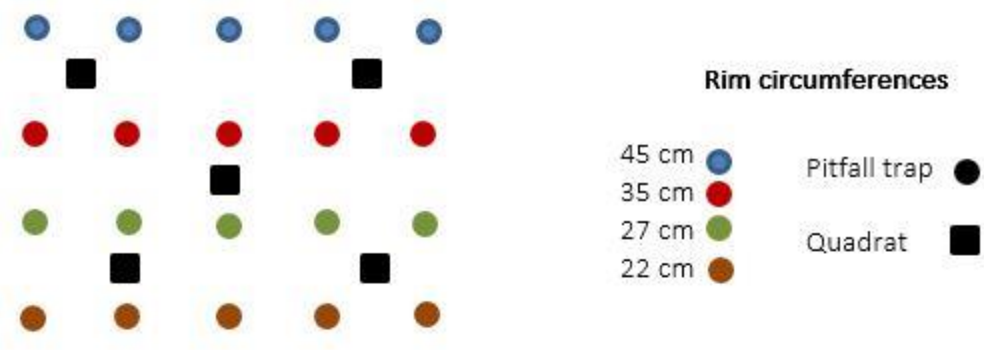

Figure 1. Spatial arrangement of the traps. Pitfall traps are represented by circles and quadrats by squares. The different colours represent different rim circumferences.

Each transect consisted of five pitfall traps of each size category placed 3 metres apart to reduce interference from other traps (4 treatments, 5 replicates = 20 traps per site, 80 traps in total over 5 days and four sites). The pitfall traps consisted of plastic cups sunk into the ground. The traps were all baited with about 2-3 cm of apple cider vinegar and set just after sunrise (7.30 am). The two smaller rim circumference size classes were both clear plastic cups, however the two larger ones were opaque yellow (largest) and white (second largest) plastic cups.

Timed quadrats were carried out in the afternoon after setting up the pitfalls (12 pm), this was to leave some time for the community to acclimatise after the disturbance of setting up the pitfall traps. The quadrat was 0.5 m^2 and built using four PVC pipes. Five random samples were taken in each site between the pitfall traps to produce a representative sample of each areas species diversity. The quadrat frame was quickly pressed into the sand and hand searching, removing vegetation/litter within each quadrat and forceps was conducted for 40 minutes in each site.

The pitfall traps were then collected in labelled tubes after the quadrat samples were completed, at around 5-6 pm, before the sun set, in order to exclusively sample the diurnal community as the quadrats do. Collected organisms were then rinsed with tap water and identified to order, species or family where possible, under a light microscope. Where the species was unidentifiable it was given a unique letter such (eg. x/y/z) in order to distinguish species diversity. Their body lengths were assessed visually and given an estimate in centimeters.

Statistical analysis

Species diversity was calculated by counting the number of different taxa in each sample and calculating a mean for each method (the four pitfall size classes and quadrats) in each site. One way ANOVAs were carried out to compare the mean species diversity estimated by the varying pitfall traps as well with the quadrat methods. In addition, the mean body length of arthropods trapped was compared between each pitfall size class. The pitfall size class bearing a diversity index that is most similar to the quadrat methods maximises the number of morpho-species and minimises the catch size bias would be the optimum pitfall rim circumference for studying ground dwelling arthopods.

Results

When the pitfall trap estimates were compared with the quadrat results in site 1, the quadrats species diversity was lower than that of the two larger pitfall size classes (Table 1).

Table 1. Species diversity of site (a) estimated by give quadrats and five pitfall traps of varying rim circumferences.

	species diversity					mean
quadrat	4	3	3	2	3	3
22cm pitfall	2	1	1	2	0	1.2
27 cm pitfall	1	2	2	0	1	1.2
35 cm pitfall	5	5	4	4	4	4.4
45 cm pitfall	3	4	5	4	2	3.6

We used a one way ANOVA to compare the mean species diversity estimated by quadrats and pitfall traps in four desert habitats and found that the pitfall traps produced significantly higher species diversity estimates than the quadrats ($p=0.028$), across all five sampling days and all sites (Figure 2).

