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The use of translocation as a conservation tool in the protection of dhub (*Uromastyx aegyptia leptieni*) against urbanisation in the Emirate of Dubai, United Arab Emirates.

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January 2023

DECLARATION

"This is to certify that the work I am submitting is my own and has not been submitted for another degree, either at University College Cork or elsewhere. All external references and sources are clearly acknowledged and identified within the contents. I have read and understood the regulations of University College Cork concerning plagiarism and intellectual property."



Declan O'Donovan

ABSTRACT

The UAE is described as hyperarid desert environment with mean maximum temperatures reaching 43.9 °C in July and mean minimum of 12.6 °C in January. It lies between 22°30' and 26°10'N and 51° and 56°25'E. The Emirate of Dubai, the second largest Emirate in the United Arab Emirates is a fast-evolving metropolitan city that has changed from a small trading hub in the Arabian Gulf to an economy based on tourism and the provision of novel and luxurious experiences.

Urbanisation pressures within Dubai, where almost 80% of the population now live in an urban setting, have increased dramatically over the last number of years. The resident population grew by over 173% in the 10 years to 2021 to approximately 3,478,300. To cater for residents and tourists alike, new roads, places to live and social and recreational activities have been developed and are being planned. As a result, previous areas of natural desert have been destroyed to make way for the continued development of the Emirate. It is imperative that procedures and protocols are put in place to protect the biodiversity of the affected lands.

The current study was carried out between October 2014 and December 2017 with intermittent data collection of environmental data until December 2019. The primary focus was on two sites, Wadi Al Safa (WAS - N 25.088360° and E 55.282707°) and Mugatrah (MUG - N 24.812233° and E 55.248874°) within the Emirate of Dubai. The study looked at various factors affecting the survival of the spiny tailed lizard, *Uromastyx aegyptia leptieni* (dhub), one of the 72 species of herpetofauna considered native to the UAE. Dhub are a diurnal, fossorial species listed on Appendix II of CITES and listed as VU on the UAE National Red List of Herpetofauna. Using dhub as a flagship species should help to raise awareness about the fragility of the desert environment, the current threats faced by the dhub and other species, and to gather vital information that could aid in potential translocation efforts.

Analysis of video data collected with CCTV cameras found that dhub are inherently a sedentary species, spending more than 80% of observed time below surface. When they did emerge, 14% of the emerged time was spent in sedentary behaviours, usually basking at the burrow or nearby on the gravel or a raised bush. The most active periods were in the spring and particularly March and April. During this time, dhub showed a unimodal burrow emergence pattern with a peak between 12:00 and 14:00. However, during the hottest months, dhub exhibited a bimodal activity pattern and usually went into their burrows between 11:00 and 13:00 before emerging and spending the majority of the time outside basking.

The orientation of burrows revealed a distinct westerly direction, in contrast to previous research on

dhub in Saudi Arabia where burrows predominantly faced southwest or southeast. In Israel, no specific orientation was identified. However, in the Wadi Al Safa site, there was a notable variation in orientation between seasons. The deployment of Radio Frequency Identification (RFID) traps showed that several different dhub could enter or leave the burrow throughout the day. The mean travel distance for all dhub over the study period (recorded as being the distance the animal moved from its first capture burrow to the furthest of the RFID traps), was similar at 128.8 m (SEM 11.0) for females and 113.0 m (SEM 10.4) for males. As the ultimate goal of the current study was to develop a mitigation translocation procedure for dhub, this information will allow field workers to decide on stocking densities of dhub, the number, spacing and dimensions of artificial or natural burrows to complete the translocation.

In a desert environment, a species' ability to use and avoid extreme temperatures is vital to its survival. Without knowing the range of temperatures, a dhub can tolerate, the ability to plan translocations is hindered. As such, the study also demonstrated, through the use of copper analogues, that the operative temperature T_e (the environmental temperature range for the species) range was ± 19 °C (a low of 19 °C in Winter to a high of 38 °C in Summer). Internal burrow temperature data collected between June through to September showed the daily temperatures did not fall below 34.5 °C in June or rise above 37.5 °C.

Foraging was the most active behaviour dhub engaged in with a mean time of 9:00 minutes for males and 6:00 minutes for females. There were a confirmed 8 forage plant species (all perennials) recorded across both sites while another 12 forage species were recorded which had been confirmed from other studies as forage plants. This indicates that there were sufficient forage resources for the dhub if grazing from larger herbivores such as camels, goats and gazelle species is controlled.

The next most active behaviour was burrow cleaning with females spending less time (mean 1:35 ± SE=0:10 minutes) engaged in this than males (1:51 ± SE=0:15 minutes). Burrow cleaning was observed at some stage every day and was probably under-represented time wise in the data since the behaviour could not be observed once the dhub went sub-surface.

A major part of any translocation is health monitoring. There were differences between the 25(OH)D levels across both sites, possibly due to overgrazing and exposure times to UV-B. If human levels of Vit D were used as the reference values, then 30% (N=7) of dhub in MUG in 2015 would be considered deficient (<25 nmol/L) and the remaining 70% (N=17) would be insufficient (<75 nmol/L) and only 40% (N=19) of dhub from WAS would be considered to have a sufficient level. Vitamin D levels were slightly better in 2016, when 74% (N=47) of dhub sampled in WAS would be considered sufficient or higher,

while 71% (N=21) of dhub in MUG would have been considered to have insufficient levels of Vit D_3. Further studies on the correct levels of 25(OH)D in dhub blood need to be investigated especially as many reference intervals used in veterinary practice are determined from captive animals and may not reflect the wild situation.

This study has shown how dhub can be successfully translocated if required. The study has also demonstrated what the consequences for the dub are if it is not done correctly. While large-scale translocations are theoretically feasible, careful consideration of various factors and insights gained from this study, such as dhub behaviour, potential travel distances, burrow orientation, vegetation needs for food and shelter, and health monitoring, is crucial. This comprehensive approach is essential to guarantee the success of any translocation project and subsequent enforced protection measures.

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United Arab Emirates

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Ireland

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To my wife Gail and sons Cian and Conor who have been understanding beyond the call of duty and have all supported and encouraged me through this journey, words cannot express my gratitude to you.

Finally, I would like to dedicate this to my late mother Philomena O'Donovan who was with me from the very beginning but sadly won't be there at the end.

GLOSSARY OF TERMS

Term	Description
Agamid	Family of Sauria that have an acrodont dentition where the teeth are fused onto the tops of the jaws and tend to overlap at their bases forming a continuous saw like row towards the back of each row.
ARB	Abnormal repetitive behaviours.
Bioindicators	Living organisms that are used as a potential tool to monitor the changes (either positive or negative) in environmental health and their possible impact on human civilization.
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora.
Eco-system engineer	Any species that creates, significantly modifies, maintains or destroys a habitat.
Ectotherms	Any animal whose regulation of body temperature depends on external sources, such as sunlight or a heated rock surface and include the fishes, amphibians, reptiles, and invertebrates.
GPS	Global Positioning System.
IUCN	International Union for the Conservation of Nature.
Parthenogenesis	Asexual reproduction in which a female can produce an embryo without fertilizing an egg with sperm.
RFID	Radio Frequency Identification Device (microchip/transponder/PIT Tag).
Sauria	Taxonomic grouping for lizards.
Squamate reptiles	Collectively known as squamates they are the largest order of reptiles, comprising lizards, snakes, and amphisbaenians.
T_b	The body temperature of the animal

T_e	The operative temperatures is the predicted equilibrium temperatures of non-regulating ectotherms i.e. body temperatures that non-regulating animals would achieve.
Thermal-safety margin	The difference between the air temperature that a species experiences and the maximum air temperature that the species can tolerate.
Thermotaxis	The movement of an organism in response to temperature.
T_{sad}	The temperature recorded on the iButton attached to the saddle. This should be similar to $T_{skin.}$
T_{Set}	Calculated set-points (T_{Set}), determined to be the optimum T_b which this species sought to achieve, for *Uromastyx aegyptia microlepis*, (taken from the literature) from Saudi Arabia were established to be 38 °C (Zari, 1991) and 36.1 °C (Al-Johany, 2003). These points were used as a comparison throughout the current study.
T_{sk}	Temperature of the skin.
UV Index	Is a measure of the level of UV radiation. The values of the index range from zero upward - the higher the UVI, the greater the potential for damage to the skin and eye, and the less time it takes for harm to occur.
VDR	Vitamin D Receptor protein modifies the transcriptional activity of the target genes.
Vitamin D_3	A fat-soluble vitamin that is naturally present in very few foods.

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CHAPTER 1: INTRODUCTION

1.1.1 Images and Maps

Unless otherwise stated and acknowledged, all maps and images within this thesis are produced and taken by Declan O'Donovan

1.1.2 The United Arab Emirates

The United Arab Emirates (UAE) is a federation of 7 individual Emirates and has a land area of 83,600 km^2. It is situated between 22°60' and 26°07' north latitude and between 51°56' and 56°35' east longitude along the south eastern tip of the Arabian Peninsula and is bordered by Qatar to the north west, Saudi Arabia to the south and west and Oman to the north and east (Figure 1-1).

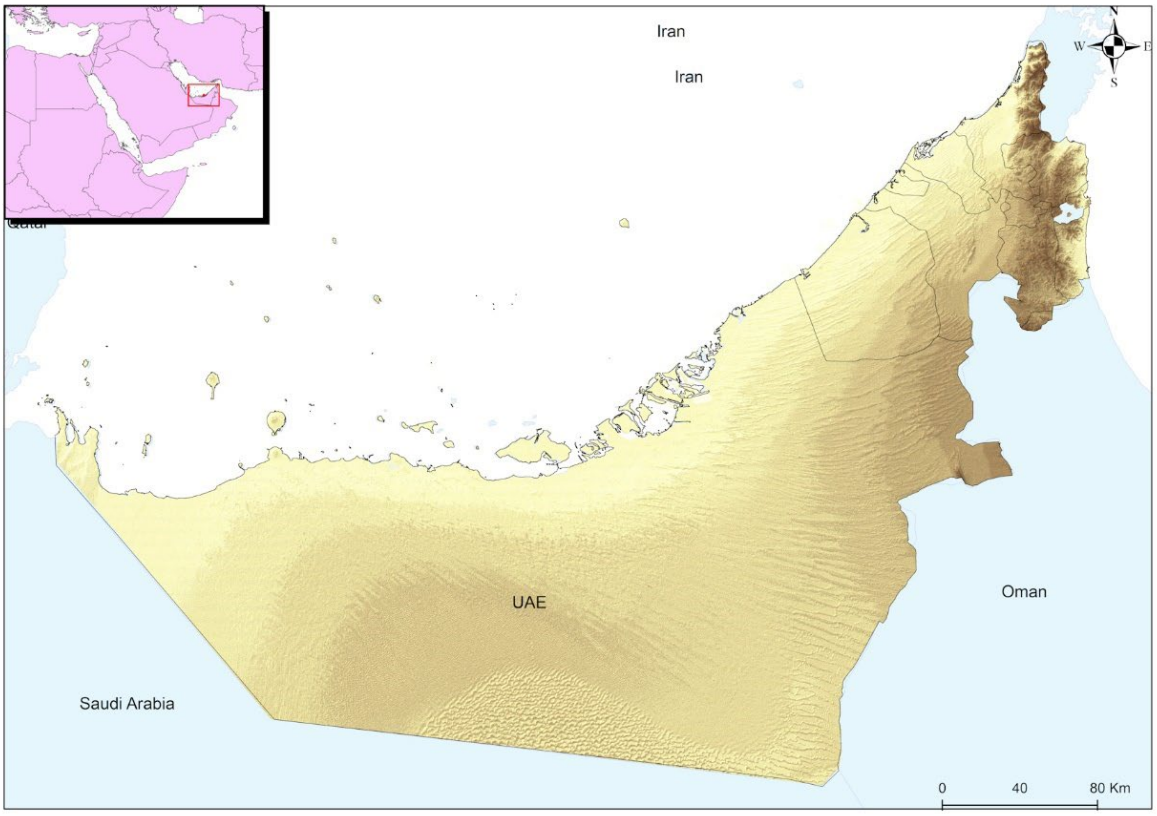


Figure 1-1. The United Arab Emirates.
UAE digital elevation model (DEM) from Bernat Burriel (2018); World Map from Diva-GIS, https://www.diva-gis.org/gdata.

1.1.3 History

Mankind has exploited the land now known as the UAE for over 100,000 years (Bretzke *et al*, 2022) Before Present (BP) although according to Aspinall (2001), the climate then was wetter than it is

currently. Today, it is a predominantly a hyperarid land (Boer, 1997) containing habitats and communities adapted to survive small amounts of infrequent precipitation, and extremes of heat with the subsequent high evaporative losses. It is dominated on the northeastern side by the large Hajar Mountains and in the west by the coastal sabkha (any form of flat salt-encrusted desert that usually lacks any significant plant cover). The rest of the country is dominated by various types of sand formations from the major transverse dunes in the southeast, longitudinal dunes in the southwest and eroded dunes in the Northern Emirates interspersed with sabkha and gravel plains. Most of the active dunes are aligned NE to SW with their steep faces in a south easterly direction.

The rainy season is from November through to April and the mean annual rainfall for Seeh Al Salam (24.827692 N, 55.311880E) in Dubai (between 2003 and 2018) was 34.3 mm. Maximum temperature recorded for the same location and period was 51.4°C in July, while the mean maximum for July and August was 45.2°C. The mean minimum temperature drops to 11.4°C in January and the prevailing wind direction in the UAE was from the north west (NCM, 2019). The UAE is characterised as having a hot desert climate (Kottek *et al*, 2006).

Severe climatic conditions mean that vegetation cover within the country is generally sparse. This is especially noticeable in areas of extremely low rainfall and where over grazing has caused further reduction in available vegetation. Along the coastal zone, which is about 650 Km long with Arabian Gulf in the north and the Gulf of Oman to the east, halophytic perennials predominate (Aspinall & Hellyer, 2005).

1.1.4 THE EMIRATE OF DUBAI

The Emirate of Dubai has a human population of approximately 3,478,300 and grew by over 173% in the 10 years to 2021 (Figure 1-2). Added to the Emirate's own population, an estimated 1.06 million additional people travel into the Emirate on a daily basis (Dubai Statistics Center, 2021).

