Diversity and composition of epigeal arthropods using pitfall trapping method in different habitat types of Abu Dhabi Emirate, UAE

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1. Introduction

The United Arab Emirates (UAE) is situated in Southwest Asia on the Arabian Peninsula at the border between the Palearctic and Afrotropical regions. UAE has unique arthropod fauna that has been explored and described since 2004, and comprises around 4000 arthropod species, of which 553 represent new species new to science (Krogmann, 2011). The fauna of the UAE, as for most countries, is dominated by the phylum Arthropoda in terms of the numbers of both species and individuals. Amongst the arthropods, the insects are by far the most numerous, but other interesting groups occur, including true spiders, camel spiders, scorpions, pseudoscorpions, ticks, centipedes and isopods or woodlice. All available major habitat types in the UAE have their own insect populations, together with at least some representatives of other arthropod groups. Even in the desert, close observation reveals much invertebrate life (van Harten, 2008).

Pitfall trapping was used to study the diversity and seasonal abundance of arthropods, especially ground dwelling darkling beetles (Tenebrionidae) at five desert sites in the west of Abu Dhabi Emirate in Al Dhafra Region from March 2009 to February 2010 (Saji and Al Dhaheri, 2011). Pitfall traps are considered reliable method for beetles and long-term trapping is required to understand the biodiversity, community composition and activity of different species in different seasons. Previous studies by the Environment Agency - Abu Dhabi (EAD) have shown that the insect Order Coleoptera (beetles) have been trapped more frequently in spring season as compared to winter and midsummer in the Al Dhafra Region of Abu Dhabi Emirate.

Pitfall trapping is the most frequently used method for sampling ground dwelling arthropods. (Saji and Al Dhaheri, 2014).
Whereas the capture of specimens in pitfall traps largely depends on the presence of number of individuals in the sampled area. Furthermore, trap design and trapping effort for a given environment can also affect sampling success. An inexpensive pitfall trap system that allows for rapid and easy field collection of invertebrates has been used widely over the years to collect a wide variety of arthropods (Freeman, 1974; Borror et al., 1989; Dunn, 1989). As the name suggests, the trap works on the principle that a small animal moving on the ground simply falls into an open (usually circular) container dug into the ground. Pitfall traps have proved to be a simple and efficient sampling technique for ant biodiversity surveys, bioindication, and conservation studies, also it is a frequently used method for sampling arthropod species (Parr and Chown, 2001; Lopes and Vasconcelos, 2008; Sabu and Shiju, 2010; Silva et al., 2013; Brown and Mathews, 2016). The abundance, richness and composition of invertebrate orders can be studied using this method (Ward et al., 2001). Pitfall trapping method is one of the mostly used methods to study surface-active invertebrates but has many potential biases that may affect the catch of invertebrates. For instance, the distance between pitfall traps (inter-trap spacing) is one such factor.

The present study aims 1) to provide data to decide on the most appropriate method for sampling of ground-dwelling arthropods measured in the habitats like sand sheets, sand dunes, gravel plains, rocky mountain, and wadi in the Emirate of Abu Dhabi 2) to investigate the peak seasonal occurrence of arthropods species during the study 3) to study the higher species composition and diversity of most represented taxa resulted by pitfall trapping method.

2. Study area

The study was conducted at five study sites 1) Al Wathba Wetland Reserve (AWWR) 2) Abu Al Abyed 3) Habshan 4) Wadi Tarabat 5) Umm Al Ghafa of different habitat types. Moreover, multiple sampling points were selected at each site to do the trapping activity (Fig. 1).

In AWWR a total of 12 sampling points were selected to deploy pitfall traps for capturing arthropod species. Whereas total of three sampling points were selected in Abu Al Abyed followed by two sampling points in Habshan area. Furthermore, multiple sampling points were also selected in Um Al Ghafa and Wadi Tarabat to maximise the capturing of arthropods species. All the selected localities were having different habitat types such as AWWR which is an Inland wetland, the dominating habitat in Abu Al Abyed and Um Al Ghafa is sand sheets sand dunes and gravel plains (alluvial and interdunal), whereas Wadi Tarabat comprises of mountain rocky terrain and wadis (Fig. 1).