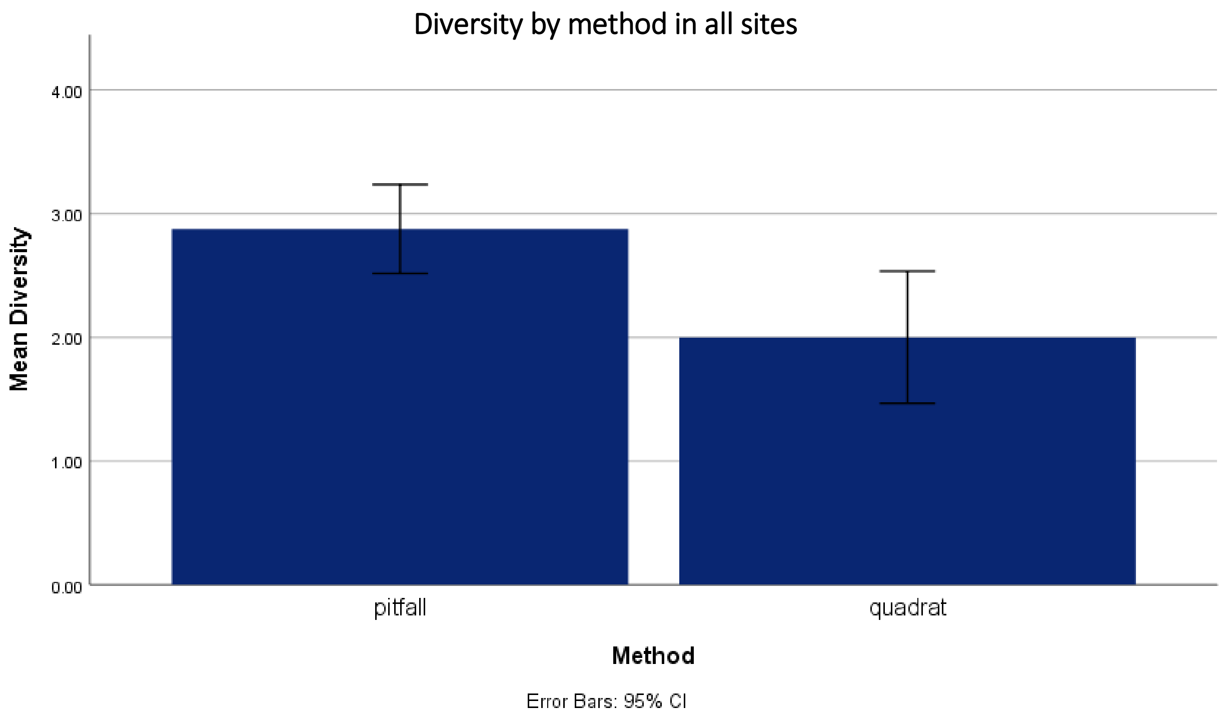

Figure 2. A comparison between the species diversity estimate produced by pitfall traps and quadrats across four sites.

Another one way ANOVA was used to compare between the mean species diversity estimates produced by each pitfall rim circumference class. The ANOVA yielded a significant result ($p<0.001$) and the 35 cm rim circumference produced diversity estimates which significantly exceeded the pitfall traps smaller and larger than it (Figure 3).

