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Original Article

Comparative performance of pitfall, ramp, and tube traps for sampling arthropods in an arid region of southeastern Iran

Masoumeh Enayatnia [1] | **Ali Mirshekar** [1] | **Alireza Zamani** [2] | **Sara Ramroodi** [1]

1 Department of Plant Protection, Faculty of Agriculture, University of Zabol, Zabol 98613-35856, Iran. Emails: enayatniam@gmail.com; mirshekar@uoz.ac.ir; sararamroodi@uoz.ac.ir

2 Zoological Museum, Department of Biodiversity Sciences, FI-20014 University of Turku, Turku 20500, Finland. Email: zamani.alireza5@gmail.com

Corresponding author: Ali Mirshekar| ✉ mirshekar@uoz.ac.ir

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ABSTRACT. Pitfall traps are widely used for collecting ground-dwelling arthropods, with ramp and tube traps serving as complementary options. This study compares the performance of these three trap types in an arid environment in southeastern Iran. Fieldwork was conducted in spring 2025 across three active orchards in the Sistan region. Six replicates of each trap type (18 total) were deployed along three paired transects. Most adult spiders were identified to the species level, while most other arthropods were identified to the family level. A total of 14,960 individuals representing 12 orders and 52 families were collected. Tube traps captured the most specimens (n = 7,706), outperforming the other trap types across the majority of taxonomic groups, including Isopoda, Coleoptera, and Araneae. Pitfall traps yielded intermediate catches (n = 5,343) and performed comparably to tube traps for several groups, such as Gnaphosidae and Formicidae, while capturing more individuals of Opiliones than the other two trap types combined. Ramp traps collected the fewest individuals (n = 1,911) but captured the highest numbers of Pompilidae and Gryllotalpidae, and, together with pitfall traps, collected several spider species that were under-represented or absent in tube trap samples. Overall, tube traps represent a practical option for sampling epigeal arthropods in arid environments. However, to achieve a more comprehensive community sample and reduce methodological bias, a combination of all three trap types is recommended for biodiversity assessments in desert ecosystems.

KEYWORDS: Ground-dwelling arthropods, Sampling methods, Sistan region, Spiders

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INTRODUCTION

Ground-dwelling arthropods (GDAs) play vital roles in ecosystems, including nutrient recycling, organic matter decomposition, and pest population control (Lami et al. 2023). Because of these functions, they serve as valuable indicators of environmental change and habitat quality (Medhi et al. 2021; Lami et al. 2023). Assessing their diversity and ecological activity requires effective sampling methods, particularly in extreme climates where temperature and humidity strongly influence their behavior.

The pitfall trap is the most commonly used method for collecting epigeal arthropods due to its simplicity and low cost (Greenslade 1964; Siewers et al. 2014; Hohbein & Conway 2018; Matevski et al. 2020b; Österman et al. 2024). However, in certain environments, pitfall traps can be difficult or impractical to deploy; for example, in rocky or protected areas where the possibility for excavation is limited. In such cases, alternative trapping methods that cause minimal disturbance and perform well under harsh conditions are required (Gao et al. 2024).

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The ramp trap offers an alternative method that does not require excavation, although its effectiveness depends on ground structure and the motility of arthropods (McNamara Manning et al. 2021). The first ramp trap was introduced by Bostanian et al. (1983), originally designed for collecting large-bodied beetles. Later, Bouchard et al. (2000) developed more general-purpose ramp trap models that were lighter, cheaper, and easier to handle than the earlier version. Most subsequent studies comparing trap performance have focused primarily on pitfall versus ramp traps for specific arthropod groups, particularly carabid beetles and spiders (Pearce et al. 2005; Patrick & Hansen 2013; Matevski et al. 2020a). Additional evaluations of other arthropod assemblages have been conducted by Österman et al. (2024) and McNamara Manning et al. (2025). However, despite the widespread use of soil-based trapping devices, no study has yet provided a focused comparison that includes tube traps.

The tube trap is a subsurface device designed to intercept ground-active arthropods through a narrow opening positioned flush with the soil surface. In its simplest form, it consists of a slim cylindrical tube buried horizontally so that only a thin slit is exposed, allowing arthropods moving across the ground to enter. Early tube traps were initially explored in forestry research to monitor the activity of certain wood-boring beetles (Tilles et al. 1986). The underlying principle, using a protected linear opening as an interception point, has since been adapted for broader arthropod sampling. As noted by Gibb and Oseto (2006), subsurface traps offer clear advantages in environments where wind, heat, or unstable substrates can compromise the performance of conventional surface-level traps. These features make tube traps a promising, yet still under-evaluated, tool for ecological surveys in challenging field conditions.

In this study, we implemented and evaluated the tube trap for sampling GDAs in an arid area of the Sistan region in southeastern Iran, and compared its performance with two other widely used trap types, namely the pitfall trap and the ramp trap. To assess the relative efficiency of these trapping techniques, we analyzed the total number of individuals collected across several arthropod groups, with particular focus on spiders, which were identified to species level whenever possible. Our goal was to determine whether the tube trap can serve as an efficient, low-disturbance tool for monitoring arthropod communities in desert landscapes, where high temperatures, strong winds, and rapid desiccation often compromise the effectiveness of conventional traps.

MATERIAL AND METHODS

Study area. Fieldwork was conducted in three orchards (31°03'24.5"N, 61°34'43.0"E; 31°02'21.9"N, 61°35'19.3"E; 31°03'38.9"N, 61°34'45.0"E) with a total area of approximately 8 ha, located 4 km east of Zabol in the Sistan region of southeastern Iran (Fig. 1). These orchards had not been treated with any pesticide, herbicide, or chemical fertilizer for at least one year before sampling. The three selected orchards represented the most common agricultural systems in the Sistan region and were chosen for their relative uniformity in vegetation structure, soil type, and microclimatic conditions. This approach allowed us to minimize habitat-induced variation and focus specifically on trap performance as the primary factor influencing arthropod captures. Although orchards are relatively disturbed habitats compared to natural environments, the exclusion of recent agrochemical treatments minimized their influence on the activity and diversity of soil-surface arthropods. We acknowledge, however, that previous fertilizer applications may have had lasting effects on the local environment.