AWWR is a complex of natural and man-made surface water bodies located approximately 40 km southeast of Abu Dhabi Island. The reserve lies north of the Musaffah–Al Ain Truck Road and is approximately 3.5 km long and 1.5 km wide (Soorae et al., 2020). Annual temperature 19–36 °C; 40–80% RH; average rainfall 2 mm/year, which occurs mostly in November February months when receive the most rain. Abu Al Abyed and Habshan are located some 50 km away from Abu Dhabi city in Al Dhafra Region. Both the localities are unique gravel plain and sand sheets and dunes area with a little vegetation, mainly dominated by one plant species, the foetid saltwort (Saussula imbricata) which is a leaf succulent perennial halophyte from the family Chenopodiaceae (Saji and Al Dhaheri, 2011).

Two localities 1) Wadi Tarabat 2) Umm Al Ghafa were selected in the east of Abu Dhabi Emirate in Al Ain Region which is located approximately 160 km from capital city of Abu Dhabi and about 120 km south of the Emirate of Dubai. Wadi Tarabat is a mountain habitat located in the foothills of Jabal Hafit National Park which is the only mountain and certainly the most prominent landscape feature, within the Emirate of Abu Dhabi. It is an isolated massif or inselberg (an isolated hill or mountain), lying just to the south of the city of Al Ain. It is aligned in a north to south direction and is approximately seventeen kilometres long, with its greatest altitude at about 1300 m above-sea-level. Jabal Hafit is the southernmost, and by far the largest, series of mountain ridges running north-south in the vicinity of Al Ain (Horny, 2004). The microhabitat identified as a mountain and alluvial plains with distinct tree vegetation. The soil substrate comprises alluvial plains, gravel, pebbles and rocky material (Brown and Sakkar, 2004) (Fig. 1). Umm Ghafa is also located in Al Ain region, the major habitat type of this locality is gravel plains (alluvial and interdunal).

Additionally, a locality Madinat Zayed was also monitored only for twice in 2010 which is located 15 km from Abu Al Abyed exit on Abu Dhabi Sila Road. This site is characterised by sand sheets and sand dunes that are exposed to strong winds year-round. The soil substrate comprises fine sand with no gravels or organic matter present, the sand is whiter in colour compared to other sites. The vegetation of this habitat is dominated by Tetraena qaterensis and Haloxylon salicornicum. Other plant species include Cyperus conglomeraus and Dipterygium glaucum.

3. Materials and methods

Sampling effort was different for each selected locality depending on logistics and available resources and field biologists in Abu Dhabi Emirate (Fig. 1). Fortnightly to monthly visits were conducted to collect data from pitfall trap containers from March 2009 to March 2015 by 1–2 experienced field biologists using 4×4 vehicles. Fortnightly to monthly trips were undertaken at two study sites, 1) Abu Al Abyed and 2) Habshan between March 2009 and February 2010. Moreover, monthly visits were undertaken to collect pitfall data in Umm Al Ghafa and Wadi Tarabat between March 2010 and December 2010. Pitfall traps data was collected from multiple sampling points in AWWR on monthly basis along with other sites from January 2011 to March 2015. The arthropod trapping was exclusively undertaken from AWWR between January 2012 and March 2015, no other sites were surveyed during this period. The sampling area in AWWR was selected a square plot of 20 x 20 meter and the distance between the pitfall traps were kept at 2 m apart in vertical lines (Saji and Al Dhaheri, 2011). Each pitfall trap comprised a plastic vessel (170 mm diameter × 180 mm deep), buried upto its rim in the soil (Fig. 2). The medium sized containers were used for the convenience of deployment in the sandy area and gravel substrates. Trapped invertebrates were separated, identified, counted, and the abundance and frequency of occurrence of taxa at each site was recorded. Furthermore, to avoid the loss of data from pitfall containers, some of the sites such as Abu Al Abyed and Habshan were visited three times in a month. As these sites experience heavy sandstorms, to avoid filling of containers the visits were conducted more frequently as compared to other study sites.