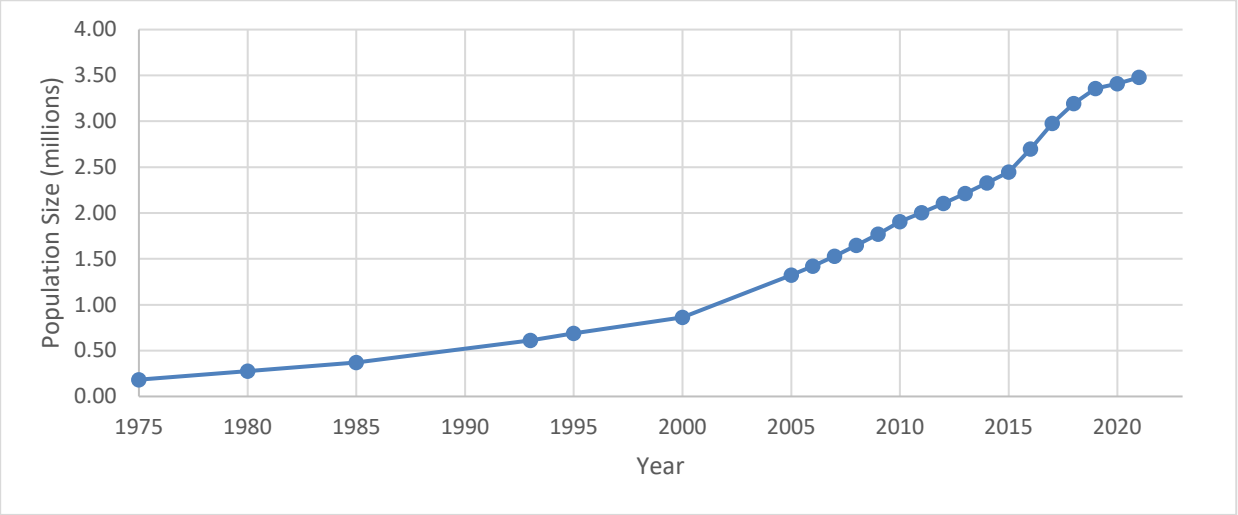


Figure 1-2. Population increase in the Emirate of Dubai from 1975 through to 2021. (Dubai Statistics Centre 2021).

In addition to this, the tourist industry brought an estimated 7.3 million visitors to Dubai in 2021.

By UAE land area it is the second-largest Emirate (3,885 km^2) after Abu Dhabi (see Figure 1-3) and is slightly smaller in area than County Tipperary in the Republic of Ireland. By the third quarter 2022, 2.8% of this area has been converted to "green areas" which were basically lawn grass, non native flowers, low bushes and shrubs.

1.1.5 Agamid Taxonomy

As of December 2022, there are 11,940 species and an additional 2,167 subspecies of reptile identified globally, with the Sauria (lizards) having 7,310 species alone (Uetz *et al*, 2023). Of these, there are 557 species in 62 genera of the Agamidae family identified which includes the genus *Uromastyx* (Uetz *et al*, 2023).

Agamids are found in environments that range from deep deserts to tropical rain forests and in habitats that range from burrows to the tops of tall trees. The various colours of this group make them amongst the most colourful of all the lizards, but they have limited abilities to change colour mostly from darker to lighter shades of the same colour.

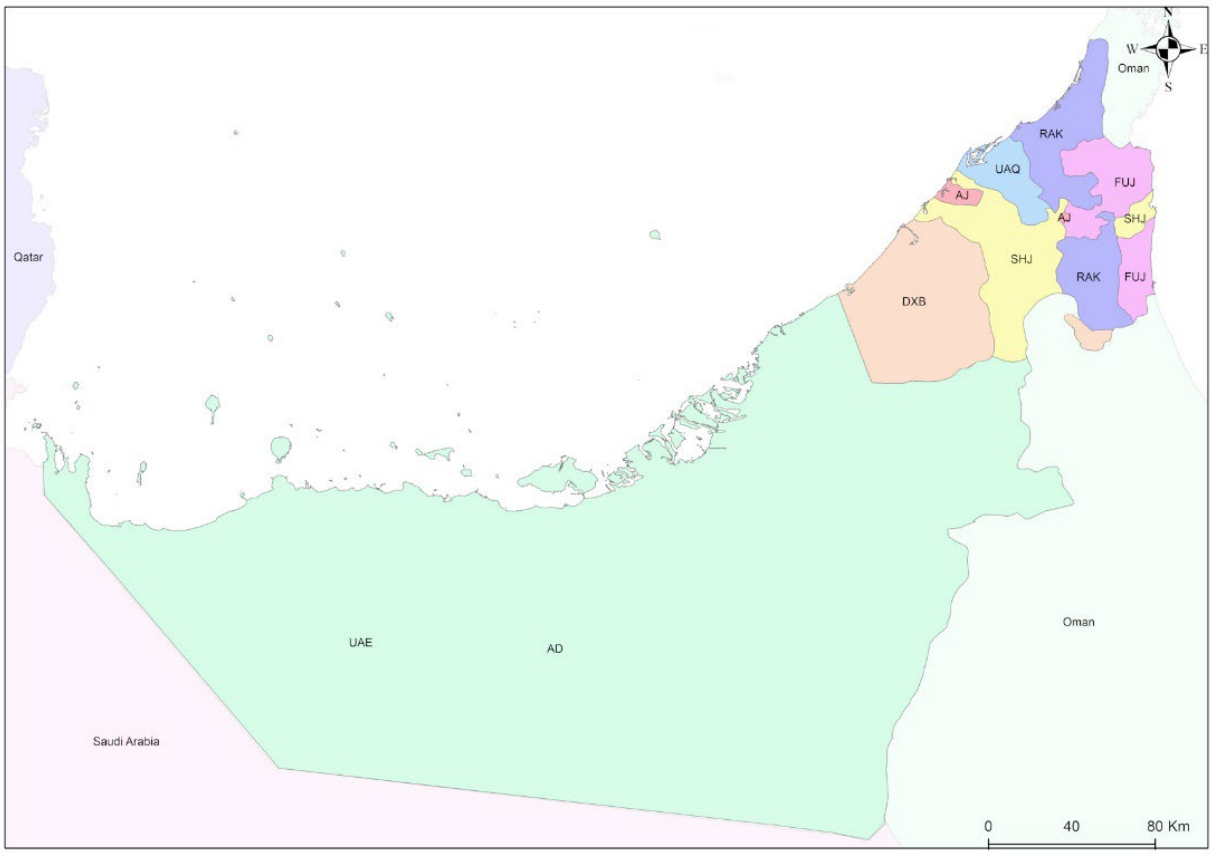


Figure 1-3. The UAE showing all seven Emirates, Abu Dhabi (AD), Dubai (DXB), Sharjah (SHJ), Ajman (AJ), Umm Al Quain (UAQ), Ras Al Kamiah (RAK)and Fujairah (FUJ).

The Agamids have an acrodont dentition where the teeth are fused onto the tops of the jaws and tend to overlap at their bases forming a continuous saw like row towards the back of each row, with Pough (1973) suggesting those of *Uromastyx* being particularly specialised. These are extremely efficient at chopping up both animal and vegetation material. Most agamids cannot replace lost, worn or broken teeth. All agamid lizards are indigenous to the Old World and are moderately large lizards with a slightly stocky build. On average they are between 15 to 30 cm total length. Biogeographic assessments of Uromastycinae mostly agree on the direction of dispersal from Asia to Africa (Tamar *et al*, 2018). Body types tend to be either depressed (flattened from top to bottom) or compressed (flattened from side to side) with the differences being associated with habitat type; those with depressed body types usually being terrestrial and with compressed bodies usually being arboreal.

Uromastyx belong to the Order Squamata and family Agamidae where there are currently 15 recognised species (Wilms *et al*, 2009a; UNEP-WCMC (Comps.), 2019; Uetz *et al*, 2023) divided into the following five groups: *U. acanthinura* group (African; five species), *U. aegyptia* (Arabian; one species), *U. ocellata* group (Arabian; five species), *U. princeps* group (African; two species) and *U. thomasi* (Arabian; one species). The polytypic species *U. aegyptia* comprises three subspecies: *U. a. aegyptia* (Forsskål, 1775), *U. a. microlepis* (Arnold, 1980) and *U. a. leptieni*, (Wilms & Bohme, 2000; Wilms *et al*,

2009a; Tamar *et al*, 2018; Uetz *et al*, 2023). *Uromastyx leptieni* was originally identified as a separate species (Wilms & Bohme, 2000), however, more recent taxonomic investigation suggests that it be included as a subspecies of the *Uromastyx aegyptia* clade (Wilms *et al*, 2012).

Of the known *Uromastyx* species, ten are listed in the IUCN Red List of Threatened Species, with two assessed as Vulnerable (*Uromastyx aegyptia* spp. included), four as Near Threatened and four as Least Concern (IUCN, 2019). There is a recent attempt by a number of individuals within the UAE to determine the range and distribution boundaries of *U. a. microlepis* and *U. a. leptieni* in conjunction with Salvador Carranza from the Institute of Evolutionary Biology (CSIC-UPF), Barcelona, Spain. This should determine whether both species are similar enough genetically to include as one subspecies or whether they need to be kept separate.

1.1.6 *UROMASTYX* SPP AND THE UAE.

As the UAE is positioned at the crossroads of the Ethiopian, Palaearctic and Oriental biogeographic regions which encompasses a wide range of habitats it supports a diverse terrestrial reptile fauna, with 60 species of terrestrial reptile listed (Burriel-Carranza *et al*, 2019), including a number of species which are endemic at the regional and national levels (Hornby, 1996; Gardner, 2008; Gardner, 2009; Gardner, 2013).

The eroded dunes and sabkha plains, of the Northern Emirates are home to many of these species including one of the larger Agamidae, *Uromastyx aegyptia leptieni* which is believed to be endemic to these parts of the UAE and north Oman, from sea level up to 400 m in elevation. The second sub species, *Uromastyx aegyptia microlepis* has a much wider distribution throughout the Arabian Peninsula, and is found in the southwest of the Emirate of Abu Dhabi and can be observed from sea level up to 200 m. It tolerates higher temperatures and lives in more arid areas than *U. a. leptieni* but it is believed not to occur in the Northern Emirates (Figure 1-4). While the two subspecies of the species *Uromastyx aegyptia* have an allopatric distribution both have different ecological preferences. Both subspecies can be found in bare areas with sand but *U. a. leptieni* prefers areas, according to Carranza *et al* (2018), where annual precipitation is higher.

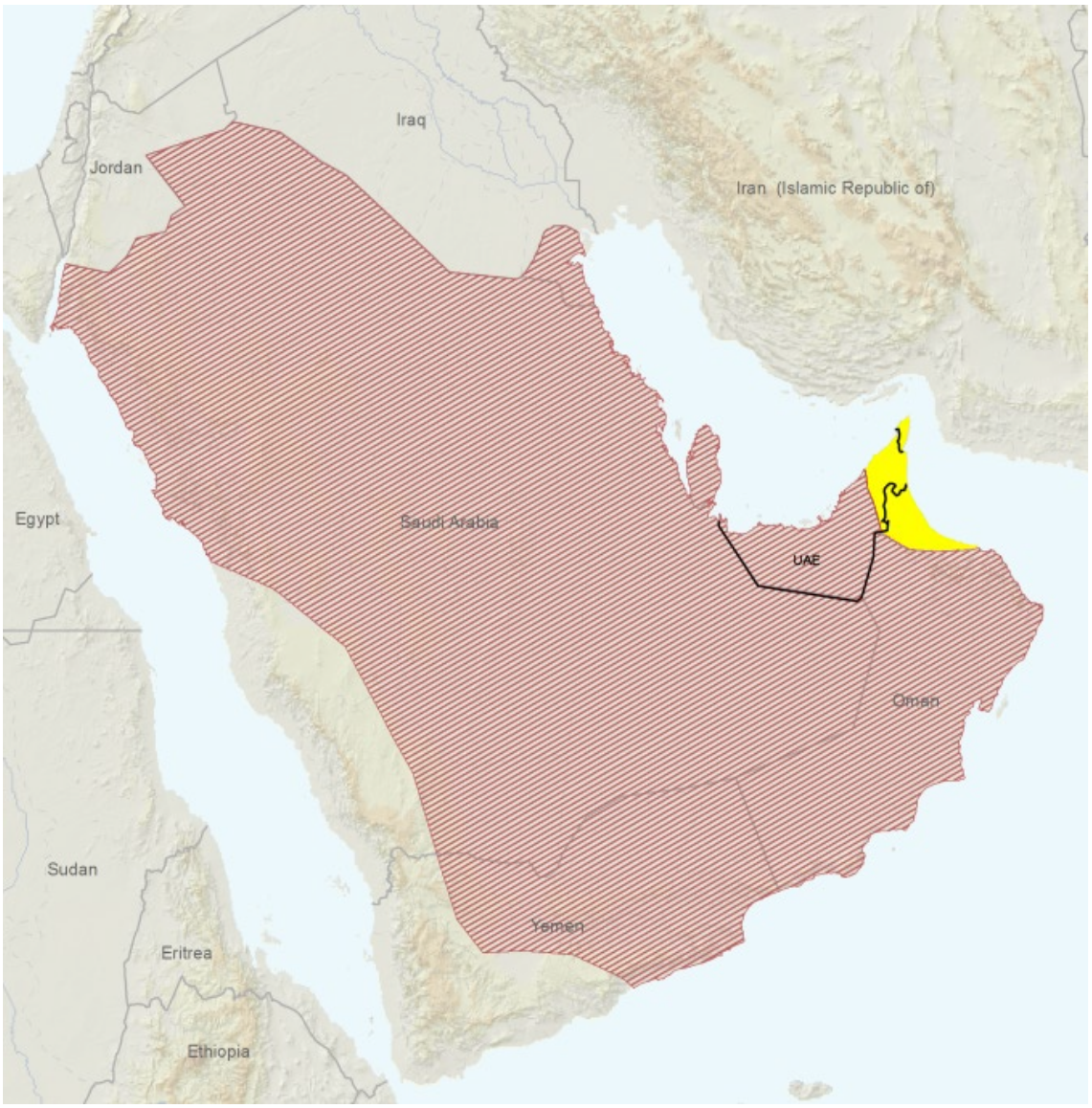


Figure 1-4. Distribution of *Uromastyx aegyptia microlepis* (red bars) and *Uromastyx aegyptia leptieni* (yellow) in Arabia. (adapted from (Cox *et al*, 2012)).

U. a. leptieni, is known locally by the Arabic word “dhub” but is also known over its extended range as the Samakat al Sahra ("fish of the desert"), the dragon or "little dinosaur" of the desert. It differs from *U. a. aegyptia* and *U. a. microlepis* by a different juvenile (Figure 1-5) colour pattern and a lower number of ventral scales seen as an adult (Wilms & Bohme, 2000).



Figure 1-5. Juvenile *U. a. leptieni.*

According to Wilms *et al* (2009a) there is a considerable scientific interest regarding the taxonomy and phylogeny of these animals but ecological knowledge remains scarce and fragmented. There has been a considerable amount of work done looking at the taxonomy of *Uromastyx* in general (Moody, 1987; Amer & Kumazawa, 2005; Wilms & Bohme, 2007; Wilms *et al*, 2009a; Amer, 2011; Amer *et al*, 2012) and *U. a. microlepis* specifically (Brown, 1982; Al-Ogily & Hussain, 1983; Cunningham, 2000; Al-Hazmi, 2001; Cunningham, 2001b, a; Al-Johany, 2003; Cunningham, 2007; Wilms *et al*, 2010; Castilla *et al*, 2011a; Castilla *et al*, 2011b; Wilms *et al*, 2011; Lotfi & Abdelmajid, 2014) but there are only a small number of published accounts on the general ecology of *U. a. leptieni*, (Naldo *et al*, 2006; Ingram & Simkins, 2009; Naldo *et al*, 2009; O'Donovan & O'Riordan, 2018) in the UAE.