The region has a subtropical desert climate (Köppen BWh), characterized by long, extremely hot summers, mild winters, and very low annual precipitation, generally below 100 mm (Zolfaghari et al. 2011). Evaporation rates are high, and dust storms are frequent, particularly during the warm season (Zolfaghari et al. 2011). These harsh environmental conditions impose strong ecological stress on surface-dwelling arthropods, making the area well-suited for testing trapping methods designed for hot and arid environments. The results of the present study therefore reflect spring assemblages under arid climatic conditions and should not be generalized to other seasons without further investigation. The main cultivated trees in the orchards were pomegranate (*Punica granatum* L.), grapevine (*Vitis vinifera* L.), and mulberry (*Morus alba* L.), all traditional and drought-tolerant crops in the Sistan region.

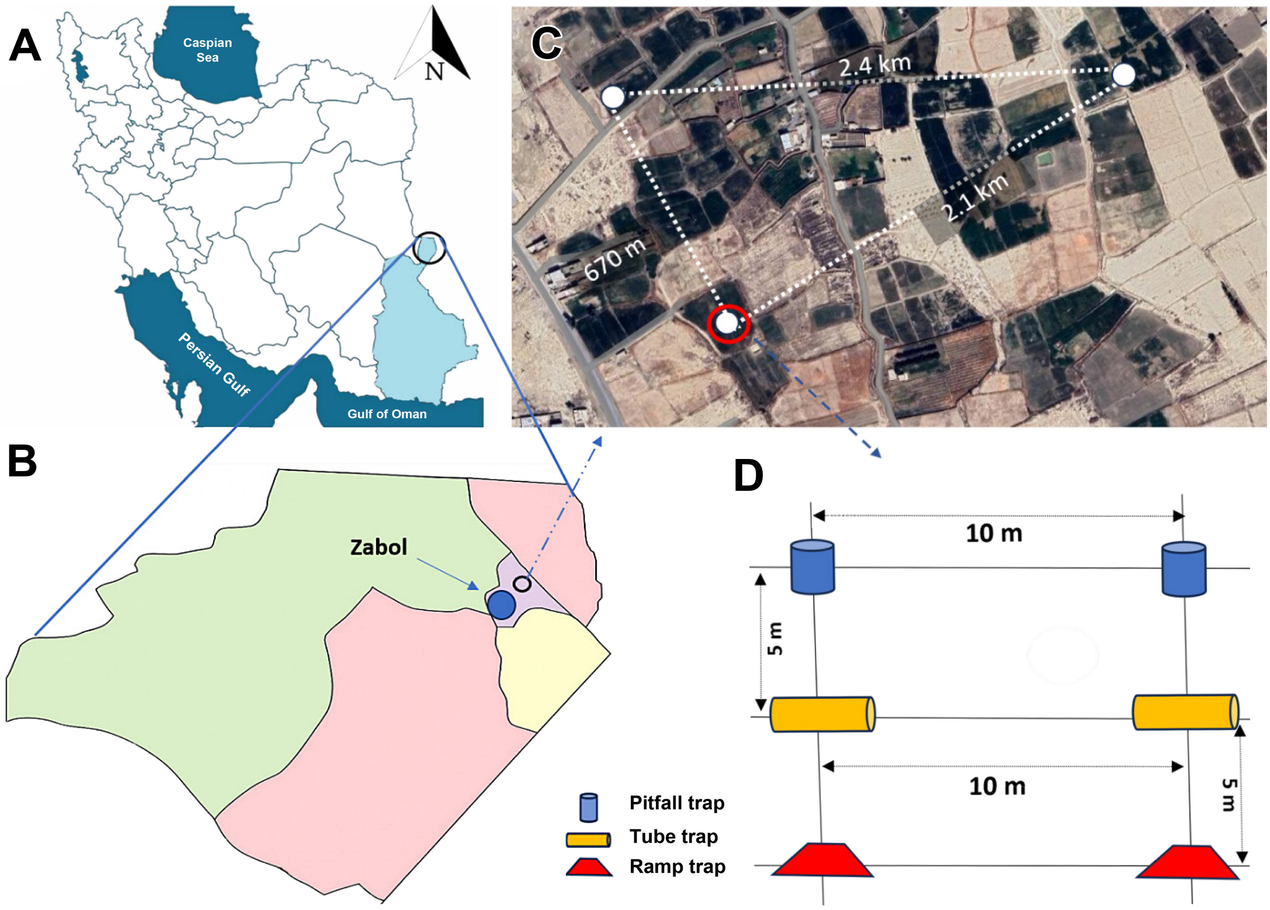

Figure 1. Location of the study site and the experimental design. **A–B.** Geographic position of Zabol County in Sistan & Baluchistan Province, Iran; **C.** Aerial view of the orchards and adjacent habitats at the sampling site (Google Earth, 2024); **D.** Schematic representation of the experimental layout and trap arrangements used in the study.

The ground vegetation was sparse, consisting primarily of scattered annual Asteraceae and Poaceae herbs, typical of semi-desert agricultural systems. Along the orchard margins, hardy shrubs and trees adapted to salinity and heat, particularly species of *Tamarix* L. and *Prosopis* L., provided limited shade and minor structural variation in the habitat. Overall, vegetation cover was low due to the arid climate, intense solar radiation, and frequent dry winds, creating an open and stressful environment for GDAs. These conditions make the site representative of desert agricultural systems in southeastern Iran and suitable for evaluating trap performance under extreme environmental circumstances. Environmental conditions in Zabol during sampling included mean daily temperatures of 25–38°C, wind speeds of 8–15 m/s, and no precipitation, characteristic of late spring and the transition to summer in the Sistan region.