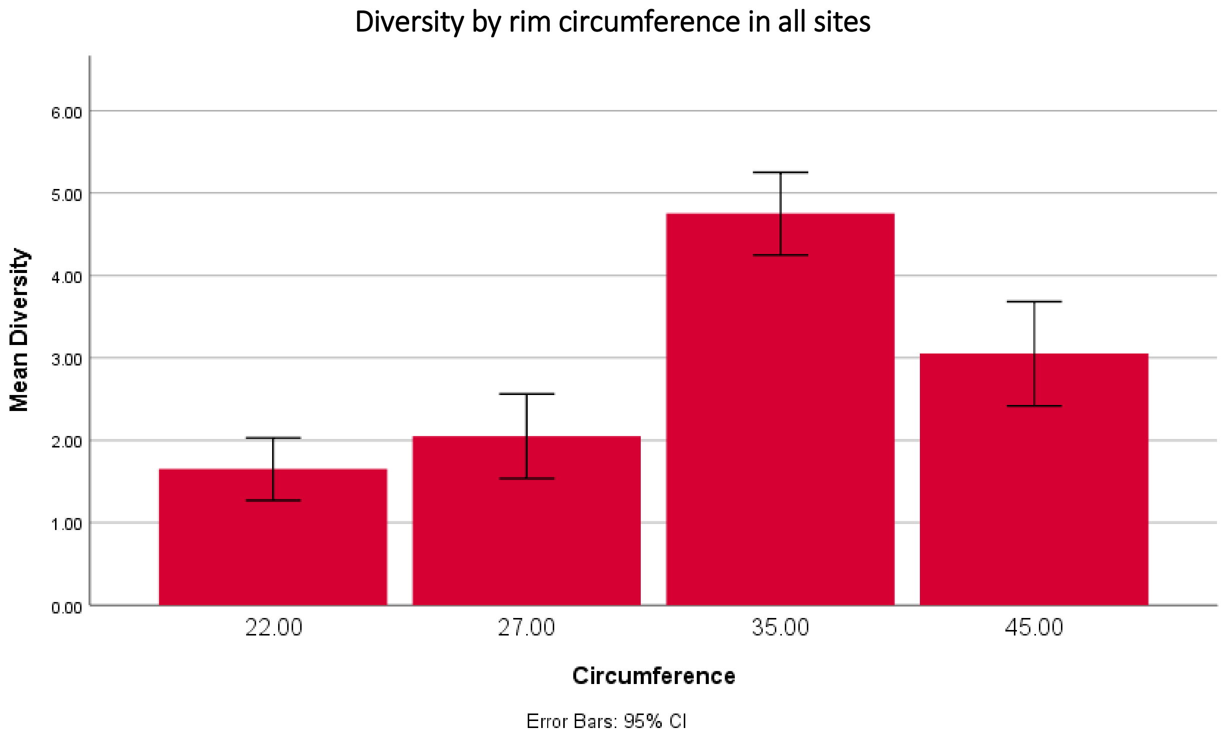

Figure 3. The mean species diversity estimates produced by the four different pitfall size classes (rim circumference 22 cm, 27 cm, 35 cm, 45 cm) across four sites.

Another one way ANOVA was run comparing the mean diversity estimated by each pitfall trap size class for the first site, the artificial lake site. The mean species diversity produced by pitfall trap with a 35 cm rim circumference was significantly higher than the largest pitfall trap, the quadrat and the two smaller pitfall traps (p=0.005) (Figure 4).