1.1.7 Biological Characteristics

As a species in general, they have a spiny whorled tail (Figure 1-6) and a distinctive diagnostic acrodont dentition (the teeth have no roots and are fused at the base to the margin of the jawbones (Cooper *et al*, 1970)). *Uromastyx* are usually diurnal, and their habitats are generally characterised by high temperatures, low precipitation, sparse vegetation and marked seasonal changes. Large soft, shifting sands are of little use to *Uromastyx* as they do not provide suitable habitat and might constitute a

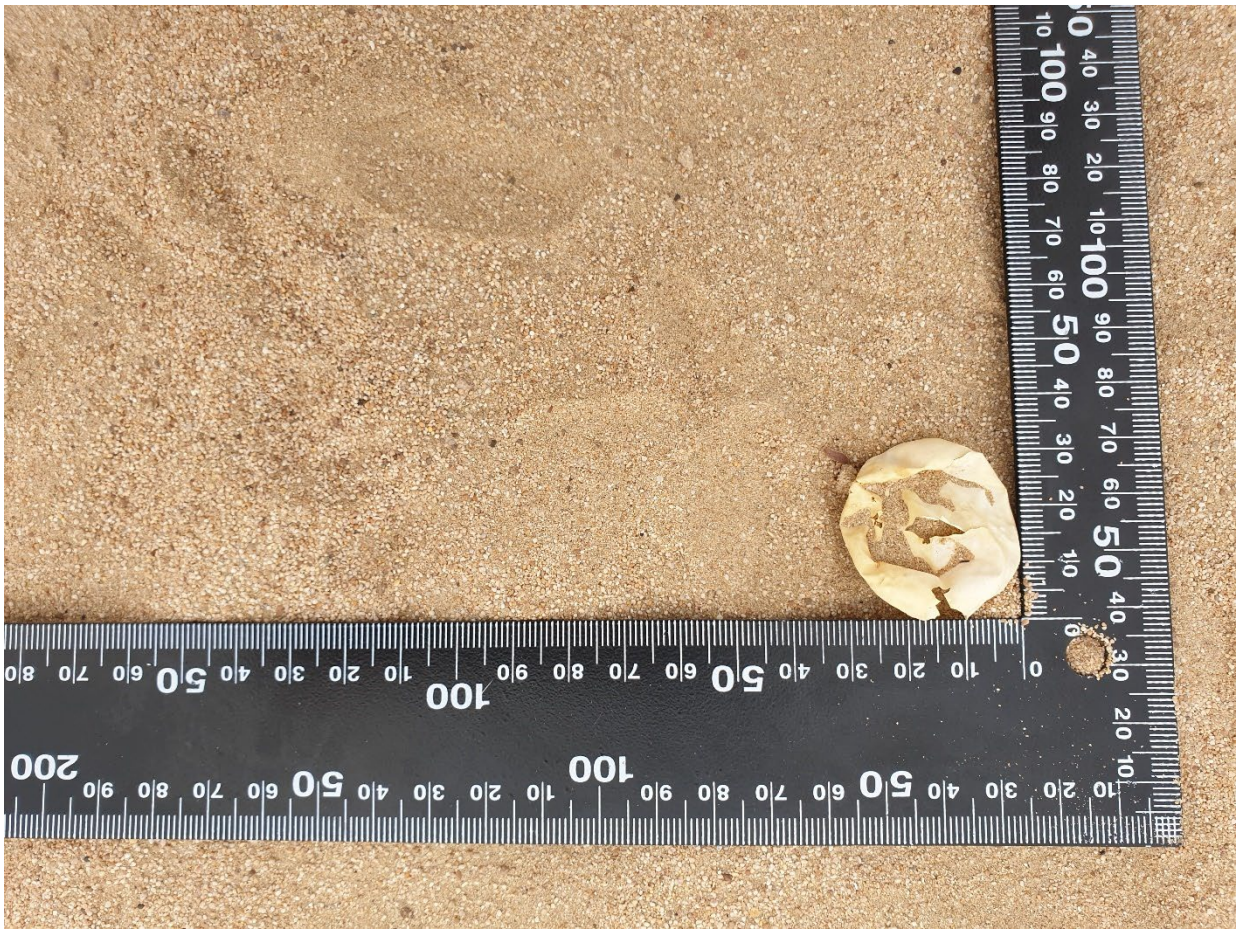
range barrier for the species (Wilms & Bohme, 2007). Basking areas are important for dhub as body temperature of day-active species, which are all essentially heliothermic, is controlled by posture and need to have the ability to retreat into shade or burrows as well as being able to use the ground as a heat sink (Arnold, 1984).

A few of the agamids are known to reproduce through parthenogenesis, but with a few exceptions agamids lay eggs and live birth is uncommon. This is certainly the case with dhub where the breeding season is predominantly during May, with six to thirteen eggs (Figure 1-7) laid inside the female's burrow. The eggs hatch after an incubation period of 70 to 80 days, usually in August (*Els pers comm*).



Figure 1-6. Tail of a dhub showing the distinctive spikes and whorls.

Young dhub usually use the hatch burrow for up to a month before leaving to dig their own. Little is known about this genus in the wild and there are far more publications concerning husbandry and captive breeding of *Uromastyx* than concerning their ecology and behaviour in the wild (Nemtzov, 2008). The longevity of dhub is put at 15 years by Hughes (1988) in captivity. However, Bringsøe (1998) suggested that the age of a wild dhub they captured at 33 years old. This would perhaps be an extreme and a life span of approximately 20 years is probably closer to the average age of wild dhub.


Figure 1-7. Hatched dhub egg found outside a burrow.

1.1.8 Ecology

Reptiles play important roles in natural systems, as predators, prey, grazers, seed dispersers and commensal species. Reptiles also serve as bioindicators for environmental health, and their often specific microhabitat associations provide the ideal study system to illustrate the biological and evolutionary processes underlying speciation (Böhm *et al*, 2013). Zaady & Bouskila (2002) argued that in arid lands reptile species diversity is determined or influenced by a variety of abiotic, biotic, and anthropogenic factors with substrate being one of the main abiotic factors. Therefore, research on habitat selection is important to understand the biological strategies that they have adapted to, to meet their needs (AlRashidi *et al*, 2021).

Among extant squamate reptiles, (lizards, snakes, and amphisbaenians), <2% of the 11,940 species are considered to eat plants as their primary source of energy with herbivory restricted to lizards (Cooper Jr & Vitt, 2002; Espinoza *et al*, 2004; Bendami *et al*, 2018). The genus *Uromastyx* as a group are ground dwelling or fossorial, medium sized to large oviparous lizards inhabiting the desert belt from North Africa to north-western India (Wilms *et al*, 2009b; Tamar *et al*, 2018). Bartlett & Bartlett (2003) described them as either omnivore or microcarnivore with most of the adult *Uromastyx* being

vegetarian. Others have described them as generalist herbivores, consuming a wide variety of plant species available to them throughout their range, with a suggestion that there might in fact be incidents of scavenging in the species, with reports of invertebrate species in the faecal analysis (Cunningham, 2001a; Castilla *et al*, 2011b). Personal observations and video analysis for the current study would suggest that adult *Uromastyx* are possibly accidental omnivores, but predominantly herbivorous. The term accidental omnivores refer to the fact that they continually lick the ground for seeds (*pers obs*) and while foraging will consume and swallow any insect which might be on the food item selected. This might have led to the findings by a number of authors (Cunningham, 2001b; Wilms *et al*, 2010; Castilla *et al*, 2011b) suggesting they consume more insects than previously thought. However, in a subsequent publication Cunningham (2001a) found that out of 170 fresh adult faecal samples, only one contained insect remains.

Dhub are found either in small colonies of one to two males and up to five females in a burrow system spread around the fringes of a sand dune or singly within 200 m of other occupied burrows Figure 1-8.

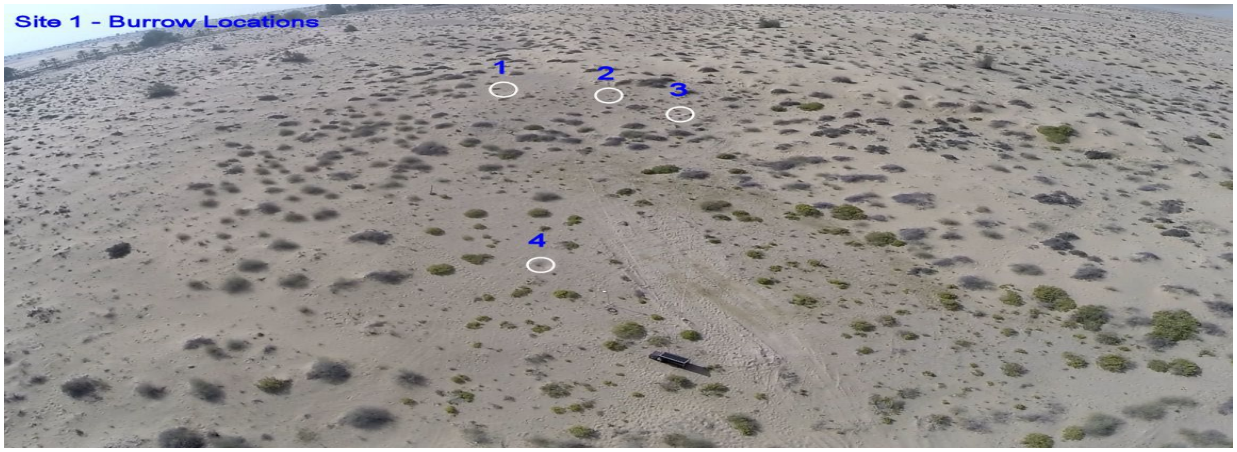


Figure 1-8. Location of 3 colony burrows (1 to 3) and a single occupied burrow (4) in MUG.

While there are some references to osteophagy (the consumption of bones as a potential substitute for phosphate deficient diets) in reptiles in the literature (Walde *et al*, 2009; Fritz *et al*, 2010), it does not appear to have been studied in as great a detail as either lithophagy (the consumption of stones) or geophagy (the deliberate consumption of soil and clay deposits by animals) (Sokol, 1971; Young *et al*, 2011; Abrahams, 2013; Đorđević & Golubović, 2013). There has been one report of a dhub consuming a pigeon wing (Figure 1-9) but the circumstances behind this are not understood and could potentially be a form of osteophagy.

A number of authors (Cunningham, 2000; Wilms & Schmitz, 2007; Wilms *et al*, 2010; Wilms *et al*, 2011; Aghanajafizadeh & Mobaraki, 2018; AlRashidi *et al*, 2021) have looked at the ecology of *Uromastyx aegyptia* over the last number of years. It is one of the few obligate herbivorous reptiles in the United

Arab Emirates. *Uromastyx aegyptia* is by far the largest member of the genus, according to some authors (Nemtzov, 2008; Wilms *et al*, 2009a; Wilms *et al*, 2010) reaching a maximum body length of more than 70 cm and a weight up to 2.5 Kg. As an eco-system engineer (Zahabian, 2018) dhub provide refuge for a variety of species such as the black scorpion *Androctonus crassicauda* (AlSaleh & AlJohany, 1995).



Figure 1-9. Dhub eating a pigeon wing (Al Ain, UAE. Source: *Peter Arras 2015*).

1.1.9 THREATS

Uromastyx aegyptia is listed as Vulnerable by the IUCN (Wilms *et al*, 2012), CITES II, Annex B EU Listing (CITES, 2022) and VU as per UAE National Red List of Herpetofauna: April 2019 (Els *et al*, 2019).

According to Ceballos *et al* (2015) we are currently in the midst of the sixth mass extinction of plants and animals and are experiencing the worst series of species die offs since that of the dinosaurs 65 million years ago. Reptiles are no exception and are particularly worrying because they indicate a general decay in environmental health (Burriel-Carranza *et al*, 2019). However, unlike previous extinction events which were caused by asteroid hits, volcanic eruptions etc, this current crisis is purely anthropogenic in nature. Dell'Amore (2014) suggests that current extinction rates are up to 1,000 times higher due to human effects which is supported by (Tourenq & Launay, 2008; Burriel-Carranza *et al*, 2019).

Dhub have been regularly reported in the international pet trade business and medicinal trade (see 1.1.10). Some of this trade is legal, while more is illegal resulting in severe collection pressure on the species. Locally it is used for food and is supposed to have medicinal purposes. Its habitat is also being lost due to over-grazing, human settlement, large-scale agricultural expansion, land reclamation, solid waste dumping and of increasing concern in the UAE, off-road vehicles. In one instance in December 2022 a colleague counted 300 vehicles in close proximity to each other entering the desert at one specific location for so called "desert safaris" or "dune bashing" (Al Mheiri *pers comm*) expressing concern that there was a lot more in the queue to enter.

Els, J in Bardsley (2019) suggests that reptiles, insects and mammals are among the wildlife under threat in the Emirates due to large-scale development projects. He added that recreational pursuits including driving through sand dunes - known as 'dune bashing' - could impact colonies of spiny-tailed lizards, a fact echoed by Robertson (2014). Over its wide range, dhub populations are very fragmented and while within the Arabian Peninsula, the species is still locally common in some places, especially protected areas, it has been extirpated in many other areas.

Customs officials stopped a 28 year old at Munich airport on his way back from Oman and found in his luggage a menagerie including 31 spiny-tailed lizards and 18 other reptiles, including geckos and wall lizards (Agence France-Presse, 2012). The arrest and imprisonment of five brothers for one month each and their father for 10 months in Saudi Arabia as a result of what some commentators referred to as an 'environmental disaster' (Figure 1-10) is evidence of changing perception of the value of native wildlife in the region (Toumi, 2014).



Figure 1-10. *Uromastyx* caught for local consumption in Saudi Arabia.
http://worldbirder.blogspot.ie/2011_12_01_archive.html

Yet, while not happening on the same scale, local poaching is having its own impact on the fragmented populations that currently exist. They are not only putting the population under threat, there are also serious welfare issues associated with the methods employed and scruples of those involved (Figure 1-11 and Figure 1-12).



Figure 1-11. Dhub which had been caught in a poachers snare set at the burrow entrance in Wadi Al Safa and died as no one came back to check the snare.



Figure 1-12. Dhub which was "hooked" by a snare in Wadi Al Safa and left to die as the snare was never checked.