Sampling design. A total of 18 traps were deployed across three spatially independent orchards (Fig. 1), with two pitfall, two ramp, and two tube traps installed per orchard. Pitfall traps consisted of plastic cups with a 1,000 mL volume (13 cm height, 15.5 cm opening diameter; Fig. 2A), filled with 500 mL of 50% propylene glycol and 75% ethanol, resulting in a liquid depth of approximately 7.5 cm. Ramp traps were adapted from the design of Bouchard et al. (2000). Each trap consisted of a square plastic container (15 × 15 × 11.5 cm, ≈2,000 mL) with a tight-fitting lid. Four openings (10 × 2.5 cm) were cut into the sides of the container, approximately 6 cm above the bottom, allowing arthropods to enter. Four trapezoid ramps were attached to each side of the container, with dimensions of 31 cm (lower edge), 10 cm (upper edge), and 26 cm (side edges), producing an incline of approximately 17°. The edges of the ramps were bent upward by 1 cm to prevent arthropods from falling off while ascending. Ramps were secured with waterproof tape and supported using plastic clips. The container was filled with 650 mL of 50% propylene glycol and 75% ethanol (≈6 cm depth) to minimize evaporation under high temperature and wind (Fig. 2B).

Tube traps were based on a design by Rakhshani (2018) and were slightly modified to suit the conditions of this study. Each trap was constructed from a PVC cylinder, 101 cm long and 6 cm in diameter, with both ends sealed. A narrow longitudinal opening (2 cm wide, 80 cm long) was created along the middle of the tube, approximately 3 cm from each end. On one side, a PVC T-connector led to a removable collection cup (9 cm high) containing 75% ethanol (Fig. 2C). Traps were installed horizontally on the soil surface with the slit facing upward, allowing ground-active arthropods to enter while minimizing the accumulation of soil and plant debris. The installation of all three trap types in the field is shown in Figure 2D–F.

A standardized installation protocol was followed for all trap types. For pitfall traps, holes were excavated using a hand trowel to match the dimensions of the plastic cups, which were then inserted so their rims were flush with the soil surface and horizontally aligned using a spirit level; any resulting gaps were filled and tamped. For ramp traps, the square container was placed on a leveled soil surface, ramps were attached and checked for stability, and to prevent wind-induced movement, and a brick or similar heavy object was placed on top of the container to prevent wind-induced movement, ensuring that ramp edges remained in continuous contact with the ground. For tube traps, trenches were dug to accommodate the PVC cylinder, which was positioned so its 80 cm slit was aligned with the soil surface, verified with a straightedge; soil was then backfilled and compacted around the tube, followed by a visual inspection to confirm the slit remained unobstructed and flush with the surrounding soil. All traps were installed at least 48 hours before the first sampling period to allow arthropods to resume normal movement patterns after disturbance, and trap positions were marked with small flags for relocation during servicing. Within each orchard, traps were arranged along two parallel transects approximately 10 m apart, positioned about 5 m inside the orchard boundary to reduce edge-effect bias. Along each transect, one trap was placed at the midpoint and the other at the endpoint, with approximately 5 m between positions. This arrangement allowed sampling from similar microhabitats while capturing small-scale variation in surface conditions. All traps were active simultaneously to ensure fair comparisons among trap types, following standard procedures for sampling epigeal arthropods (Österman et al. 2024). Sampling was conducted over six consecutive seven-day periods in spring 2025 (April 24–June 5), yielding a total of 108 sampling events (18 traps, 6 weeks). This period was selected as it represents peak activity and abundance for epigeal arthropods in the region. During each weekly check, the solution and collected specimens were drained from the trap, and a fresh solution was introduced. Collected material was transferred to labeled glass jars, filtered through fine mesh, and preserved in 75% denatured ethanol for long-term storage.

Identification of specimens. Collected arthropods were generally identified to the family level, whereas adult spiders were identified to species whenever possible; specimens that could not be identified to species were assigned to morphospecies. Several groups, including mites (Acariformes and Parasitiformes), springtails (Collembola), flies (Diptera), mayflies (Ephemeroptera), true bugs (Hemiptera), booklice and barklice (Psocodea), pseudoscorpions (Pseudoscorpiones), fleas (Siphonaptera), and thrips (Thysanoptera), were detected in the samples but excluded from the analysis due to their minute size, the difficulty of reliable identification to lower taxonomic levels, and their very low capture numbers, as these taxa are not typically collected using the trap types employed in this study. Despite not being identified to the family level, Isopoda were retained in the dataset due to their very high abundance (more than 43% of all samples) and the clear differences observed in their capture rates among trap types.

Data analysis. All statistical analyses and visualizations were performed in R version 4.5.1 (R Core Team 2025). Differences in the abundance of arthropod orders, families, and spider species among the three trap types were analyzed using the mvabund package (Wang et al. 2022), which fits generalized linear models specifically designed for multivariate count data. Negative binomial models with a log-link function were used to account for overdispersion, and statistical significance was assessed using 999 residual-based resampling iterations (Warton et al. 2017). *P*-values from univariate tests were corrected for multiple comparisons, with values below 0.05 considered statistically significant. To evaluate differences in arthropod community composition among trap types, non-metric multidimensional scaling (NMDS) based on Bray-Curtis dissimilarity was performed using the vegan package, with differences among trap types tested using PERMANOVA with 999 permutations. The datasets supporting the findings of this study are publicly available in the Zenodo repository.