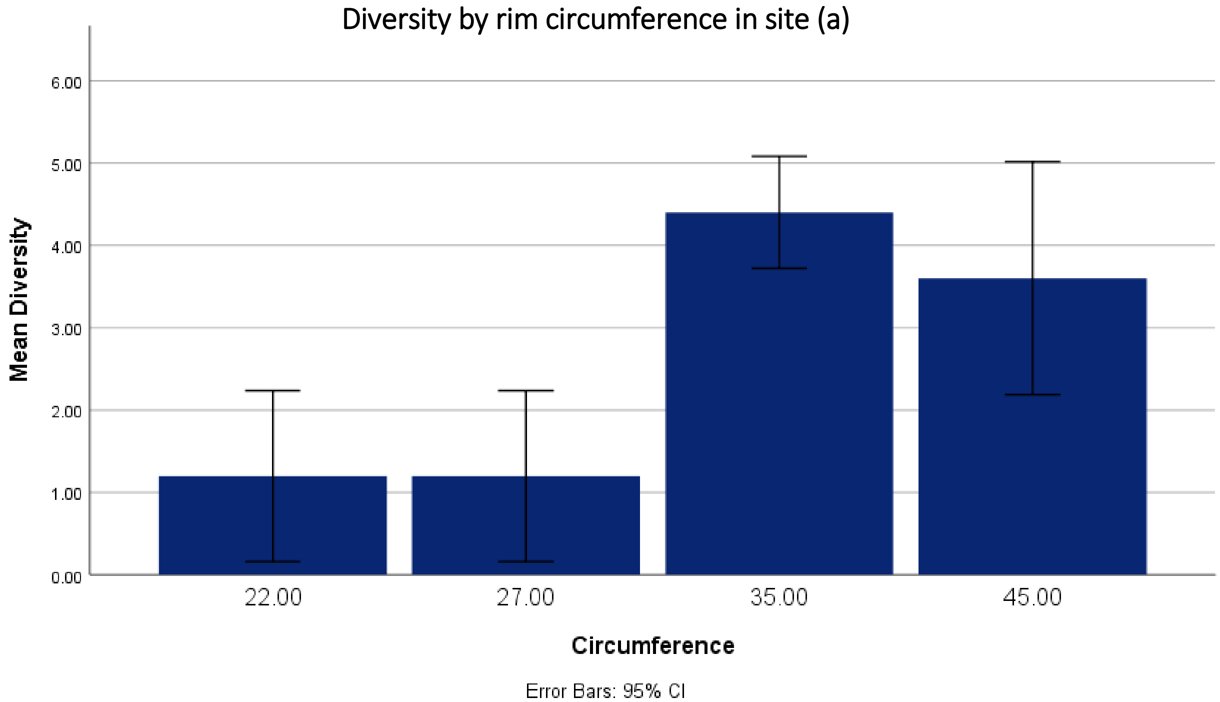

Figure 4. Mean species diversity estimates produced by the pitfall traps of varying rim circumferences in site (a). Again, a rim circumference of 35 cm seemed to maximise species diversity.

Additionally, a catch size bias associated with larger pitfall rim circumferences was identified after a one way ANOVA comparing the mean lengths of the arthropods caught by each pitfall size class. Larger rim circumferences could trap arthropods with significantly higher mean body lengths ($p<0.001$) (Figure 5.)

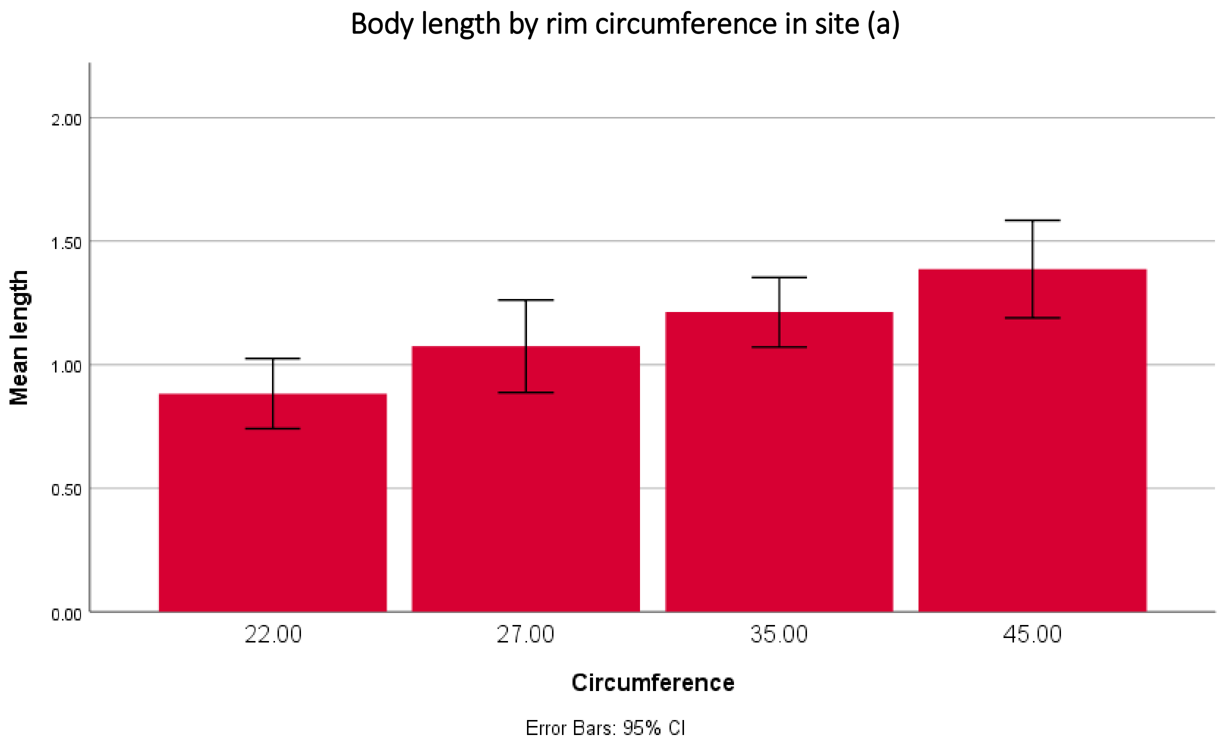

Figure 5. Pitfall traps with larger rim circumferences caught a significantly larger proportion of larger arthropods, the mean body length of the catch increased as rim circumference increased.