Grimwood (1962) describes dhub hunting as one of the major sports of the Operation Oryx expedition in Oman. A number of other authors refer to dhub being part of the occasional diets of inland settlers (Elmahi, 2002; Monchot *et al*, 2014). According to Rashid Mohammed an Emirati in his 40s who has barbecued the lizards many times during outings in the desert, "It tastes like chicken." Rashid is remorseful that "Now it is not allowed to eat them, which is too bad, because they are tasty and are a very well-known delicacy among the Gulf nationals". He also suggests that their meat is full of nutrients and the fat can be boiled and used as a liniment as well as being used to cure impotence (Ghazal, 2012).

Böhm *et al* (2013), suggests that nearly one in five reptilian species are threatened with extinction, with another one in five species classed as Data Deficient. Conservation actions specifically need to mitigate the effects of human induced habitat loss and harvesting, which are the predominant threats to reptiles. A recent assessment coordinated by the IUCN, analysed 10,196 reptile species, and concluded that at least 1,829 of them (~21%) are threatened by extinction. They report that for turtles and crocodiles the fractions are even higher (57.9% and 50.0%). The most important factors increasing extinction risk in reptiles are habitat destruction from agricultural expansion, urban development (Figure 1-13), and deforestation (Cox *et al*, 2022).



Figure 1-13. Destruction of prime desert habitat through the addition of A) irrigation ring main and B) roads to get better access to construction sites.

Allan *et al* (2019) suggests that impacts to species are widespread and occur across 84% of Earth's surface with almost one-quarter of assessed species being impacted across more than 90% of their distribution, and approximately 7% impacted across their entire range.

Al-Melhim *et al* (1997) found during the analysis of little owl (*Athene noctua*) pellets 10.9% consisted of *Uromastyx aegyptia microlepsis*. These were young animals as indicated by their jaw size. As the time

of year or number of samples collected were not stated in the paper, it would probably have been in August when young dhub hatch and possibly are most vulnerable. However, from the percentage of the diet which did comprise dhub, it would suggest a high mortality for newly emerged animals. Arnold (1984) suggested that the monitor, *Varanus griseus* is also a consumer of dhub. Again, this is most likely immature animals rather than adults as during the current study, while monitors were seen entering burrows, none were seen eating dhub. In fact, there was evidence of aggression being directed by the dhub towards the monitor. Predation, while possibly not one of the main threats, could potentially be an issue in areas where dhub are under other environmental pressures.

1.1.10 TRADE

In the United Arab Emirates, birds, reptiles, invertebrates, mammals, and fish are the most popular taxa involved in the exotic pet trade (Spee *et al*, 2019) and Uromastycinae members have long been a part of the reptile pet trade, with reports dating to the 19th century (Tamar *et al*, 2018). Throughout their range they are extensively collected for the pet trade, food and their supposed medicinal value (Klemens & Thorbjarnarson, 1995; Knapp, 2004; Irwin & Irwin, 2006; da Nobrega Alves *et al*, 2008; Faiza, 2015; Robinson *et al*, 2015; Auliya *et al*, 2016; Ching & Chng, 2016).

Between 2000 and 2021 (the last year trade details were available) there were 3,894 *Uromastyx aegyptia* exported from the UAE to 9 countries around the world (CITES, 2022). The biggest importers were the United States, Japan and Belgium respectively. The last major live export from the UAE was in 2013. Looking at the global trade in *U. aegyptia*, for the same period a total of 25,089 live *U. aegyptia* were traded, while a total of 590,467 *Uromastyx* spp. were traded worldwide during the same period. Of *U. aegyptia*, 62.7% went to the US, 15.8% to Japan, 5.2% to the UK and 1.2% being imported to the UAE. Most probably the UAE imports were for re-export (CITES, 2022). A recent TRAFFIC Report suggested that at a Malaysian agri trade fair where *Uromastyx* products were for sale, the vendor stated that animals used for medicinal purposes were wild-caught spiny-tailed lizards (*U. aegyptia*) from Egypt (Ching & Chng, 2016). However, the Egyptian Government introduced a ban on the export of *Uromastyx* species from its country in 1992 (Knapp, 2004) suggesting that there is an active trade in illegally caught animals.

1.1.11 URBANISATION

The UAE's urban population increased from 54.4% in 1950 to 84.4% in 2010 (Shahbaz *et al*, 2014). From 1960 through to 2010 the number of people living in urban areas increased from 0.098 million to over 7.1 million people (Macrotrends, 2013). With the increasing urbanisation and rapid economic development, the country faces serious environmental challenges that arise from the high pace of

population growth resulting in ever greater pressure on the natural environment to provide new areas for development (MOCCAE, 2018). Since the early 1960s, when oil was first extracted, the UAE moved from fishing and agricultural-based economy to an oil-based economy. The UAE is one of the biggest oil producers in the world and with it, camel numbers (a sign of affluence) have increased by 50% in Abu Dhabi alone since 2010 (Sanderson, 2019). This has resulted in an increase in camel herds with a deep change in the traditional systems of livestock management. The traditional "heema" (Dakdouk, 2007; Tourenq & Launay, 2008) system, which facilitated the sustainable use of rangelands and other natural resources by setting aside large reserves during times of environmental stress, was abandoned in the 1960s in the Arabian Peninsula.

With the increased wealth and urbanisation has come the expected population growth and in the years between 2010 and 2021 (when the most recently published figures were available), Dubai's population grew 173% (Dubai Statistics Center, 2021) (Figure 1-14).



Figure 1-14. Progress of development at the 84 Ha Al Reem project from 2012 through to 2021 its expansion to a 635 Ha development. (2012 and 2021 Images sourced from Google Earth).

The Dubai World Central Airport (Al Maktoum International) which was officially opened in October 2013 near Jebel Ali together with the associated residential, logistical and other activities have claimed 140 Km^2 of sabkha plains, low dunes and gravel plains. The many new developments throughout the Emirate and the UAE will push a number of species on the edge of existence into a state of decline (Els *et al*, 2019). Gardner & Howarth (2009) list a number of mitigating measures designed to reduce the impact of development on the environment including the use of translocation.

1.1.12 Climate Change

While urbanisation and its associated issues are a major threat, global climate change will affect organisms in all biomes and ecosystems. Two natural compensatory responses are possible. Given enough time and dispersal, species may shift to more favourable thermal environments, or they may adjust to new environments through behavioural plasticity, physiological plasticity, or adaptation.

However, this can be more difficult for species at the upper limit of their thermal range such as the *Uromastyx*. Compensatory thermoregulatory behaviours impose costs such as energy loss, predation risk, and missed opportunities for foraging and breeding (Sears *et al*, 2016). They and Sinervo *et al* (2010) also suggest that the energetic costs in relation to modified thermoregulatory behaviours required to find suitable microclimates constrains costly metabolic functions like growth, maintenance, and reproduction, thereby undermining population growth rates and raising extinction. Failure to adjust or adapt culminates in demographic collapse and extinction (Sinervo *et al*, 2010).

1.1.13 CONSERVATION

Watson *et al* (2014) suggest that even though global protected area coverage is growing biodiversity is still declining. It could be argued that conservation efforts are usually limited and that due to political and economic reasons it is impossible to preserve all species and habitats. Insufficient funding and limited resources, coupled with social, political, and cultural complexities, frequently compel conversation managers to make challenging decisions in allocating resources, aiming to maximize the impact of conservation efforts (Walls, 2018). Therefore, conservation efforts should be targeted at the most threatened species with clear danger of extinction. In the UAE, a re-evaluation of the conservation policy for the terrestrial reptile species should be considered, so that the newly assessed CR and VU species are included under conservation legislation (Burriel-Carranza *et al*, 2019). Focusing on ambassador or iconic species such as the dhub, will help raise awareness of the perils of biodiversity loss and also help protect the other less obvious but equally essential species in a desert environment.

1.1.14 PHYSICAL REQUIREMENTS OF DHUB

Of the studies conducted in the UAE on the physical requirements of dhub, most were conducted over a short time period (Cunningham, 2000, 2001a, b) had a combined observation time of 480 hours and focused on 20 individuals in one site. Ingram & Simkins (2009) looked at burrow occupancy and not specific behaviours while Naldo *et al* (2006) and Naldo *et al* (2009) looked at the health status of the species. In general, most of the reported studies of *Uromastyx aegyptia* spp. were conducted in one study site and there was little information describing behaviours, foraging or other requirements of dhub. The present study is focused on a longitudinal study over a number of seasons and different sites where all of these factors together with those issues listed below, will be examined.

1.1.15 HEALTH ASSESSMENT

The potential and realized effects of disease on wild and captive populations of threatened species

have received increased attention (Griffith *et al*, 1993; Woodford, 1993; Daszak *et al*, 2000). Reptile-associated salmonellosis in humans is an increasing public health issue (Pasmans *et al*, 2005). Sound and comprehensive bio-ecological knowledge, although essential to a project, is insufficient if an understanding of the health status of the focal species is not adequately understood and addressed. According to IUCN/SSC (2013), the management of disease and known pathogen transfer is important, both to maximise the health of translocated organisms and to minimise the risk of introducing a new pathogen to the destination area.

The current study focused on the vitamin D status of dhub but was also concerned with other physiological aspects which might influence the ability to safely keep the species in captivity in the event this was required as part of a translocation event. During the study, a number of individuals were found near burrows either emaciated (Figure 1-15) or dead and in a mummified state.



Figure 1-15. Severely emaciated dhub with enlarged joints on the front legs.

1.1.16 TRANSLOCATION

The continued rapid and irresponsible construction practices risks harming biodiversity across the UAE

and the Gulf in general. In a way to mitigate some of these issues, there have been a number of attempts to translocate dhub from major development areas, (Jebel Ali, Dubai, Al Maktoum International Airport, Dubai and Abu Dhabi Airport extension, Abu Dhabi). However, very few data are available on the success or otherwise of these ventures. Having discussed the methods employed with people involved, it is obvious that the use of hard releases (where the animals were brought to the translocation site and released immediately) was the tool of choice. While Thomas Wilms and Brien Holmes documented the work they did for the capture of *U. a. leptieni* in Abu Dhabi (Soorae *et al*, 2008), there is little information available on the release of the animals caught and even less information available from the Dubai translocations (Soorae *pers comm*).

For the current study, a number of translocation aspects were investigated (see Chapter 6) such as; what was the success of a local translocation (within the same site), how does the animal establish in a new burrow within a 2 Km range of its original burrow? What was the success of longer translocations, do animals establish in new release area? What is the best method ie soft or hard release? Will utilising existing burrows in the release site be more effective. The study utilised remote monitoring via CCTV cameras, RFID traps (bespoke Radio Frequency Identification or microchip reader placed at the burrow entrance) and direct capture to determine the behaviour of dhub.

1.1.17 LOCATION:

Two locations (Figure 1-16) were chosen to monitor *Uromastyx aegyptia leptieni* in Dubai.
Location 1. Wadi Al Safa is located at N 25.088360° and E 55.282707° and has a perimeter length of approximately 19 Km and an area of 18 Km^2.
Location 2. Mugatrah is located at N 24.812233° and E 55.248874° and has a perimeter length of 12.6 Km and an area of 9.4 Km^2. Within this area, there was the possibility of increasing the survey/release area by another 8.6 Km^2 if necessary.

A third site Nakhlee (N 25.086355° and E 55.566758°) was also investigated but due to various circumstances and security concerns, access to the site was not guaranteed. This was the site of the first translocated dhub where they had to be dug out due to construction pressures. It is also the site where artificial burrows were installed. More detailed information is provided in the relevant chapters below.

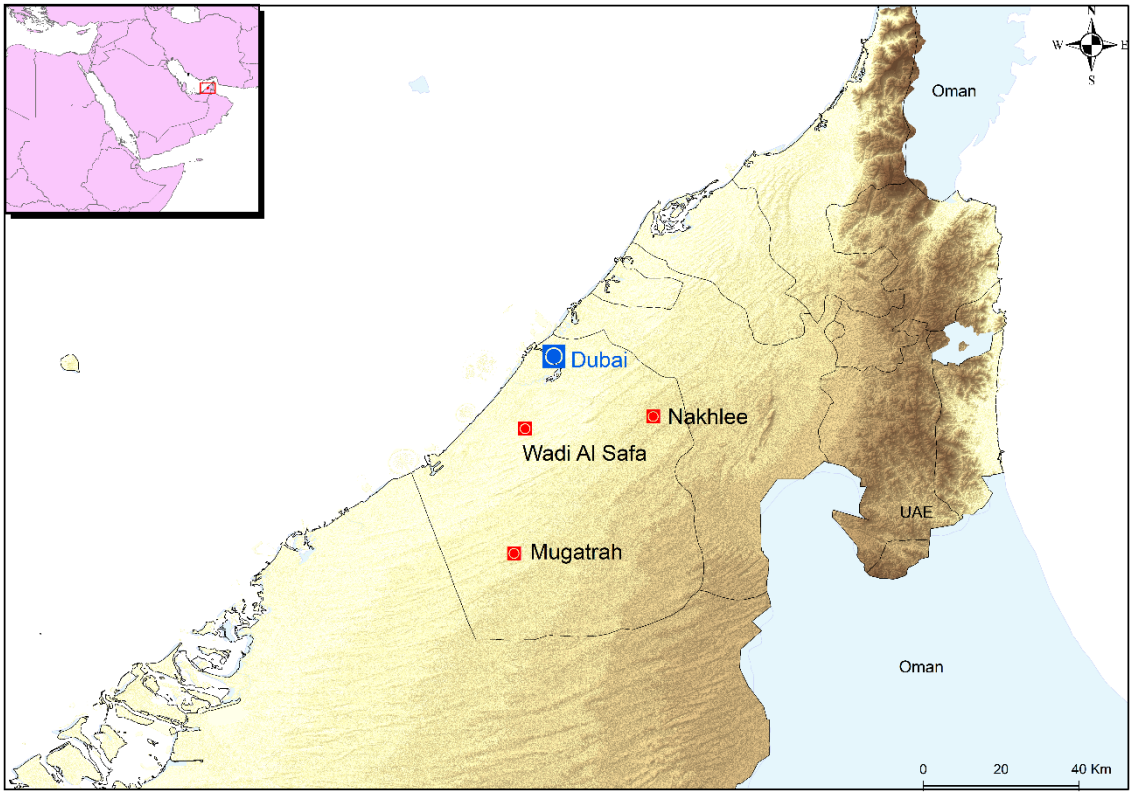


Figure 1-16. *U. a leptieni* monitoring locations (red square).

1.1.18 THIS STUDY

The current study has been designed to look at the factors needed to enable the successful translocation of *Uromastyx aegyptia leptieni* as a means of conserving the species. As the rapid expansion of the population of Dubai increases it was essential to formulate a plan to mitigate some of the issues associated with this expansion. The study was also used as an attempt to investigate the behaviours and ecological requirements of the species which would allow for its successful holding and potential breeding in captive situations while site mitigation or emergency removal were required prior to translocation.