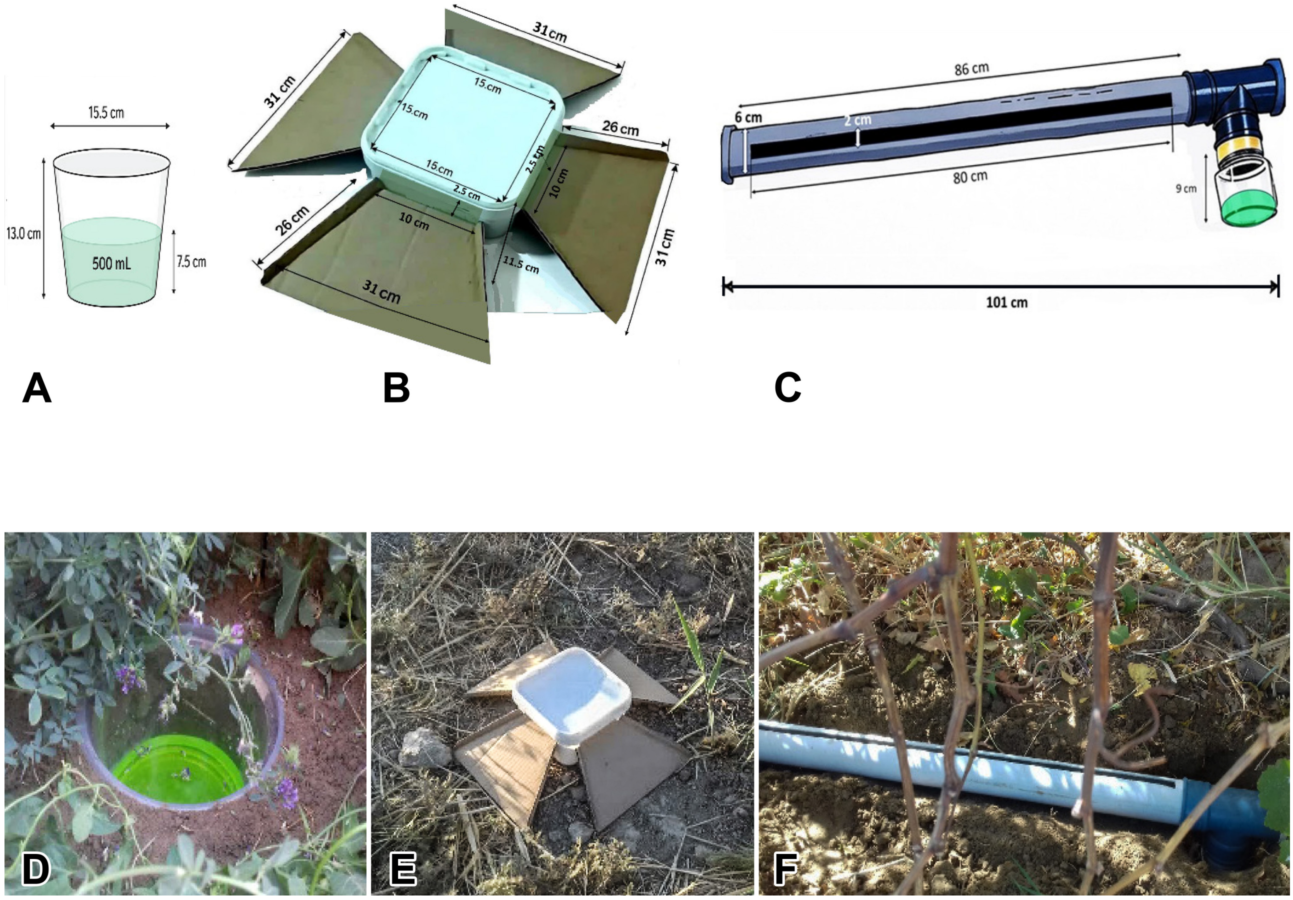

Figure 2. Trapping methods used in this study. **A.**, **D.** Pitfall trap; **B.**, **E.** Ramp trap; following Bouchard et al. (2000), with modifications; **C.**, **F.** Tube trap; following Rakhshani (2018), with modifications. Schematics of the traps were created using BioRender (BioRender 2025).

RESULTS

A total of 14,960 arthropod specimens were collected, representing 12 orders and 52 families (Table 1). Tube traps captured 7,706 individuals from 11 orders and 45 families, pitfall traps 5,343 individuals from 12 orders and 50 families, and ramp traps 1,911 individuals from 11 orders and 42 families (Table 1). Concerning spiders (Araneae), 864 adult specimens representing 36 species and 18 families were identified (Table 2). Some families exhibited trap-specific capture patterns. Tube traps captured the only scytodids (n = 2) present in the material, while no oxyopids were collected by this trap type (n = 6 in other traps). Furthermore, specimens of Dysderidae, Eresidae, Palpimanidae, Pholcidae, Sicariidae, and Sparassidae were captured only by the combination of tube and pitfall traps (Table 2). Tube traps collected the largest number of individuals, yielding 435 individuals representing 32 species. Among these, three species were collected exclusively by this trap type: *Evippa luteipalpis* (n = 2), *Cryptodrassus helvolus* (n = 4), and *Scytodes* sp. (n = 2). Pitfall traps yielded 251 individuals representing 31 species, including one species found only in this trap type, *Bassaniodes drangianus* (n = 4). Ramp traps collected 178 individuals representing 23 species, with *Chalcoscirtus karakurt* recorded only in this trap type (n = 1) (Table 2). Several taxa showed clear differences in abundance among trap types, and some differences were also observed between sampling periods and orchards, although temporal and spatial patterns are not analyzed in detail here. For each taxon, the highest number of individuals captured among the three trap types is underlined in Tables 1 and 2.

Table 1. Total individuals of each arthropod order (in bold) and family collected using tube, pitfall, and ramp traps in this study; for each taxon, the highest number is underlined. Taxa excluded from the analysis are listed in the Materials and Methods.

Taxa	Tube	Pitfall	Ramp	Total
Araneae	**435**	**251**	**178**	**864**
Corinnidae	8	6	2	16
Dysderidae	9	3	0	12
Eresidae	2	1	0	3
Gnaphosidae	177	143	90	410
Linyphiidae	14	4	6	24
Lycosidae	123	10	8	141
Oecobiidae	3	14	16	33
Oonopidae	28	12	6	46
Oxyopidae	0	4	2	6
Palpimanidae	3	2	0	5
Philodromidae	43	22	27	92
Pholcidae	1	2	0	3
Salticidae	5	1	2	8
Scytodidae	2	0	0	2
Sicariidae	1	2	0	3
Sparassidae	1	1	0	2
Thomisidae	5	17	13	35
Zodariidae	10	7	6	23
Blattodea	**39**	**59**	**27**	**125**
Corydiidae	31	59	27	117
Termitidae	8	0	0	8
Coleoptera	**1,106**	**618**	**243**	**1,967**
Anthicidae	388	107	66	561
Buprestidae	4	1	1	6
Carabidae	364	194	37	595
Cleridae	0	2	2	4
Coccinellidae	3	7	7	17
Curculionidae	28	22	25	75
Elateridae	98	40	20	158
Histeridae	41	37	13	91
Latridiidae	52	73	30	155
Scarabaeidae	11	5	0	16
Staphylinidae	19	5	18	42
Tenebrionidae	98	125	24	247
Dermaptera	**50**	**35**	**6**	**91**
Forficulidae	50	35	6	91
Hymenoptera	**2,089**	**2,032**	**1,042**	**5,163**
Apidae	3	14	26	43
Bethylidae	5	3	4	12
Braconidae	0	2	3	5
Chalcididae	3	2	10	15
Chrysididae	0	1	2	3
Formicidae	2,052	1,928	928	4,908
Ichneumonidae	0	2	1	3
Mutillidae	8	1	1	10
Platygastridae	10	21	8	39
Pompilidae	5	18	49	72
Sphecidae	3	5	1	9
Vespidae	0	35	9	44
Isopoda	**3,892**	**2,224**	**336**	**6,452**
Lithobiomorpha	**1**	**3**	**3**	**7**
Lithobiidae	1	3	3	7
Mantodea	**0**	**4**	**0**	**4**
Mantidae	0	4	0	4
Opiliones	**5**	**50**	**6**	**61**
Phalangiidae	5	50	6	61
Orthoptera	**42**	**43**	**62**	**147**
Gryllidae	11	24	3	38
Gryllotalpidae	31	19	59	109
Scorpiones	**39**	**16**	**7**	**62**
Buthidae	39	16	7	62
Solifugae	**8**	**8**	**1**	**17**
Galeodidae	8	8	1	17
Total	**7,706**	**5,343**	**1,911**	**14,960**
Families	**45**	**50**	**42**	**52**
Orders	**11**	**12**	**11**	**12**