3.1. Species identification

Specimens were collected from the pitfall traps and preserved in 70% Ethanol and efforts were made to dry pin the specimen in the laboratory for the insect collection. Furthermore, voucher specimens (specimens collected from study sites and preserved for future reference) were identified up to species level using the books Insects of Eastern Arabia (Walker and Pittaway, 1987) and Arthropod Fauna of UAE, 3: Order Coleoptera, family Tenebrionidae (Schawaller, 2010) and by comparing with already identified spec-
imens in EAD invertebrate reference collection. Also, some specimens were identified in the laboratory under the binocular microscope. All the identified specimens were deposited in the invertebrate collection of EAD. Photographs of the specimen were also taken in field to identify and differentiate the species.

3.2. Data analysis

To do the analysis, study period was divided into two seasons, winter season (from October to March) and summer season from (April to September). Raw data processing and yearly summation was carried out in MS excel. One-way-ANOVA test were used to find the difference in the number of species and the number of individuals across seasons and across the months. Descriptive analysis was carried out using SYSTAT 10 (2000). The species diversity and evenness were calculated using Shannon-Weiner Diversity Index in MS Excel. The cluster analysis and species richness were calculated using Biodiversity-Pro (1997).

4. Results

To collect data of arthropods species from the five different localities, a total of 94 visits were undertaken from March 2009 to March 2015. The highest number of 21 visits were undertaken in 2009 when only two study sites 1) Habshan 2) Abu Al Abyed were visited for data collection fortnightly to monthly. Followed by 18 fortnightly to monthly visits undertaken in 2011 at three different sites. Moreover, monthly visits were undertaken to collect data only from AWWR between March 2012 and March 2015. Over all 61% of the total visits were conducted in AWWR whereas 39% in all other study sites. The efforts were made to collect pitfall traps data each month regardless of the weather conditions mainly from AWWR. In Madinat Zayed study site, only two visits were made to collect data from the pitfall traps and only one species of darkling beetle (Adesmia stoekleini rasalkhymana) was recorded.

4.1. Arthropods species diversity and abundance

A total number of 121 species belonging 14 orders and 46 families were recorded from five study sites of different habitat types. On average $36 \pm 6$ (mean $\pm$ SE) species were recorded every year.
from all the localities between March 2009 and March 2015. Furthermore, an average of 37.5 ± 3 (mean ± SE) species were recorded every month of every year. The highest number of 60 species were encountered during the month of March from all the survey sites whereas the lowest number of 25 species were recorded during the month of February (Fig. 3).

The number of Arthropod species recorded did not vary significantly across the years (df = 6, F = 1.42, p = 0.20 One-Way-ANOVA) and across the months (df = 11, F = 0.48, p = 0.91 one-way—ANOVA) (Fig. 3). The order Coleoptera (beetles) was recorded to be the most dominant order with 46 species followed by Hymenoptera (ants, bees & wasps) with 24 species and 2 orders (Neuroptera & Prostigmata) were represented by only one species (Fig. 4). Moreover, family Tenebrionidae (Darkling beetles) was recorded to be the dominant family with 28 species followed by Formicidae (ants) with 15 species. Besides, a total of 22 families were represented by single species. We found that a total of (n = 56) 46% arthropod species were recorded year-round at all the study sites whereas (n = 30) 24% species were only recorded in summer season and (n = 35) 28% species were recorded during the winter season. However, the difference in number of species is not statistically significant (df = 1, F = 1.31, p = 0.25 one-way—ANOVA). Moreover, only 9 species were collected from pitfall traps which were recorded every month from January to December.

The invertebrate fauna was recorded to be highly diversified from across the different habitats in Abu Dhabi. However, the number of individuals were not evenly distributed across the study sites and across the different habitats (H) 1.10, (E) 0.53, Shannon Diversity Index) (Fig. 5).