In site (b), the Ghaff forest grove, the same trend was repeated where the 35 cm pitfall produced a significantly higher species diversity than the other pitfall traps and the quadrat method (p<0.001) (Figure 6).

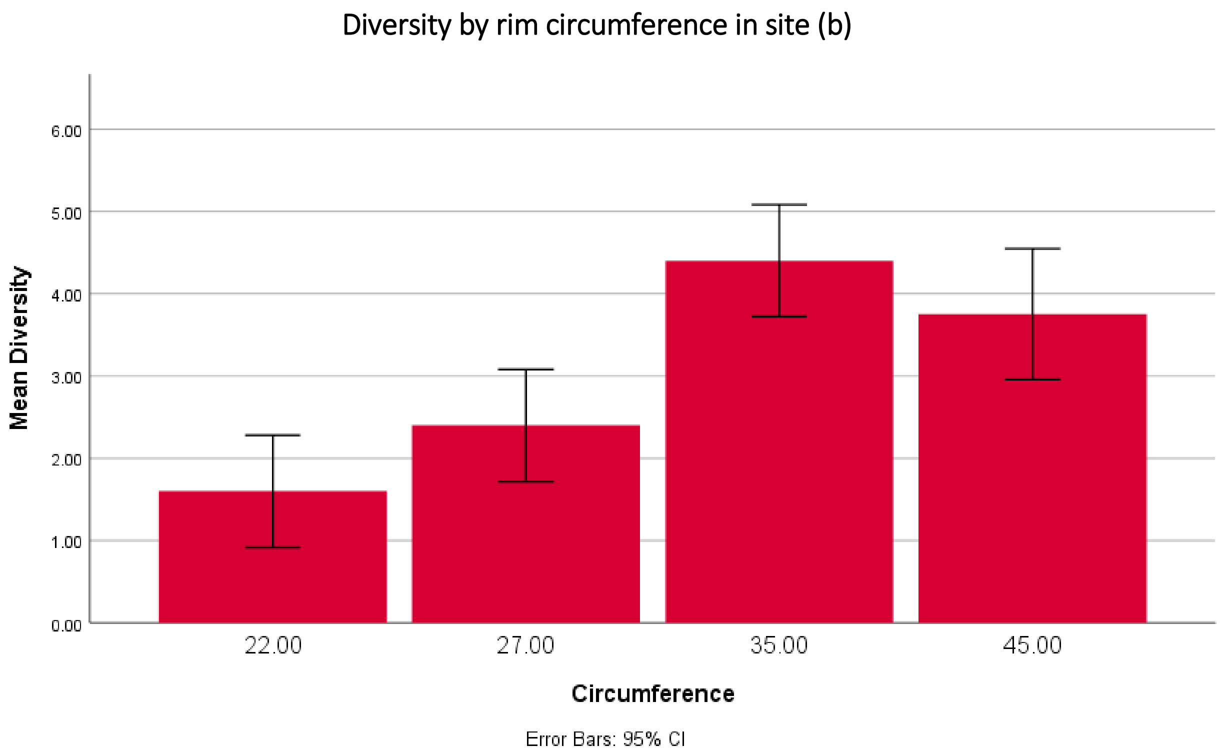

Figure 6. The pitfall trap with a rim circumference of 35 cm maximized the species diversity estimates and produced estimates that were significantly higher than the other pitfall traps and quadrats employed in site (b).

However, the catches were only slightly significantly influenced by increasing rim circumference (p=0.042) so a strong bias associated with larger rim circumferences could not be concluded (Figure 7).