Table 2. Total number of adult individuals of each spider family (in bold) and species collected using tube, pitfall, and ramp traps in this study; for each taxon, the highest number is underlined.

Taxa	Tube	Pitfall	Ramp	Total
Corinnidae	**8**	**6**	**2**	**16**
Castianeira arnoldii Charitonov, 1946	8	6	2	16
Dysderidae	**9**	**3**	**0**	**12**
Dysdera sp.	9	3	0	12
Eresidae	**2**	**1**	**0**	**3**
Stegodyphus sp.	2	1	0	3
Gnaphosidae	**177**	**143**	**90**	**410**
Berlandina afghana Denis, 1958	8	1	1	10
Cryptodrassus helvolus (O. Pickard-Cambridge, 1872)	4	0	0	4
Marinarozelotes jaxartensis (Kroneberg, 1875)	10	11	0	21
Marinarozelotes lyonneti (Audouin, 1826)	8	4	3	15
Micaria ignea O. Pickard-Cambridge, 1872	10	14	9	33
Minosiella intermedia Denis, 1958	118	101	60	279
Sosticus loricatus (L. Koch, 1866)	6	3	0	9
Zelotes laetus (O. Pickard-Cambridge, 1872)	7	4	4	15
Zelotes sarawakensis (Thorell, 1890)	5	3	12	20
Zelotes scrutatus (O. Pickard-Cambridge, 1872)	1	2	1	4
Linyphiidae	**14**	**4**	**6**	**24**
sp. *	14	4	6	24
Lycosidae	**123**	**10**	**8**	**141**
Draposa oakleyi (Gravely, 1924)	99	7	7	113
Evippa luteipalpis Roewer, 1955	2	0	0	2
Wadicosa fidelis (O. Pickard-Cambridge, 1872)	22	3	1	26
Oecobiidae	**3**	**14**	**16**	**33**
Oecobius nadiae (Spassky, 1936)	2	10	15	27
Uroctea thaleri Rheims, Santos & van Harten, 2007	1	4	1	6
Oonopidae	**28**	**12**	**6**	**46**
sp. *	28	12	6	46
Oxyopidae	**0**	**4**	**2**	**6**
Oxyopes globifer Simon, 1876	0	4	2	6
Palpimanidae	**3**	**2**	**0**	**5**
Palpimanus sp.	3	2	0	5
Philodromidae	**43**	**22**	**27**	**92**
Rhysodromus medes Zamani & Marusik, 2021	0	1	1	2
Thanatus sepiacolor Levy, 1999	36	7	5	48
Thanatus vulgaris Simon, 1870	5	10	13	28
sp. *	2	4	8	14
Pholcidae	**1**	**2**	**0**	**3**
Artema sp.	1	2	0	3
Salticidae	**5**	**1**	**2**	**8**
Chalcoscirtus karakurt Marusik, 1991	0	0	1	1
Cyrba ocellata (Kroneberg, 1875)	4	0	1	5
Plexippus paykulli (Audouin, 1826)	1	1	0	2
Scytodidae	**2**	**0**	**0**	**2**
Scytodes sp.	2	0	0	2
Sicariidae	**1**	**2**	**0**	**3**
Loxosceles rufescens (Dufour, 1820)	1	2	0	3
Sparassidae	**1**	**1**	**0**	**2**
Eusparassus sp.	1	1	0	2
Thomisidae	**5**	**17**	**13**	**35**
Bassaniodes drangianus Zamani & Marusik, 2025	0	4	0	4
Stiphropus strandi Spassky, 1938	5	13	13	31
Zodariidae	**10**	**7**	**6**	**23**
sp. *	10	7	6	23
Total	**435**	**251**	**178**	**864**
Families	**17**	**17**	**11**	**18**
Species	**32**	**31**	**23**	**36**

*Taxa not identified to genus level. Images available at: https://doi.org/10.5281/zenodo.19541502

Statistically significant maxima were recorded for tube traps in Araneae, Isopoda, Coleoptera, Lycosidae, and *Draposa oakleyi*, and for pitfall traps in Opiliones; no significant maxima were observed for ramp traps. Overall, Gnaphosidae and Lycosidae were the most abundant spider families, with *Minosiella intermedia* and *Draposa oakleyi* as dominant species, most of which were captured by tube traps (Table 2; Fig. 3F). Tube traps also yielded higher abundances of spiders overall, as well as beetles, particularly Carabidae, and woodlice (Isopoda: Oniscidea) (Fig. 3A–C, E–F).