Chapter 2 will look into the behaviours of the species which were determined through the use of a selection of video data from the 50,000 hours collected. As the capture and potential captive management of the dhub would be a requirement for any proposed translocations, this chapter is dedicated to the elucidation of the complex behavioural repertoire of dhub. This is the longest continual behavioural project for dhub that the author could find and examined how much time was spent active, the daily/monthly/seasonal activity patterns, the amount of time dhub spent foraging, intraspecific relationships, anti predator relationships if present. It is hoped that as well as providing

fundamental information as a pre-requisite to translocations of dhubs, an insight into the behaviour of free-living reptiles, using this technique, will enable herpetologists involved in captive breeding projects to enhance captive environments.

Chapter 3 investigates the species use of burrows and utilises data from the 1,653 individual burrows investigated and associated surveys. Little is known about the burrow and thermal characteristics of natural populations of dhub, which are fundamental prerequisites to allow successful translocations. Thus, the objectives of this part of the research were to identify the most accurate way to determine the maximum effective temperature (T_e) for the dhub in current locations, to determine the preferred orientation, shape and size of the burrow and to determine whether there is burrow philopatry.

Chapter 4 investigates the vegetation requirements of the species and looks at the vegetation over a single time period . As this was a survey restricted to one time period it was intended to serve as a snapshot of what plant species were available to the *Uromastyx* within their normal foraging range i.e. the vegetation type and abundance within a 40m (50 paces) distance of preselected *Uromastyx* burrows in the two survey sites, as this was estimated to be the average distance dhub travelled while foraging (O'Donovan *pers obs*). From these data it was hoped that a suitable combination of substrate type and vegetation cover/availability could be determined to indicate optimum areas for translocation projects. This also presented an opportunity to investigate the vegetation status of two protected areas within the Emirate of Dubai. From the resultant data, areas of preferences based on presence or absence of dhub burrows would be identified.

Chapter 5 will look at the very basic veterinary requirements for the species but looks in depth at the requirement for the species requirement for Vitamin D and the species Vit D levels available in the survey areas over a specific period of time. Vitamin D was chosen due to its known effects in captive reptiles in relation to metabolic bone disease and the possible issues if dhub had to be held in holding pens for any great period of time (Mans & Braun, 2014; Hetenyi *et al*, 2015; Baines *et al*, 2016; Kumar *et al*, 2018). As the "normal" vitamin D state is not known for dhub and many other squamate species, related to the potential translocation of the species from anthropogenically threatened locations, the objective of this chapter was to determine the circulating levels of $25(OH)D_3$ in wild dhub. The influence of the time of the year was investigated to determine any seasonality ("season") as well as differences between males and females. From these data, Reference Intervals (RI) for the species which would act as the "standard" for *U. a. leptieni* would be reported. Other metabolites such as calcium, ionised calcium and phosphorous are reported in a general form. Reference Intervals for a number of these metabolites were also derived and available in the appendices.

Chapter 6 will attempt to draw together the experience from the study and complete a number of local and distance translocations. When this study started, within the Emirate of Dubai, there were no guidelines and only minimal Environmental Impact Assessment requirements by Dubai Government in place. More recently, however, Dubai Government have released two documents directly referencing mitigation translocation (DM, 2018, 2019) as a requirement during development projects.

Further to conversations with individuals who had been involved in some ad hoc translocation of dhub within the UAE, (which were by and large unsuccessful), a proof of concept was attempted whereby the requirements of a successful translocation were investigated. The aim of this was to determine if dhub from one location could potentially be caught, moved, released and establish within the new location and whether a hard (catch at the donor site and release immediately in the receiving site) or soft release (catch at the donor site and hold at the receiving site to acclimatise to the new environment) would be the preferred release method for these animals.

Chapter 7 develops a short protocol for those interested in mitigation translocations of dhub. It provides information on the requirements from stakeholders, how to complete surveys for vegetation and dhub, methods of capture, data logging and monitoring for post release surveys.

Chapter 8 This chapter brings the major findings of this research together with particular reference to what can be used to conserve the species. Over the last number of years this study has evolved from a curiosity and effort to determine if there were any policies in place from Dubai Government to ensure that there would be a cohesive plan between their aspiration to be the best and to provide the best safety measures for the fragile environment of the Emirate. Recently Dubai Municipality who are responsible for all environmental considerations within the Emirate of Dubai, have introduced tougher legislation and guidelines (EPSS, 2014, 2018, 2019).

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CHAPTER 2: DHUB BEHAVIOURS

2.1 INTRODUCTION

The study of behaviour looks at when and why individuals engage in specific activities. In human behavioural science, behavioural scientists can experimentally examine the impact of factors such as conscious thoughts, motivation, social influences, contextual effects, and habits. In non-human animal behaviour, similar studies to the above have been carried out on mammals (Kumar, 2021; Hopper, 2022), birds (Ebisawa *et al*, 2021; Rose *et al*, 2022), amphibians (Figueiredo Passos *et al*, 2021; Hosie & Smith, 2021) and reptiles (Burghardt, 1977; Cunningham, 2000a; Cunningham, 2000b; Rose *et al*, 2017) amongst others. However, the study of wild state behaviours is not as common in reptiles as in other groups. Many of the welfare programs in place today in zoos and captive collections are based on studies carried out in captive environments which might not demonstrate the correct behavioural repertoire of the species concerned. Supporting this argument, in a study by Azevedo *et al* (2021) they suggested that behaviours indicative of poor welfare and captivity stress were considered 'normal' by up to one quarter of their respondents who were owners of their clinic patients.

Reptiles have been shown to be capable of displaying signs of anxiety, stress, distress, excitement, fear, frustration, pain, and suffering (Lambert *et al*, 2019). Although these emotional states have been shown to exist, Eagan (2019) suggests that the number of environmental enrichment studies for reptiles in captivity appears to be very small (a fact supported by Rose *et al* (2014) and Benn *et al* (2019)) and those that have been completed are taxonomically scattered. In fact Melfi (2009) suggests a bias in favour of mammals and birds with only 1.8% of reviewed studies relating to reptile welfare. She suggests that there is an emphasis on monitoring and identifying indicators that represent bad welfare and by default if these are non-existent, then the animals are in a good welfare state. Furthermore, there is a reported paucity of information on housing and husbandry and how this affects animals, placing more emphasis on issues like space and companionship rather than other possibly more subtle issues like temperature, humidity, light etc. (Melfi, 2009; Green *et al*, 2020; Azevedo *et al*, 2021). According to Benn *et al* (2019) current guidelines for the captive management of reptiles utilize resource-based, rather than animal-based, indicators (the size of the vivarium, environmental enrichment etc rather than observed repetitive behaviours, poor body condition etc), an issue which needs to be addressed.

2.1.1 CAPTIVE MANAGEMENT

The ability of people to meet the needs of an ectothermic species in captivity is at the heart of the ethical debate on the acceptability of keeping reptiles and other animals as pets (Warwick, 2014; Lambert *et al*, 2019; Azevedo *et al*, 2021). As early as the mid-1970s Spellerberg (1975) argued that

much more basic herpetological research needed to be completed during the following years in an effort to preserve some of Britain's rarer reptiles. This is probably even more important today due to the increases in habitat loss and while our understanding of reptile behaviour is increasing, it is not doing so as quickly as with other animal families. For example, in reptiles, the first reported use of social cues to solve a problem was Wilkinson *et al* (2010) where they showed that red-footed tortoise (*Geochelone carbonaria*) can learn from the actions of a conspecific in a detour task.

From a management perspective where translocation of a species might be required, it is important to understand and meet the basic behaviours and requirements of the animals in question and to mitigate some of the issues mentioned above. This could be achieved by contacting enthusiasts/keepers in the pet trade, etc. However, by doing this, there is a high risk of misinformation, with behaviours being misunderstood (Hoehfurtner *et al*, 2021) and being based on what is perceived correct in a captive situation yet proving to be incorrect *in situ*. For example, Figueiredo Passos *et al* (2021) suggest that vocalisations from wild golden mantella frogs (*Mantella aurantiaca*) led to an increase in movement and social behaviours while calls from captive frogs did not. This was especially true of frogs bred for more than five generations in captivity. Caution should be used in applying some observations from behavioural studies if activity patterns are based solely on animals in a captive environment, it is highly likely that decisions based on incomplete observations could be made. A similar suggestion has been made in Chapter 5 where it is argued that Vitamin D requirement levels in some reptiles could actually be overstated based on results from animals held in captivity. Figueiredo Passos *et al* (2021) further suggest that the change in vocalisation patterns could impact the reproduction of captive golden mantella frogs if released to the wild.

2.1.2 VIDEO RECORDING

It is not only behavioural scientists who are interested in animal behaviour and in an effort to service the general public's insatiable appetite towards learning about wildlife there are complete media networks such as Discovery Channel dedicated to the promotion and supply of wildlife documentaries and content. Series such as those by David Attenborough have been known to show behaviours which had never been recorded before. An added benefit of these media productions is that they can also be used to encourage behavioural and enrichment responses when played to non-human primates (*O'Donovan pers obs* and also (Ogura, 2012)). While these expertly produced programmes can demonstrate novel behaviours, they are not of much use from a research perspective due to the fact that many of the behaviours might, amongst other issues, be taken out of the correct chronological order. Excerpts of video captured in research studies are now commonly used as a means of presentation in science or as key examples in lectures or conferences primarily as an illustrative tool, rather than as a means of determining behavioural sequences and patterns (Nelson & Fijn, 2013). The

advent of cheaper and more scalable video recording equipment has opened new data opportunities for researchers while also removing the possibility of introducing observer mediated behavioural changes to wildlife monitoring.

The first reported use of what later became known as the "trail cam" was by George Shiras in the 1880s who later published many of these images in National Geographic (Livingston, 2013) while the first of the modern day trail cams was developed by students at Missouri State University in the 1980s (Johnston, 2019). The use of trail cams offers an inexpensive way to maintain an observational presence in a particular area without having to be physically present. To date, there have been numerous animal behaviour studies completed using trail cams such as Surmacki & Podkowa (2022) monitoring species inhabiting artificial nest boxes, Harrison *et al* (2019) monitored cliff nesting golden eagles (*Aquila chrysaetos*), Elizondo & Loss (2016) estimated free-ranging domestic cat abundance in urban areas while Unger & Santana (2019) looked at turtle usage of artificial platforms. St John (2022) used trail cams to examine the relationship between human disturbance and wildlife behaviour in protected areas. However, Harrison *et al* (2019) suggest that the use of trail cams can lead to the permanent manipulation of animal behaviours as the data needs to be retrieved from the camera amongst other issues, citing his experience of two nests where adult eagles did not return to nests or exhibited behaviours suggesting avoidance of the cameras until such time as they were removed.

2.1.3 VIDEO ANALYSIS

There have been numerous publications utilising video analysis in reptiles, but these have mainly been in laboratory environments or on animals in a managed situation. In fact, Giersberg & Meijboom (2022) have suggested a number of measures specifically related to behavioural analysis of video data recorded in captive situations. Unfortunately, there is little evidence of the use of long-term videography in behavioural studies of wild reptile behaviours.

Understanding the processes that affect habitat selection is also critical for guiding and managing conservation initiatives and the benefits of using long term video monitoring to determine many of the interacting requirements of dhub behaviour provides a huge insight into this. As there is currently a growing trend towards greater spatial proximity between people and wildlife and their reliance on the same resources, it is likely to lead to an increase in the frequency and intensity of conflict (Anthony & Szabo, 2011). As such, for the management and conservation of reptiles, amongst other species, high quality species and population data are required to understand and predict the potential impacts caused by human activities (Foley *et al*, 1992; Cogalniceanu *et al*, 2014).

To date, there have been only a few behavioural studies of dhub in the wild (Al-Ogily & Hussain, 1983;

Bouskila, 1985; Cunningham, 2000b; Cunningham, 2000a; Al-Hazmi, 2001; Cunningham, 2001; Al-Johany, 2003; Cunningham, 2009b; Wilms *et al*, 2009; Wilms *et al*, 2010; Wilms *et al*, 2011) with most having been conducted in Saudi Arabia and Kuwait. To the author's knowledge, this is the first long term study looking at reptile behaviour where video recordings are exclusively used, the preceding studies predominantly employed direct observation for behavioural assessments. Jenssen *et al* (1995) did look at 41 hours of videotaped behaviours of the green anole (*Anolis carolinensis*).

The use of video has been shown to be a good means of capturing uncommon or previously unknown behaviours and providing evidence that these behaviours occur. Throckmorton (1980) used a 16 mm cine camera to record the chewing cycle of dhub in his lab, while more recently Rößler *et al* (2022) have used infra-red video technology to determine REM sleep-like state in jumping spiders. Ord *et al* (2002) showed that video playback of specific behaviours would illicit behavioural responses from male Jacky dragons, (*Amphibolurus muricatus*), at the same rate and intensity as those when a live specimen was present as did Trainor & Basolo (2000) with the green swordtail, (*Xiphophorus helleri*), while Bird & Emery (2008) argued that that video playback is a useful technique for investigating rook (*Corvus frugilegus*) social behaviour.

2.1.4 AIMS

As the capture and potential captive management of the dhub would be a requirement for any proposed translocations, this chapter is dedicated to the elucidation of the complex behavioural repertoire of dhub. This is the longest continual behavioural project for dhub that the author could find and was primarily interested in:

- How much time was spent active which would help determine the expected activity and time spent outside the burrow, helping to identify the success of translocated dhub in settling into their new range.
- Daily/Monthly/Seasonal activity patterns to determine the optimum translocation time.
- How much time was spent foraging which would help determine what species of forage and whether translocated dhub were foraging for the same or similar amount of time.
- Relationships between different animals to determine how social dhub are to each other. Are there differences between males and females.
- Relationships between dhub and potential predators to determine whether dhub are naive or vigilant which would have a direct relationship to translocation success rates.

It is hoped that as well as providing fundamental information as a pre-requisite to translocations of dhubs, an insight into the behaviour of free-living reptiles, using this technique, will enable herpetologists involved in captive breeding projects to enhance captive environments.

2.2 MATERIALS AND METHODS

2.2.1 STUDY SITE

The study took place within the Mugatrah (MUG) site (Figure 2-1), Dubai, UAE.



Figure 2-1. Location of MUG in the UAE (red dot) and the two sites within the MUG site, where the cameras were placed.

Wadi Al Safa (WAS) was also considered as a potential location to install the cameras and there was a number of days of data recorded from there (see below). However, it was a less secure site in that it had no security at the entrance and more open access to members of the public with a genuine risk of loss of equipment if cameras were left there.

In MUG where there was 24 hour security presence at the entrance gate, cameras were positioned from March 2014, sufficiently far away (between 10 and 15 metres) from the burrows to allow one to see a wide array of the dhubs behaviours but close enough to see when the animal emerged from its burrow (Figure 2-2)

Site 1 was located at N24.814058°, E55.249189° while Site 2 was located 180 m south west at N24.812814°, E55.248115°.