During the study period between March 2009 and March 2015 a total of 36,238 individuals of arthropods were recorded from five different study sites. On an average of 5177 ± 1364 (mean ± SE) individuals were recorded every year from all the sites. Moreover, the highest number of 12,063 individuals were recorded in 2012 and lowest number of 424 individuals were recorded from January to March 2015. The number of individuals were recorded higher in 2012 as compared to other years and the numbers varied significantly across the years (df = 6, F = 3.08, p = 0.00 one-way ANOVA). On an average 3020 ± 315 (mean ± SE) individuals of invertebrates were recorded every month, the highest number of 4536 individuals were recorded during the month of May and lowest of 826 recorded in the month of February and the number of individuals did not vary significantly across the months (df = 11, F = 0.72, p = 0.71 one-way ANOVA).

4.2. Species occurrence across the sites

During the monthly visits, AWWR had recorded the highest number of 66 species followed by Wadi Tarabat with 39 and Um Al Ghafa with 32 species (Fig. 6). Moreover, 36% of the total species were recorded from inland wetland habitats followed by 23% gravel pans (alluvial and interdunal) and 21% from mountain and rocky terrain and wadis and the 20% from the coastal plains, sand sheets and low dunes (Fig. 6). Monthly occurrence of the species were recorded higher in AWWR as compared to the other study sites (Fig. 7).

Furthermore, a total of only two visits were undertaken in Madinat Zayed which was the sixth study sites in year 2010, where one single species Adesmia stoekleini rasalkhymana was encountered. Cluster analysis was performed in order to identify similarities between the study sites in terms of species diversity and richness, the results shows that three localities 1) Abu Al Abyed 2) Habshan 3) Umm Ghafa were closely related to each other in terms of arthropod species diversity and richness. However, AWWR and Wadi Tarabat were found to be having another cluster to show the similarity to support arthropod fauna (Fig. 8). Moreover, Wadi Tarabat had recorded the highest species diversity (H) = 2.7, (E) = 0.75 followed by AWWR with (H) = 2.1, E = (0.51) and Abu Al Abyed with H = (1.97), E = 0.54. Shannon Diversity Index. Furthermore, the site Habshan had also recorded the highest species diversity with H = 1.7, E = 0.51 followed by Umm Ghafa with H = 1.5, E = 0.45 (Shannon Diversity Index). Four species, 1) Aptenotechnes arabicus arabicus 2) Lepisma sp 3) Mesostena puncticollis 4) Trachyderma philistina were recorded from all the study sites. Whereas, 16 species out of total 121 species were exclusively found in mountain habitats in Wadi Tarabat, 32 species were uniquely recorded only from AWWR. Moreover, five unique species of arthropods were only recorded from Habshan area, whereas 10 species were only recorded from Umm Al Ghafa study area. On the other hand, a total of 9 species were exclusively recorded from sand sheets and dunes habitats of Abu Al Abyed site.

5. Discussion

Pitfall traps have been used over the years to collect a wide variety of animals (arthropods) (Borror et al., 1989; Dunn 1989). Most of the ground-dwelling arthropods are medium to very small in size and are found numerous in numbers in different habitats. Pit-
Fig. 4. Number of orders representing (>3) species recorded from March 2009 to March 2015.

Fig. 5. The Chart showing distribution of Arthropod Species across all the study sites between March 2009 and March 2015.

Fig. 6. Number of Arthropod species recorded from the study sites in Abu Dhabi Emirate between March 2009 and March 2015.
fall trapping method is effective in extracting a high proportion of this invertebrate group. The methods employed widely to survey ground-dwelling arthropods are pitfall trapping (Holland and Reynolds, 2005; King and Porter, 2005; Ward et al., 2001; Standen, 2000; Brennan et al., 1999; Holland and Smith, 1999; Mommertz et al., 1996; Mesibov et al., 1995; Olson, 1991). In current study, we have deployed pitfall traps in different habitat types across five different study sites in order to understand the efficacy of pitfall traps on different substrates in studying ground-dwelling arthropods. Additionally, during the study pitfall traps were deployed in winter and summer seasons to identify the peak season of the occurrence and abundance of arthropod species which are active on ground.