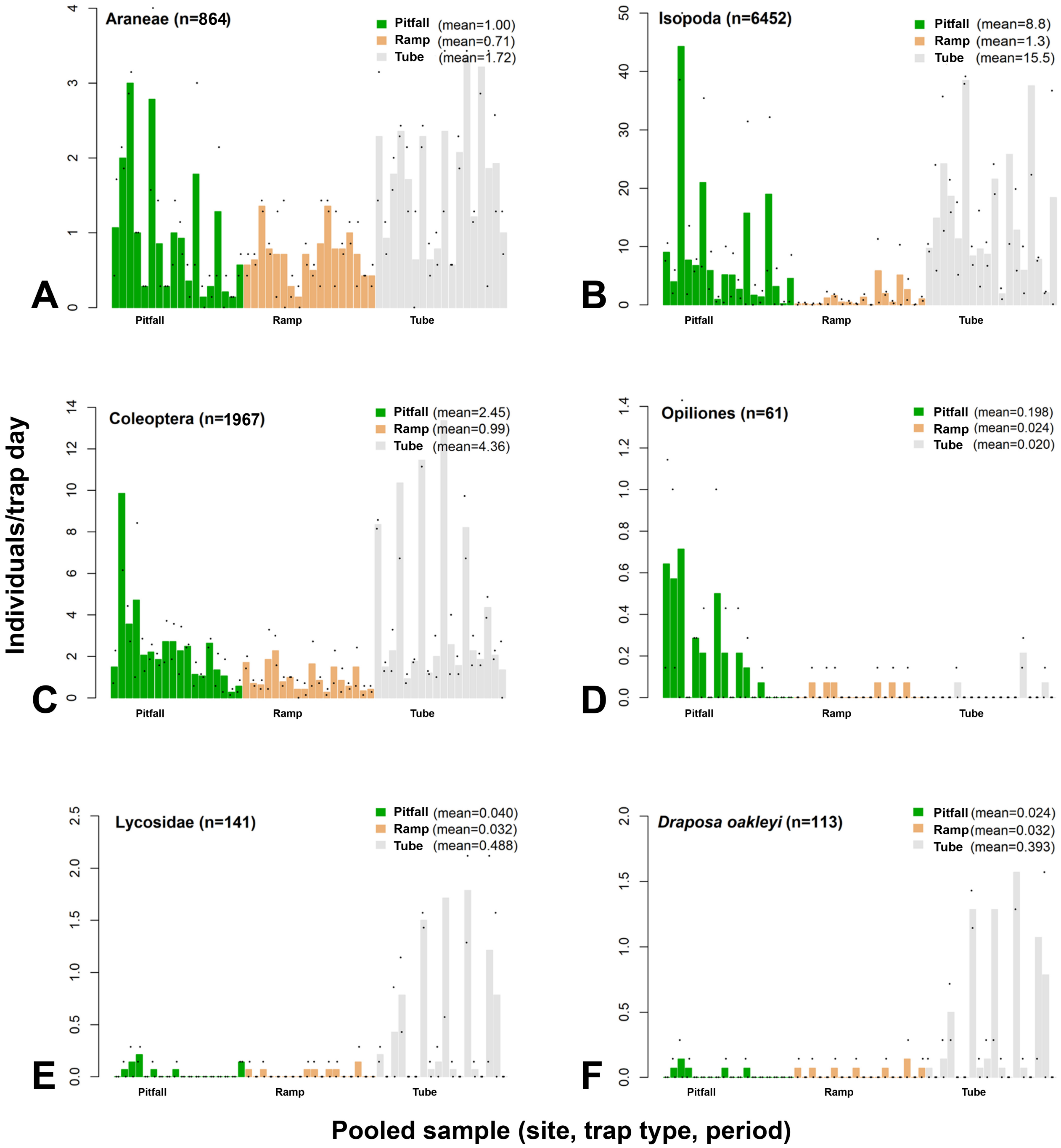

Figure 3. Mean number of arthropods captured per trap day for six taxonomic groups (A–F). Bars represent means (n = 3 per site, trap type, and sampling period); points show individual samples. Tube traps captured significantly more individuals of **A.** Araneae ($p < 0.001$); **B.** Isopoda ($p < 0.001$); **C.** Coleoptera ($p < 0.01$); **E.** Lycosidae ($p < 0.01$); **F.** *Draposa oakleyi* ($p < 0.05$). Pitfall traps captured significantly more individuals of (D) Opiliones ($p < 0.001$).

Pitfall traps performed comparably to tube traps for several groups, including Gnaphosidae and Formicidae, while collecting more harvestmen (Opiliones) than the other two trap types combined (Fig. 3D). Individuals of only a few taxa, such as Pompilidae, Gryllotalpidae, and *Oecobius nadiae* were numerically more abundant in ramp traps, and these differences were not statistically significant (Tables 1 and 2). Multivariate analysis revealed significant differences among trap types (PERMANOVA, $F = 10.75$, $p = 0.001$).

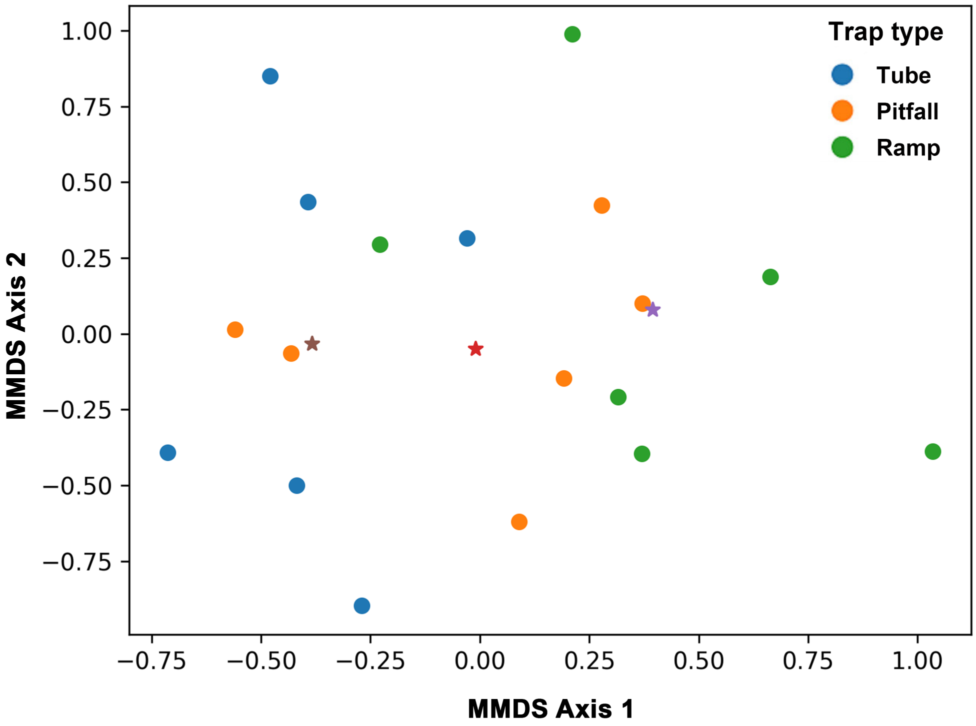

Figure 4. Non-metric Multidimensional Scaling (NMDS) ordination plot based on Bray-Curtis dissimilarity of arthropod family-level abundances captured by the three trap types (stress = 0.089). Each point represents a single trap sample (n = 6 per trap type). Stars indicate the centroid (multivariate mean) of each trap type.