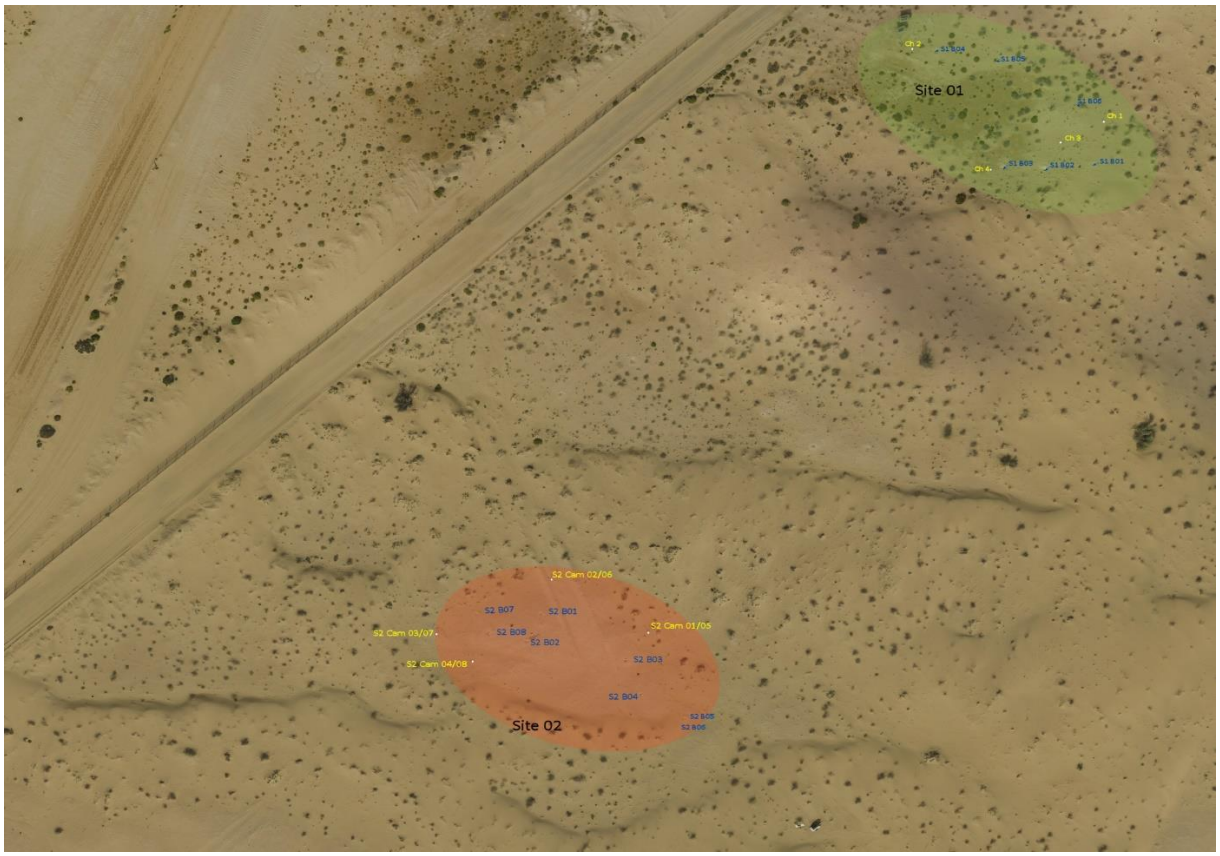


Figure 2-2. Location of Site 1 and Site 2 in Mugatrah, UAE, with the camera locations in yellow and the burrows being monitored in blue.

2.2.2 SOFTWARE AND STATISTICS

Statistical analysis was completed using MedCalc Statistics v 20.1, MedCalc Software, Ostend, Belgium; https://www.medcalc.org/; and Minitab v 21.1.

2.2.3 VIDEO RECORDING

Nine CCTV cameras were setup in the two areas (Site 1 and Site 2) in Mugatrah and a further four setup in Wadi Al Safa (Site 3). All were designed to run from solar power and start recording at 5.30 am and switch off at 7.30 pm. Data from Chapter 3 have shown that dhub do not emerge before 05:30 and do not remain outside of their burrows after 19:30. As such video recording was designed to coincide with these times throughout the day. In mid-July 2014 due to security concerns and the fact that the animals being observed at Site 3 in Wadi Al Safa abandoned their burrows, the four cameras from Wadi Al Safa were removed and subsequently relocated to Mugatrah in September 2014. On average, the cameras were recording between 96 and 110 hours of video per day. To the end of September 2015, there was in the region of 50,000 hours of video collected for Site 1 and 2 in Mugatrah.

The four cameras deployed at Site 1 were Labgear (LAB-BA7VS) analogue cameras linked to a four port

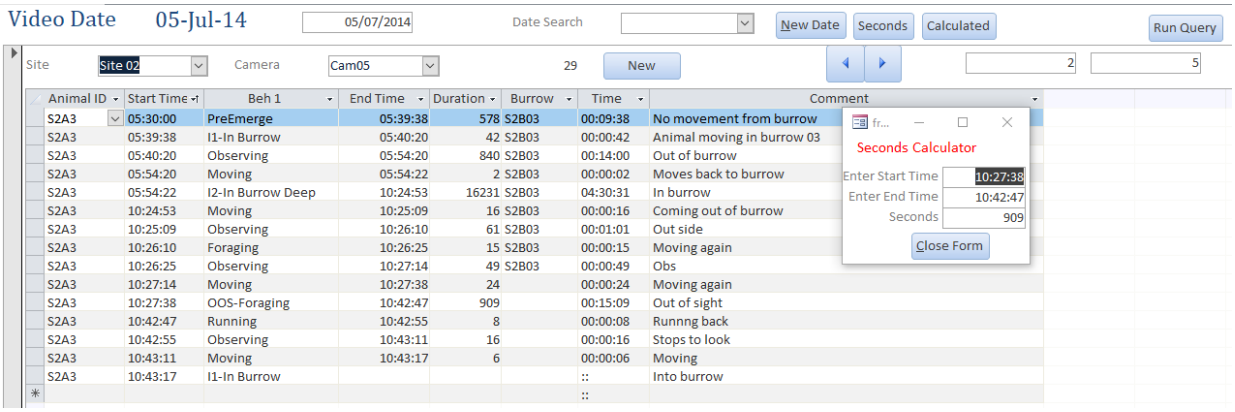
ProLab NVR where the data was transferred onto a 16Gb USB every week (Figure 2-3). Power was supplied via a solar panel which charged a deep cycle lead acid battery and DC voltage was supplied through a rectified DC distribution board to the NVR which powered the cameras. The second site (Site 2) was monitored by five 2Mb ProLab PN-IBT1W IP cameras linked back to a solar powered NVR (Prolab PA-N16E) camera and recording suite. In latter days from September 2014 through to the end of the study in July 2015, the power source was switched to mains, supplied from a power source 200 metres away. Data was archived on various models of external USB 3 hard drives.



Figure 2-3. Equipment used for the A) four analogue cameras at Site 1 (these had been pushed over by a herd of camels), B) five IP cameras at Site 2, C) backup power unit for either site if required and D) GoPro camera used for additional footage of burrows.

2.2.4 VIDEO ANALYSIS

Video analysis was completed using Pot Player, Kakao, South Korea (https://potplayer.tv/). A bespoke MS Access database (Figure 2-4) was created to capture and analyse the data from the video recordings.



Animal ID	Start Time	Beh 1	End Time	Duration	Burrow	Time	Comment
S2A3	05:30:00	PreEmerge	05:39:38	578	S2B03	00:09:38	No movement from burrow
S2A3	05:39:38	I1-In Burrow	05:40:20	42	S2B03	00:00:42	Animal moving in burrow 03
S2A3	05:40:20	Observing	05:54:20	840	S2B03	00:14:00	Out of burrow
S2A3	05:54:20	Moving	05:54:22	2	S2B03	00:00:02	Moves back to burrow
S2A3	05:54:22	I2-In Burrow Deep	10:24:53	16231	S2B03	04:30:31	In burrow
S2A3	10:24:53	Moving	10:25:09	16	S2B03	00:00:16	Coming out of burrow
S2A3	10:25:09	Observing	10:26:10	61	S2B03	00:01:01	Out side
S2A3	10:26:10	Foraging	10:26:25	15	S2B03	00:00:15	Moving again
S2A3	10:26:25	Observing	10:27:14	49	S2B03	00:00:49	Obs
S2A3	10:27:14	Moving	10:27:38	24		00:00:24	Moving again
S2A3	10:27:38	OOS-Foraging	10:42:47	909		00:15:09	Out of sight
S2A3	10:42:47	Running	10:42:55	8		00:00:08	Runnng back
S2A3	10:42:55	Observing	10:43:11	16		00:00:16	Stops to look
S2A3	10:43:11	Moving	10:43:17	6		00:00:06	Moving
S2A3	10:43:17	I1-In Burrow				::	Into burrow

Figure 2-4. Front end for data entry of the MS Access data base.

As the video recording was playing, the animal id, the start time of the behaviour , the behaviour and the end time of the behaviour were recorded. Any relevant notes would also be added to the comments section. The duration (seconds) and time (HH:MM:SS) were calculated. The hourly data was computed from the seconds interval with the following SQL query:

Site01: Format(Int([TS01]/3600),"00") & ":" & Format(Int(([TS01]-(Int([TS01]/3600)*3600))/60),"00") & ":" & Format((([TS01] Mod 60)),"00")

Behaviour	Duration	TS01	TS02	TS03
In Burrow	104:51:04	84:21:14	17:30:16	01:18:59

Where TS01 was the time in seconds a behaviour was recorded for location.

More than 40.000 hours of video was recorded during the study, a classic case of research infobesity, a term used to describe information overload whereby companies, decision makers, researchers collect more information than they need, or they can efficiently use (Mohammed & Aliyu, 2014; Malik *et al*, 2022).

Unfortunately, a lot of these data were lost/misplaced in transit on return to Ireland so that only 4416:05:37 hours were actually analysed.

2.2.5 SEASONS

Seasons (Table 2-1) were taken to be as per those used in Chapter 3.

Table 2-1. Determination of seasons

Season	Dates
Spring	1st Feb to 30th Apr
Summer	1st May to 31st Jul
Autumn	1st Aug to 31st Oct
Winter	1st Nov to 31st Jan

2.2.6 DHUBS OBSERVED

From the possible 470 days where data were recorded, approximately 124 individual days were analysed from April 2014 through to May 2015 on 24 individuals between the two sites (Table 2-2). As described above, the data analysed was all the data available at the time.

Table 2-2. The number of hours of data analysed for each animal and its sex where known, the site at which it was recorded. Animals were identified through direct capture at the burrow being observed.

Animal	Sex	Site	Times (Hr:Min:Sec)
S1A2	Male	Site 01	626:57:37
S2A3	Male	Site 01	209:31:14
AQ01	Female	Site 02	04:35:05
S1A1	Female	Site 01/02	803:30:44
S1A3	Female	Site 01	616:01:06
S1A4	Female	Site 01	625:36:09
S1A5	Female	Site 01	24:29:02
S2A1	Female	Site 02	206:01:04
S2A2	Female	Site 02	236:39:15
S2A4	Female	Site 02	96:25:56
***UnkMale**	Not Recorded	Site 01	00:01:53
Juv_Unk	Not Recorded	Site 01	03:15:06
Juv_Unk02	Not Recorded	Site 01	03:30:03
JuvB06	Not Recorded	Site 01	67:43:13
S1A2B	Not Recorded	Site 01	14:00:00
S1A6	Not Recorded	Site 01	449:58:52
S1B03B	Not Recorded	Site 01	09:29:13
S2A3U01	Not Recorded	Site 02	28:51:46
S2A5	Not Recorded	Site 02	23:46:45
S2A7	Not Recorded	Site 02	126:01:58
S2A8	Not Recorded	Site 02	126:00:00
S3A1	Not Recorded	Site 02	06:45:56
Unk	Not Recorded	Site 01	84:07:39
UR	Not Recorded	Site 02	22:46:01

**UnkMale was called this as it was a large looking dhub, but the actual sex could not be confirmed.*

There were a total of 3538:11:51 hours of observations for Site 1 and 877:53:46 hours of observations in Site 2. As each site was a colony of dhub, Site 1 primarily had observations from a single male with up to six females being observed in the associated burrows. Site 2 was also a colony and had a larger number of dhub associated with it, however, it was difficult to confirm the sex of some of the dhub as they were not caught in a particular burrow.

2.2.7 BEHAVIOURS

Table 2-3. List of all behaviours recorded for the 4,416 hours of video recorded. These were recorded at "Behaviour" level and merged to Super Behaviour for analysis.

Activity	Super Behaviours	Behaviour	Description
Active	Active	Moving	Animal moving slowly from one location to the next. Measured as the time it started to the time it engaged in next behaviour.
		Running	Animal is running to a location - usually burrow.
		W1-Walking Normal	Walking from one location to another
		W2-Walking Fast	Animal was not running but was not walking at usual pace. Usually observed when it was going somewhere definite.
	Aggressor	Chasing	Animal is chasing another dhub.
		Fighting	Animal is fighting with another dhub.
		Following	Animal is following another dhub but not actively chasing it.
		Chased	Animal is being chased by another dhub or other species.
	Avoidance	Avoid-1	When an animal moves away from another for safety to directly avoid interacting with approaching animal. Time is taken from the time behaviour starts until it stops. New behaviour will start immediately after this.
		Avoid-2	When an animal enters burrow for safety to directly avoid interacting with another animal. As soon as it enters, "In burrow" behaviour will start.
	Breeding	Dragged	Female being dragged by tail from burrow.
		Dragging	Male dragging female from burrow
		Intertwined	Act of copulation when both are together
		Mating	Animals seen mating.
		Receptive	Female on ground and not moving away from male while mating behaviour is in progress. Can be on her back.
		Scent Marking	Animal is actively scent marking an object (animal or other)
	Cleaning	Cleaning	Animal is cleaning its burrow
	Foraging	Eating	Animal stops to specifically eat food
		Foraging	Animal is actively walking, stopping and picking at vegetation.
		OOS-Foraging	Animal has moved out of sight of the camera but is suspected to be foraging.
	Interacting	Approaching	When an animal directly approaches burrow or animal for the purpose of interaction.
		Defence	Animal moves towards threat but does not engage. Behaviour stops when animal changes behaviour.
		Displaying	Walking and head bobbing at the same time.
		Head-bobbing	Animal is either stationery or moving and engaged in head bobbing.
		Interacting	Interacting with another dhub.

Table 2-3. (*continued*). List of all behaviours recorded for the 4,416 hours of video recorded. These were recorded at "Behaviour" level and merged for analysis.