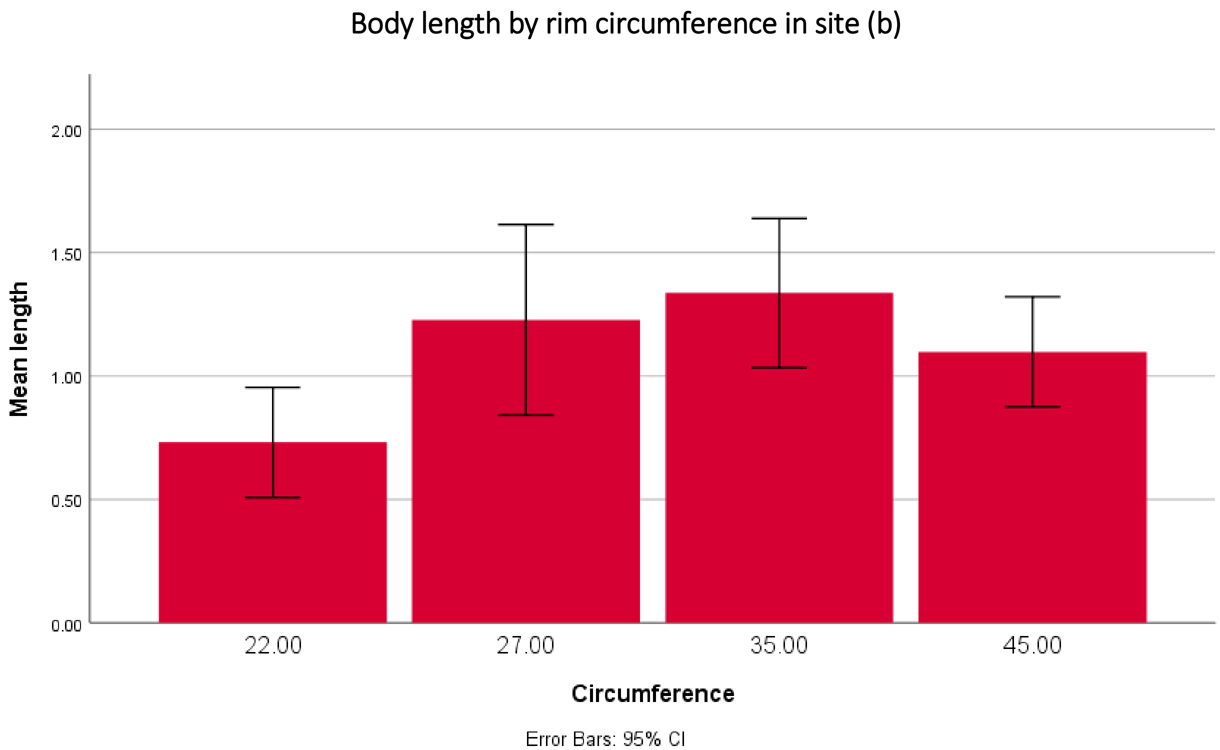

Figure 7. Pitfall traps of differing rim circumferences in site (b) had catches with significantly different mean body lengths, however, the different is slight (p=0.042).

In the third site, a dune habitat, no size bias was apparent as a one way ANOVA comparing rim circumference and body length produced a non significant result (p=0.851). However, varying pitfall circumference significantly influenced the estimated mean species diversity (p<0.001). Again, rim circumference 35 cm maximized species diversity estimated by pitfalls (Figure 8.)