NMDS ordination (*stress = 0.089*) showed that tube traps formed a distinct cluster, while pitfall and ramp traps partially overlapped (Fig. 4). This separation was driven by higher abundances of Isopoda, Lycosidae, Gnaphosidae, and Coleoptera in tube traps, and greater representation of Oecobiidae and Pompilidae in ramp traps. The partial overlap between pitfall and ramp traps reflects their shared effectiveness for ground-active taxa.

DISCUSSION

This study represents one of the few comparative assessments of arthropod trapping methods conducted under arid field conditions. By systematically evaluating pitfall, ramp, and tube traps (Bouchard et al. 2000; Rakhshani 2018), we expand the understanding of sampling performance in arid environments, confirming the general effectiveness of pitfall traps for epigeal arthropods while revealing important limitations under extreme aridity. The Sistan region supports a diverse arthropod assemblage (Zamani et al. 2025); however, its location within an arid to hyper-arid inland basin, characterized by extremely hot summers, a July average temperature of 41.4°C, and prolonged '120-day winds' (Zolfaghari et al. 2011), poses significant logistical and methodological challenges for conventional sampling.

Pitfall traps have historically been the dominant method for surveying epigeal arthropods (Hohbein & Conway 2018), but our results demonstrate that extreme aridity can substantially limit their effectiveness. We observed rapid evaporation of the preservative solution, exacerbated by the absence of rain covers and direct sunlight exposure. Wind-blown dust accumulation and occasional disturbance by small vertebrates, including lizards and rodents, further compromised sample quality. These challenges are consistent with reports from other arid and hyper-arid ecosystems (Saji et al. 2021; Stašiov et al. 2021; Ahmed et al. 2023), and demonstrate the need for alternative methods in such environments. Ramp traps, originally designed for environments where digging is difficult (Bostanian et al. 1983; Bouchard et al. 2000), provided a workable alternative under certain site conditions but were the least productive sampling method overall. Their low-profile design offered little protection against intense sunlight and persistent winds, leading to partial evaporation of the preservative within 2–3 days; the solution was therefore replenished every three days to prevent complete desiccation (Császár et al. 2018; Weary et al. 2019). Despite lower overall yields, ramp traps captured higher numbers of wall spiders and spider wasps than the other trap types, consistent with observations from forested and less-arid systems (Work et al. 2002; Österman et al. 2024), indicating their value as a complementary tool for taxa less likely to encounter pitfall or tube traps. The tube trap, implemented here based on the design of Rakhshani (2018), proved to be the most effective and environmentally resilient method overall. Its subsurface configuration, with only a narrow slit at the soil surface, greatly reduced evaporation, minimized dust contamination, prevented vertebrate bycatch, and enhanced stability under strong winds. These advantages extended practical servicing intervals to 10–14 days, compared with 2–4 days for pitfall and ramp traps, providing a significant logistical benefit in remote field settings. The extreme conditions of the Sistan plain (high evaporation, dust-laden winds, and intense solar radiation) help explain the underperformance of conventional traps and indicate the suitability of the tube trap for hyper-arid environments. Nonetheless, trap dimensions and structural details remain critical, as variations in slit geometry or burial depth can influence catches (Brennan et al. 1999; Koivula 2003).

Tube traps collected the highest number of individuals overall (n = 7,706), outperforming the other trap types across the majority of taxonomic groups, including Isopoda, Araneae, and Coleoptera. Within Araneae, tube traps were particularly effective in capturing Gnaphosidae and Lycosidae, and among Coleoptera, Carabidae were most frequently collected in tube traps. Pitfall traps yielded intermediate total catches (n = 5,343) and performed comparably to tube traps for several groups, including Formicidae and Gnaphosidae, while capturing considerably more Opiliones than the other two trap types combined. In contrast, ramp traps consistently collected the fewest individuals (n = 1,911) across most taxonomic groups, although they had the highest proportions of certain taxa, including Pompilidae and Gryllotalpidae.

At the species level within Araneae, tube traps again collected the highest number of individuals (n = 435) and species (n = 32), with catches dominated by gnaphosids and lycosids. In particular, *Minosiella intermedia* was the most abundant spider species overall (n = 279) and was most frequently collected in tube traps. Pitfall traps yielded intermediate spider catches (n = 251, 31 species) and performed comparably to tube traps for several gnaphosid species, while capturing higher numbers of several species, such as *Thanatus vulgaris* and *Stiphropus strandi*. Ramp traps collected the fewest spiders overall (n = 178, 23 species), though they had the highest catches for a few species, such as *Oecobius nadiae*, *Zelotes sarawakensis*, *Thanatus vulgaris*, and an unidentified species of Philodromidae.

Trophic level further influenced capture patterns: predators were well represented in tube and pitfall traps, detritivores predominantly in tube traps, and herbivores or parasitoids in ramp traps. These patterns are reflected in the NMDS ordination, which revealed that tube traps formed a distinct cluster, while pitfall and ramp traps showed partial overlap, indicating that these two surface-based methods capture more similar arthropod communities. This separation was driven primarily by the higher abundance of Isopoda, Lycosidae, Gnaphosidae, and Coleoptera in tube traps, and the greater representation of Oecobiidae and Pompilidae in ramp traps. These patterns reflect trait-based capture efficiency, shaped by body size, locomotion, and microhabitat preference, rather than species-specific responses (Topping & Sunderland 1992; Hancock & Legg 2011).