In Abu Dhabi Emirate, terrestrial invertebrates have the highest \( n = 2488 \) species in any category. Class Insecta has the highest \( n = 2358 \) (95%) species and Order Hymenoptera which includes (bees, wasps & ants) has the highest number of 793 species, followed by Coleoptera which includes beetles with 440 species (Khan et al., 2019). In the current study showed that family Tenebrionidae (Darkling beetles) was recorded to be the dominant family with 28 species. Most of them were ground-dwelling nocturnal species and pitfall trap method was found to be the best suitable for trapping this group of insects.

Invertebrates have some preferences for certain habitats – desert ecosystems generally have a low biodiversity abundance and richness due to the challenging climatic conditions. The UAE has a hyper-arid climate with extreme temperatures and low, patchy rainfall (Soorae et al., 2020). Wetlands exhibit enormous diversity according to their geographical location, water regime, chemistry, dominant species, and soil and sediment characteristics (Space Applications Centre, 2011). The study areas that we had selected for invertebrate study were of different habitat types to test the efficacy of the pitfall method within Abu Dhabi Emirate. Al Ain region having higher rainfall on average 8.21 mm per year as compared to the western region having most of the sand dune habitats the rainfall has been recorded 3.23 mm per year (NCM, 2020).

The AWWR has six major habitat types and is known to support rich biodiversity, the biodiversity richness of this reserve is represented by 61% bird species, 30% of reptile and amphibian species, 20% of mammal species 16% of invertebrates and 9% of Abu Dhabi Emirate’s plant species (Soorae et al., 2020). Several invertebrate species...
species new to science have been discovered within AWWR in the recent past. Despite the small size of this wetland reserve, the AWWR has diversity of habitat types which is why biologists from EAD have discovered new species of invertebrates from the Wetland Reserve. (Soorae et al., 2020). Invertebrates are recognised as important components of biodiversity (Oliver and Beattie, 1996; Yen and Butcher, 1997). In our study, 33% of the total arthropod fauna was recorded from AWWR as compared to other study sites. Also, AWWR was visited more frequently and regularly as compared to other sites because logistically the site is easy to access. Arthropod diversity and its abundance in AWWR were found to be relatively dissimilar in cluster analysis as compared to other study sites because of diversity of habitat types (Fig. 8). On the other hand, species diversity and abundance were found to be relatively similar in Umm Al Ghafa and Abu Al Abyed and Habshan with pitfall sampling method (Fig. 8).

AWWR has six main habitat types as per the Abu Dhabi habitat map dataset: 1) coastal salt flats, 2) sand sheets and dunes with dwarf shrub cover, 3) sand sheets and dunes with perennial herbs and graminoids 4) semi-artificial lakes, 5) moist ground with phragmites, Tamarix sp and grass mats, and 6) forestry plantations) (Al Dhaheri et al., 2017). In our results species diversity and abundance was recorded higher in AWWR as compared to other sites as more than 50% of the total monitoring visits to do pitfall trapping were undertaken in AWWR as compared to other localities.

Furthermore, 19% of the total species trapped in pitfall traps were recorded from Wadi Tarabat having a variety of plants diversity (Brown and Sakkir, 2004). In Abu Dhabi, Wadis refer to the upper and middle reaches of the wadi system before it merges into the flood plain and open terrain (Al Dhaheri et al., 2017). The trapping efforts in Wadi Tarabat were undertaken for a short period of time between March 2010 to December 2010 as compared to AWWR. The reason is it was difficult to set pitfall traps on a rocky and steep substrate as compared to other sites where the substrates were on sandy and gravels plains. During the study, it was found that setting up pitfall traps on rocky substrate in Wadi Tarabat was not easy especially on the rocky slopes, therefore pitfall traps were placed in plain areas having soft alluvial sand and gravels. Despite the difficulties in setting up the traps on rocky substrate, our results indicate that species diversity was recorded higher and dissimilar as compared to other sites. One of the reasons could be the presence of high diversity of flora species in Wadi Tarabat (Fig. 8). There are 209 species of vascular plants have been recorded from Jabal Hafit and surrounding wadis in Al Ain (Sakkir and Brown, 2013).