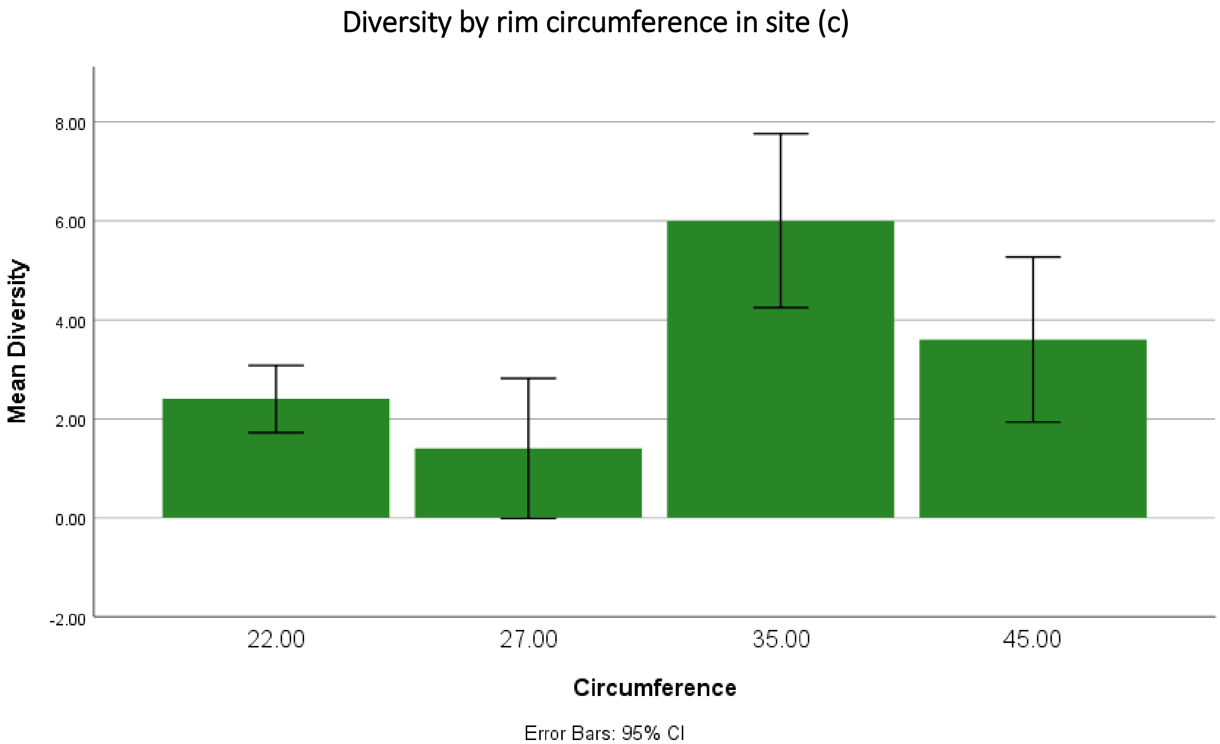

Figure 8. The pitfall trap with a rim circumference of 35 cm maximized the species diversity estimates and produced estimates that were significantly higher than the other pitfall traps and quadrats employed in site (c).

Likewise, site (d), the final site, a gravel plain, no size bias associated with the pitfall trap rim circumferences as circumference did not significantly affect body length ($p=0.482$), according to a one way ANOVA. Again, the 35 cm size class produced a significantly higher species diversity than the others rim circumferences ($p<0.001$) (Figure 9.)