This study has several limitations that should be acknowledged. Sampling was restricted to spring, when arthropod activity is high and extreme summer temperatures, often exceeding 45°C, make continuous sampling impractical. This seasonal restriction limits generalizability, and future studies should span multiple seasons to capture phenological shifts in community composition. The uniform orchard sites may also have reduced inter-trap variability, as habitat heterogeneity is known to amplify differences among trap types (Topping & Sunderland 1992). These results should therefore be treated as a controlled baseline requiring further testing across seasons and habitat mosaics. Future studies should also explore design modifications to the tube trap and evaluate its performance across different habitats and ecosystems (Santos et al. 2007; Sereda et al. 2014). A quantitative trait-based approach incorporating body size measurements, locomotion assays, and foraging mode classification, combined with multivariate methods such as RLQ analysis, would further clarify trap selectivity mechanisms, while behavioral observations and video recordings could enable the development of bias-correction factors.

Overall, tube traps demonstrated the most consistent performance across sites and sampling periods, capturing the greatest diversity and abundance of epigeal arthropods while offering practical advantages in terms of DNA preservation, reduced debris accumulation, and lower field and laboratory workload. We recommend tube traps as the primary sampling method in arid to hyper-arid environments, supplemented by pitfall and ramp traps to reduce sampling bias and improve community-level coverage. Proper flush-surface installation is essential for consistent capture efficiency. Future research should optimize trap architecture, integrate microclimatic monitoring, and evaluate performance across a wider range of dryland ecosystems.

AUTHOR'S CONTRIBUTION

The authors confirm their contribution to the paper as follows: M. Enayatnia: sampling and sorting the specimens, data curation, drafting; A. Mirshekar: conceptualization, formal analysis, data curation, writing original draft, writing and editing, visualization, supervision; S. Ramroodi: conceptualization, methodology, revising, supervision; A. Zamani: conceptualization, methodology, data validation, writing, review and editing, taxonomic identification. All authors read and approved the final version of the manuscript.

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AVAILABILITY OF DATA AND MATERIAL

The datasets supporting the findings of this study are available in the Zenodo repository under the following URL: https://doi.org/10.5281/zenodo.19541502

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study only included arthropod material, and all required ethical guidelines for the treatment and use of animals were strictly adhered to in accordance with international, national, and institutional regulations. No human participants were involved in any studies conducted by the authors for this article.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this paper.

GENERATIVE AI STATEMENT

AI tools were used only for language editing and had no involvement in the research or analytical process. All content is the authors' own work.

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مقایسهٔ عملکرد تله‌های گودالی، شیب‌دار و لوله‌ای برای نمونه‌برداری از بندپایان در یک منطقه خشک در جنوب‌شرقی ایران

معصومه عنایت‌نیا[1]، علی میرشکار[1]، علیرضا زمانی[2]، سارا رامرودی[1]

۱ گروه گیاهپزشکی، دانشکده کشاورزی، دانشگاه زابل، ایران
۲ موزه جانورشناسی، گروه تحقیقات تنوع زیستی، دانشگاه تورکو، فنلاند

نویسندهٔ مسئول: علی میرشکار | mirshekar@uoz.ac.ir

ویراستارعلمی
بهزاد میری

دریافت: ١٣ بهمن ١٤٠٤
ویرایش: ٢٥ فروردین ١٤٠٥
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چکیـده: تله‌های گودالی به‌طور گسترده برای نمونه‌برداری از بندپایان خاک‌زی به کار می‌روند و تله‌های شیب‌دار و لوله‌ای نیز گزینه‌هایی مکمل در این زمینه محسوب می‌شوند. پژوهش حاضر با هدف مقایسه کارایی این سه نوع تله در یک محیط خشک در جنوب‌شرق ایران انجام شد. نمونه‌برداری میدانی در بهار سال ۱۴۰۴ در سه باغ فعال در منطقه سیستان صورت گرفت. از هر نوع تله شش تکرار (جمعاً ۱۸ تله) در طول سه مسیر نمونه‌برداری قرار داده شد. اکثر عنکبوت‌های بالغ تا سطح گونه و اکثر سایر بندپایان تا سطح خانواده شناسایی شدند. در مجموع، ۱۴۹۶۰ فرد متعلق به ۱۲ راسته و ۵۲ خانواده جمع‌آوری گردید. تله‌های لوله‌ای با صید ۷۷۰۶ فرد، بیشترین تعداد نمونه را به خود اختصاص دادند و در اغلب گروه‌های آرایه‌شناختی از جمله جورپایان (Isopoda)، قاب‌بالان (Coleoptera) و عنکبوت‌ها (Araneae) از دو نوع تله دیگر کارآمدتر بودند. تله‌های گودالی با ۵۳۴۳ نمونه در جایگاه میانی قرار گرفتند. اگرچه از نظر عملکرد در گروه‌هایی مانند Gnaphosidae و Formicidae با تله‌های لوله‌ای قابل‌رقابت بودند، اما در صید درازپایان (Opiliones) عملکرد بهتری نشان داده و تعداد بیشتری از این گروه را نسبت به مجموع دو نوع تله دیگر به‌دست آوردند. تله‌های شیب‌دار با ۱۹۱۱ فرد، کمترین تعداد صید را داشتند، اما بیشترین تعداد فرد از Pompilidae و Gryllotalpidae را ثبت کردند و همراه با تله‌های گودالی، چندین گونه عنکبوت را صید نمودند که توسط تله‌های لوله‌ای کمتر نمونه‌برداری شده بودند یا کلا جمع‌آوری نشده بودند. به‌طور کلی، تله‌های لوله‌ای گزینه‌ای عملی و کارآمد برای نمونه‌برداری از بندپایان خاک‌زی در محیط‌های خشک محسوب می‌شود. با این حال، برای دستیابی به نمونه‌ای جامع‌تر از جامعه زیستی و کاهش سوگیری روش‌شناختی، استفاده ترکیبی از هر سه نوع تله در ارزیابی‌های تنوع زیستی اکوسیستم‌های بیابانی توصیه می‌شود.

واژگـان کلیدی: بندپایان خاک‌زی، روش‌های نمونه‌برداری، منطقه سیستان، عنکبوت‌ها