Activity	Super Behaviours	Behaviour	Description
Active	Out of sight	OOS-Other	Animal is out of sight and not sure what the behaviour it is engaged in.
	Safety	Person	When an animal seeks refuge due to a person or for other safety reason. Once inside burrow, the behaviour will stop.
	Safety	Predator	When an animal seeks refuge due to predator or for other safety reason. Once inside burrow, the behaviour will stop.
Sedentary	At burrow	I1-In Burrow	Animal is in the burrow with head visible - prior to emerging.
		I3-At Burrow	Animal still has its tail or some part of its body still in the burrow or is sitting on the rim of the burrow.
	Basking	Attentive	Animal is sitting in a basking situation, but the head is raised.
		B1-Basking Ground	Animal is basking but not attentive.
		B2-Basking Bush	Animal is basking in a raised position on a bush or similar.
		B3-Basking Marker	Animal using stone for burrow marker as heat source.
		No Activity	Data examined but no activity recorded
		Observing	Animal looking around but stationary - similar to attentive.
	In Burrow	I2-In Burrow Deep	The animal was deep in the burrow as if overnight, during cleaning process when no dust is visible emerging from the burrow, when the animal enters to avoid predator or other issue or retreated after basking.
		Pre-Emerge	Time from 05.30 through to the time it emerges from burrow that day. If it does not emerge, then the full observation day is pre-emerge.

2.3 RESULTS

2.3.1 GENERAL

There were 24 dhubs whose behaviour was studied at Mugatrah (see Table 2-2). Females were observed (physically seen outside the burrow) during 48% of total observation count and contributed 42% to the mean time (seconds of behaviour) that dhub were observed (Figure 2-5). Males were observed during 18% of total observation count and contributed 36% of the mean times (seconds of behaviour) that dhub were observed. As such males while not as common as females, were observed for almost as long, while the dhubs of unknown sex were responsible for 34% of the total observations recorded, they only contributed 22% to the mean times for the behaviours.

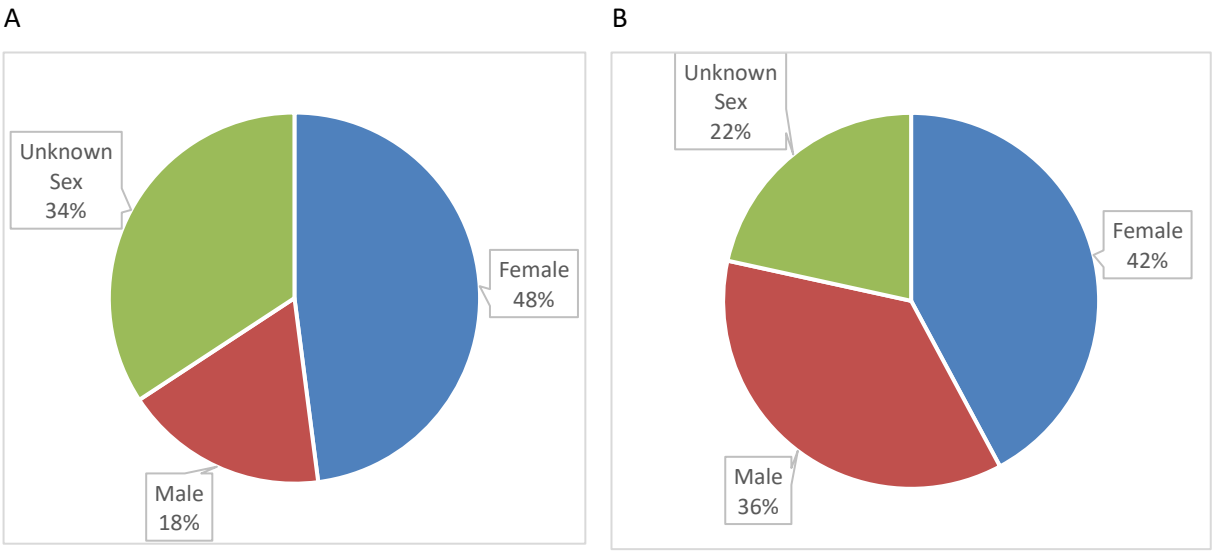


Figure 2-5 a). Percentage of contribution of observations for females, males and unknown animals throughout the study period and B) the percentage of mean time (seconds) each sex contributed to the data over the study period (April 2014-May 15) at Mugatrah, UAE.

2.3.2 GENERAL BEHAVIOUR PATTERNS FOR THE FOUR SEASONS COMBINED

In general, it can be said that over the study period, for the four seasons combined, (Figure 2-6), males (28%) were slightly more active than females (26%). The number of aggressor behaviours was highest in males (22 records) while females were also observed as aggressor (13 records). The highest number of records for females was in August (hatching month) (N= 1272) and May (breeding month) (N=557) and there was only one record of a male being on the receiving end of aggression from another dhub. Females tended to be more cautious (rapidly retreated into the burrow more readily than males) and spent more time in the burrow and in the vicinity of the burrow (41% of observations) than males (34.5% of observations). There were equal amounts of observations of males and females foraging, while males interacted more than females and were also out of sight more often than females. Females were observed more often cleaning their burrows (3.8% of observations) than males (2.8% of observations).

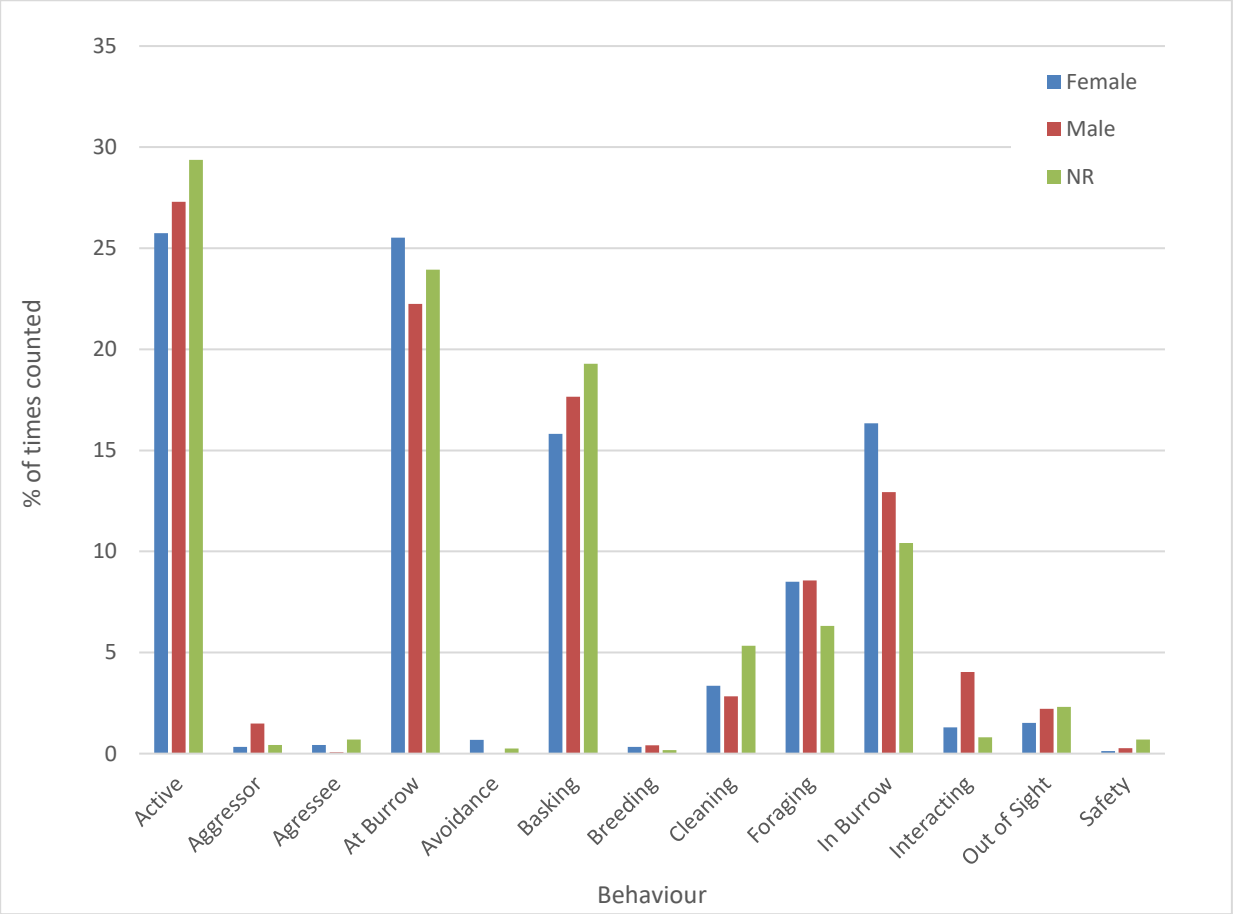


Figure 2-6. The percentage of the number of times a dhub was recorded engaged in one of the observed behaviours at MUG between April 2014 and May 2015. This does not include the duration of the behaviour.

2.3.3 DAILY ACTIVITY PATTERN 05:00 THROUGH TO 19:59

To reduce the impact on the graphs that the total time a dhub would spend "In Burrow" would have, the count of the number of times a particular behaviour was initiated for males, females and not recorded was used. The data were broken into half hourly times from 05:30 to 05:59, hourly from 06:30 to 18:59 and again for the last half hour of 19:00 to 19:30 every day. These data included observations when the dhub was seen going into its burrow and underground. Apart from 13:00 to 13:59, dhubs were underground for more than 50% of the time. When "In Burrow" was removed (Figure 2-7), the majority of the behaviours across the day were dominated by inactive behaviours when the dhubs were either basking or at the burrow.

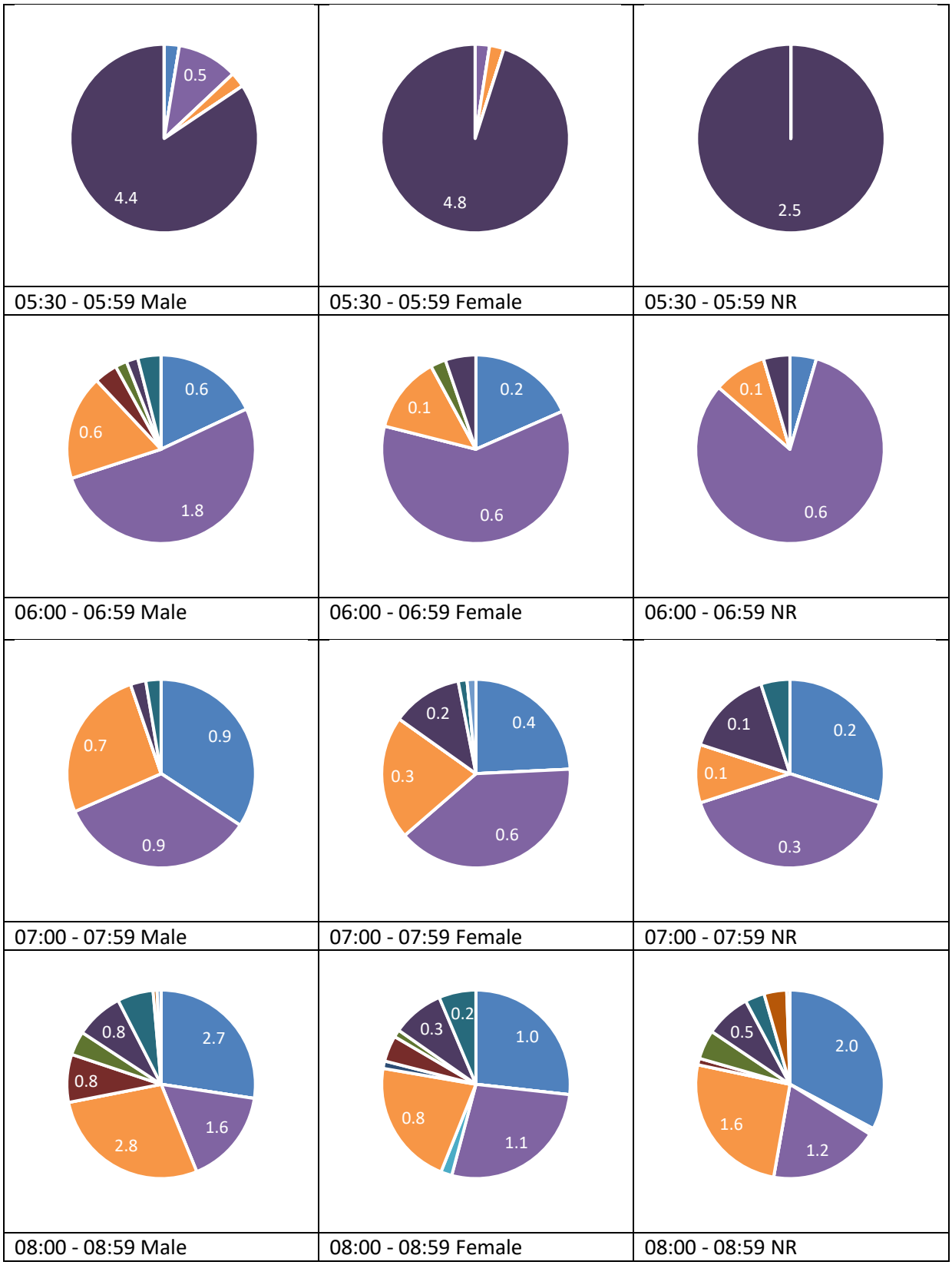


Figure 2-7. The percentage (total counts) of observation a dhub was engaged in a behaviour for males, females and not recorded (NR) for each time period throughout the day from 05:30 through to 08:00 from April 2014 through to May 2015.