In general, trap-ability increases as the structure of habitat becomes more open (Melbourne, 1999). During the study period, Madinat Zayed was also selected and visited only twice, a total of three sampling points were selected to setting up pitfall traps. Nevertheless, due to heavy sandstorms, pitfall traps were found buried with sand and it was very difficult to relocate. Hence the data collection could not be continued. In other studies, it has been found that filling of the pitfall trap with sand has been a challenge in sand sheets and low dunes areas. (Matalin and Makarov, 2011). Furthermore, it is recommended that to overcome the challenges of losing pitfall traps in the sand sheets and sand dune habitats, the monitoring frequencies can be increased from monthly visit to weekly or fortnightly.

Pitfall trapping was undertaken in AWWR for more than three years and it has yielded plenty of data on ground dwelling insects and other species. Long-term monitoring studies on invertebrates by EAD have reported a large variety of insect fauna from AWWR (Soorae et al., 2020). A total number of 66 invertebrate species were recorded from AWWR which equates to 14% of the total fauna recorded at AWWR. In UAE, 4000 invertebrate species been recorded out of which almost 2488 are in the Emirate of Abu Dhabi (Khan, et al., 2019). In collaboration with the International Union for the Conservation of Nature (IUCN) regional Red list assessment was done by EAD to assess the status of serval invertebrate species which has regional and local importance (Saji & Al Rashdi, 2020 In press). Yellow Desert Scorpion (Vachoniulus globimanus) has been listed as Critically Endangered (CR) locally by IUCN National Red list of species in Abu Dhabi (Javed et al, 2020 (in press) followed by Camel Spider (Galeodes arabs) as an Endangered (EN) species. Both species were recorded during the field surveys from Abu Al Abyed as well as from AWWR. Furthermore, Arabian Black Fat-tailed Scorpion (Androctonus crassicauda) which is listed as vulnerable (VU) was also trapped in pitfalls at many sampling points of AWWR.

The appearance and disappearance of the beetles were strongly linked with seasonal changes (Saji and Al Dhaheri, 2011). Invertebrate surveys undertaken to establish an understanding of species and to assess habitat and diversity of ground dwelling invertebrates in a Houbara Protected area, which is also a release site for Asian Houbara (Chlamydotis undulata macqueenii). During the study, the highest number of Tenebrionids were trapped during the Spring (March to April) season whereas moderate numbers were recorded during winter season and the lowest number of ground dwelling insects were trapped in summer season (Saji and Al Dhaheri, 2011). In our study at five different sites, total of (46%) of arthropod species were recorded year-round whereas (24%) species were only recorded in summer season and (28%) species were recorded during the winter season (Fig. 7). In contrary to the previous study in Houbara Protected Area, higher species diversity was recorded during the winter season. Moreover, only 9 species were collected from pitfall traps which were recorded in all the seasons in every month from January to December.

Previous studies undertaken by EAD in 2014, invertebrate composition and diversity was found to be relatively similar in Umm Ghafa and Wadi Tarabat using a pitfall sampling method (Saji and Al Dhaheri, 2014). In contrast, we found that Wadi Tarabat turned out to be a completely different site with no similarity with other sites in terms of supporting unique invertebrate fauna. (Fig. 8). The reason is this site has rocky habitat and having different vegetation cover as compared to sandy deserts and gravel plains.

6. Conclusion

Pitfall trapping proved to be one of the most efficient methods to study epigeal arthropods composition and diversity in different habitats especially in rocky mountains, sandy deserts and inland wetlands. The deployment of pitfall traps in the mountain and rocky habitats was one of the challenges because of uneven and steep substrate. Moreover, pitfall trapping to be avoided in the high dunes where wind blowing could be another challenge to setup the pitfall traps. We recommend that the pitfall trapping surveys to be conducted from March until May to maximise the insect species encounters. During the study, only a few sampling sites were selected to test the efficacy of pitfall methods as well as to document the species composition and diversity. More studies need to be carried out to test the appropriateness of pitfall trapping in other habitat types of other Emirates of the UAE. Pitfall traps are easy to transport and deploy and they are very cost effective and this trapping methods can yield many individual ground-dwelling arthropod species. Therefore, application of this sampling technique is strongly recommended.

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