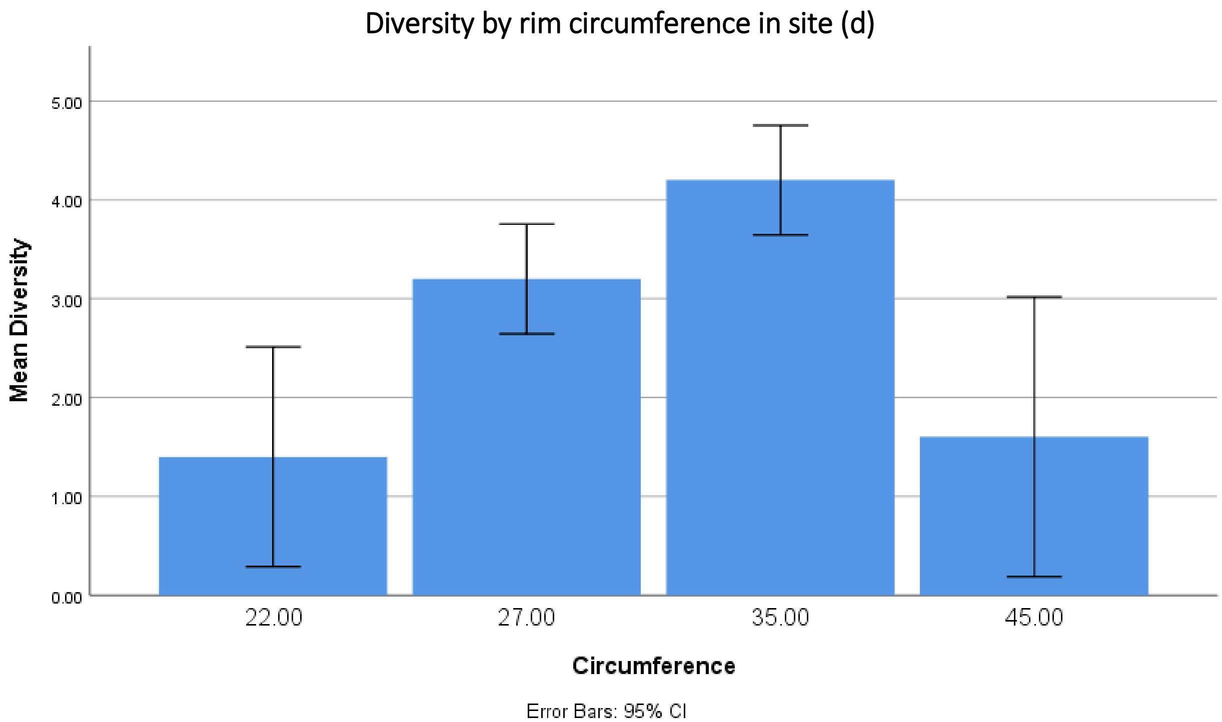

Figure 9. Mean species diversity as estimated by each pitfall trap size class in site (d). The diversities significantly differed according to rim circumference. The rim circumference 35 cm caught the highest number of species.

Discussion

In almost all of the sites, the quadrat species diversity estimates were significantly lower than the two larger pitfall traps, implying that the quadrats did not produce true estimates of species diversity. This is likely to be due to the quadrats' small size (0.5 m^2), for a desert habitat. Optimal quadrat size is generally influenced by the spatial distribution of the target populations and the degree of association between them (Pringle, 1984). In a desert ecosystem, vegetation and animal populations are scarce, thus larger areas of habitat need to be sampled for robust and useful data (Ksiksy and El-Keblawy, 2013). For this reason, quadrat data was not used to compare with the varying pitfall rim circumferences as planned. Instead, optimal rim circumference was decided based on the apparent strength of any apparent body size bias associated with that circumference, which was judged by looking for significant differences between the mean body length of the catch caught by each pitfall size class. Optimal trap sizes for efficient sampling were also considered as the pitfall trap sizes that give the highest species diversity for a standardised number of traps (Abensperg-Traun and Steven, 1995).

When all of the sites were tested using a one way ANOVA, rim circumference seemed to significantly influence the mean body lengths of the pitfall trap catches ($p=0.005$). Larger rim circumferences caught arthropods with higher mean body lengths, these results are concurrent with Luffs (1975) identifying a positive catch size bias towards larger bodied arthropods. However, when the sites were analyzed separately this was not always the case. The first two sites showed only a slight positive size bias towards larger species associated with larger rim circumferences, whilst the last two had non-significant ANOVA results. This may be because the rim circumferences selected did not differ substantially for a strong catch size bias to be noticeable. In addition, the largest pitfall trap was relatively ‘small’ (45 cm), as much larger pitfall traps have been used in other studies (eg. Diameters > 100 cm).

In terms of determining an optimal pitfall trap rim circumference, the second largest rim circumference (35 cm) was consistently the most efficient. In all of the sites, this rim circumference sampled the highest number of species for equal numbers of trap and handling time. The larger rim diameter of 45 cm did not perform as well as the 35 cm traps, possibly due to a decreased retaining ability for smaller species, as Luff (1975) found that smaller beetles escaped most from larger traps. In addition, larger trap sizes are more prone to increased capture rates of non-target species such as small mammals and reptiles, making the pitfall trap with a rim circumference of 35 cm more appropriate ethically than larger traps. To conclude, a standardization protocol requiring using traps with a rim circumference of around 35 cm in future studies would facilitate future comparison between studies.

Another factor linked with pitfall trap design and construction that could have significantly affected the recorded species composition and abundance estimated by the pitfall traps is the colour of the traps. The two smaller pitfall traps were both transparent in colour and the larger two were opaque and white. A previous study in an open grassland habitat found that carabid beetles and spiders were more likely to be caught in pitfall traps that were white or opaque (Buscholz et al. (2010)), possibly because they were attracted to bright colours due to the sharp contrast between the trap and its surroundings. However, catch species from the Formicidae did not significantly differ between pitfall trap colour, due to the strong effect the clustered occurrence of ants has on the numbers of ants caught by traps (Laeger & Schultz, 2005). There is also a spatial component in catch size and species composition which could have been caused by variation in environmental characteristics that were not measured so could not be included in the analyses.

Because of these limitations, additional studies investigating optimal rim circumference for studying surface dwelling arthropods in desert habitats are required. Studies should be carried out over short as well as long trapping periods and through different seasons. Many issues in the present studied could be addressed in future studies, such as controlling for trap colour and including environmental variable measurement. In addition, catchability of species is likely to be affected by behavioural differences between species, sex and ages (Merrett and Snazell, 1983; Topping and Sunderland, 1992), further analyses at a species level is recommended.

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