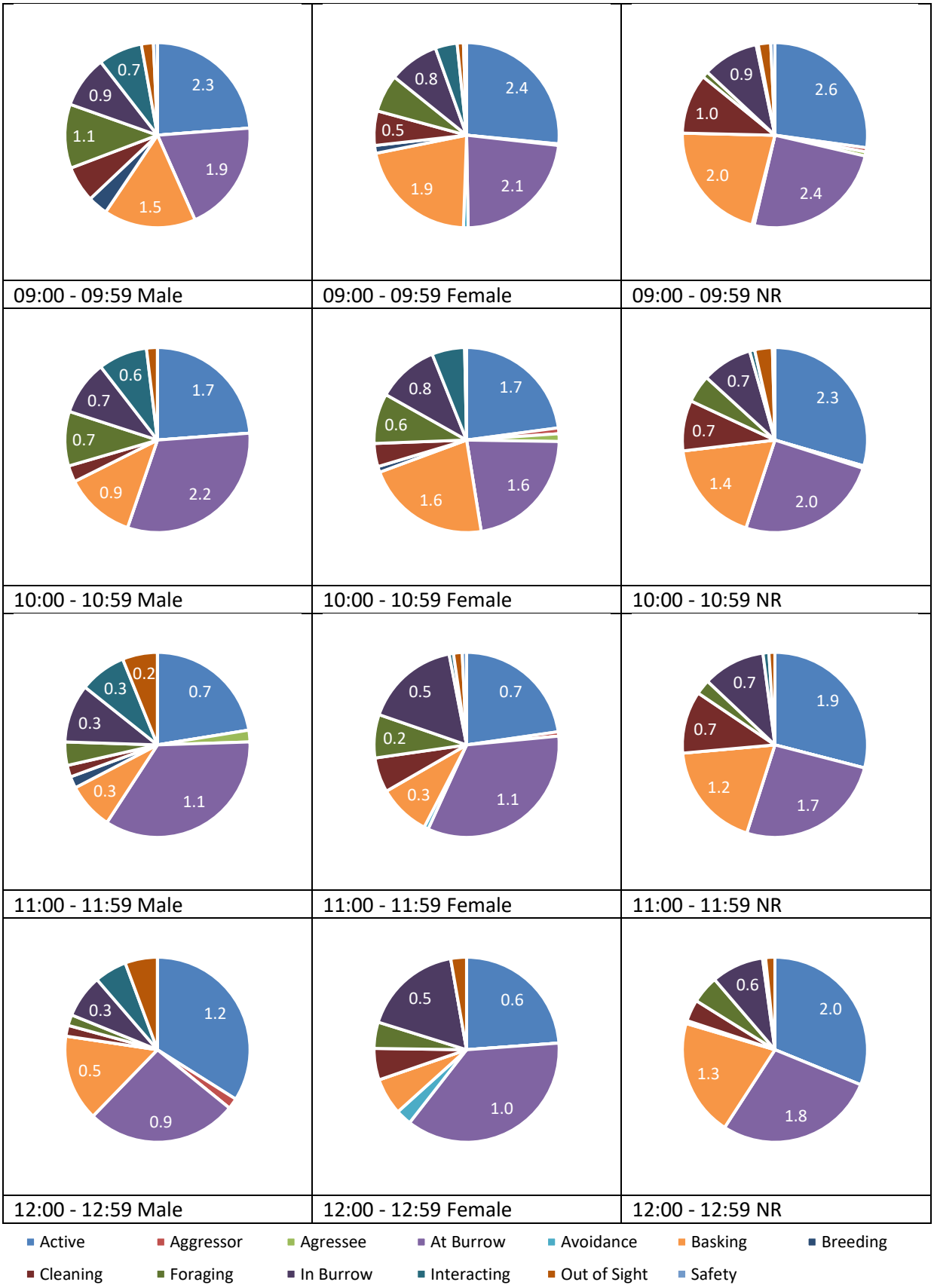


Figure 2-7 (*continued*). The percentage (counts) of observation a dhub was engaged in a behaviour for males, females and not recorded (NR) for each time period throughout the day from 05:30 through to 08:00 from April 2014 through to May 2015.

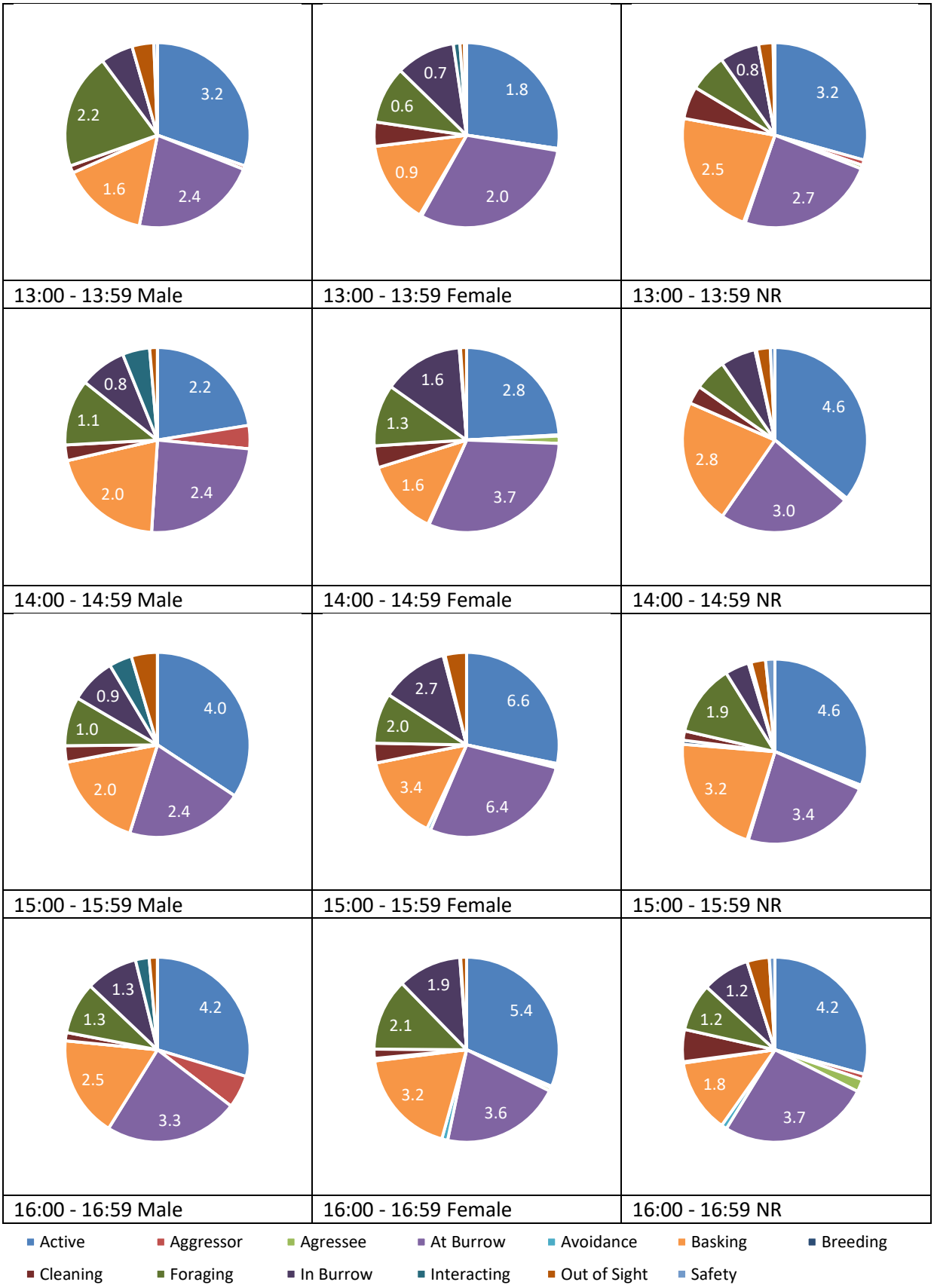


Figure 2-7 (*continued*). The percentage (counts) of observation a dhub was engaged in a behaviour for males, females and not recorded (NR) for each time period throughout the day from 05:30 through to 08:00 from April 2014 through to May 2015.

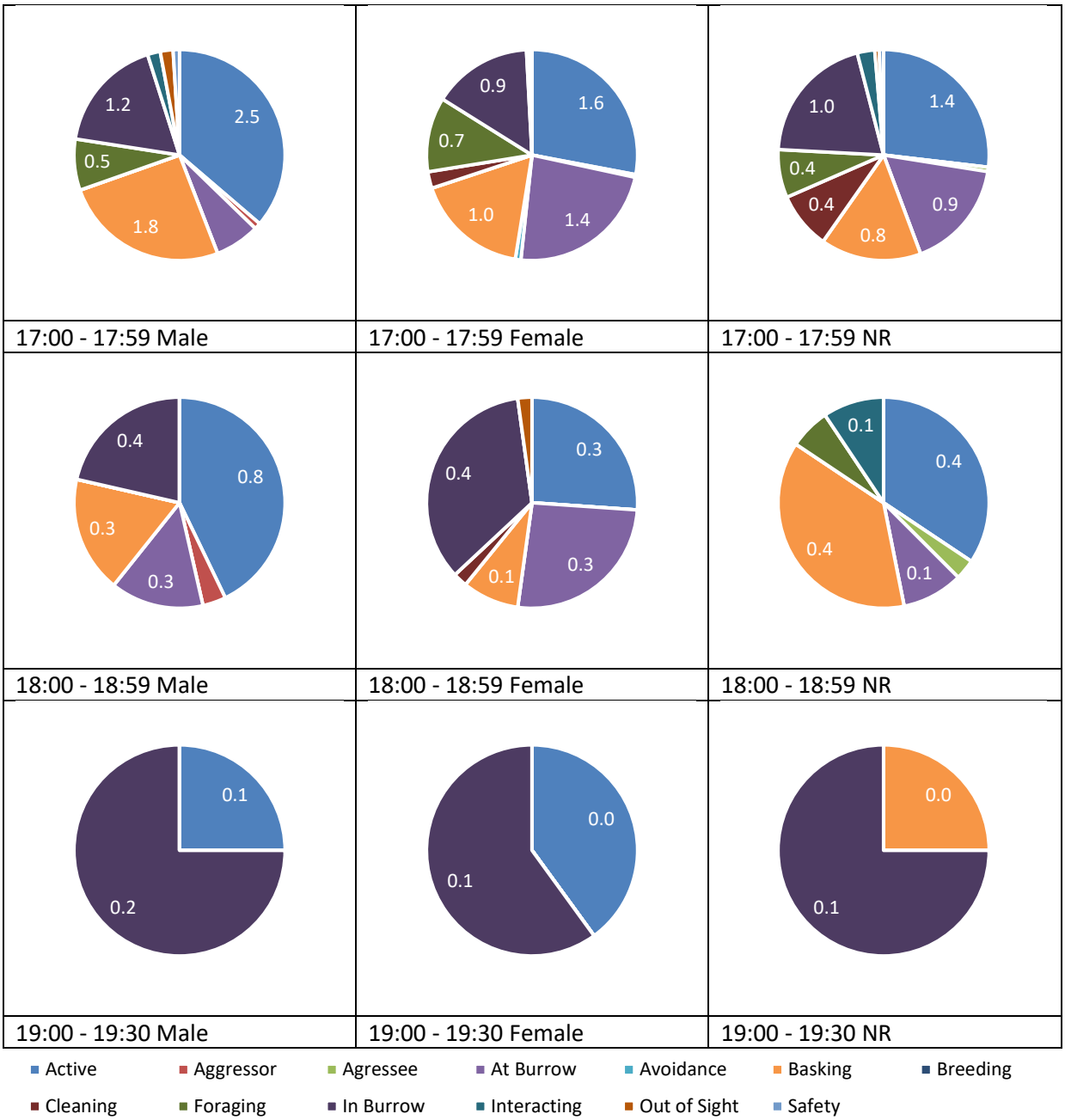


Figure 2-7 (*continued*). The percentage (counts) of observation a dhub was engaged in a behaviour for males, females and not recorded (NR) for each time period throughout the day from 05:30 through to 08:00 from April 2014 through to May 2015.

When one looks at the data and how each behaviour contributes to the overall behaviour repertoire (Figure 2-8) of dhub, it is clear that while the behaviour of being deep inside the burrow contributes to 82% of recorded time, it only contributes to 14% of the total observed behaviours.

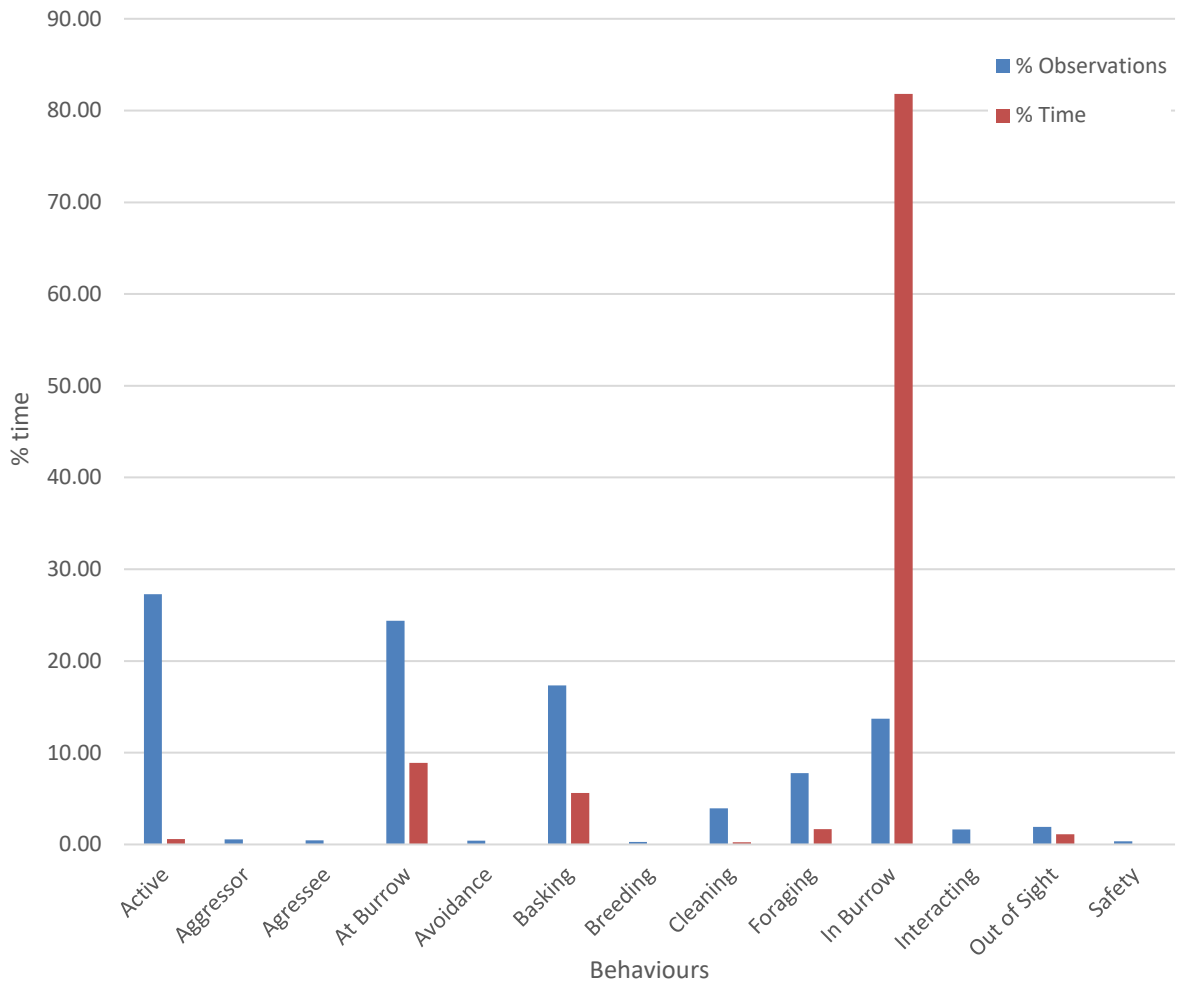


Figure 2-8. Percentage of time dhub spent completing a behaviour v the percentage of observations recorded for that behaviour over the whole study (N=4,419 hours).

It is also clear from the above data that when dhub are above the surface, the majority of time, 41%, is spent sedentary, i.e., basking which is sitting in an area away from the security of the burrow, to being at the burrow or with part, or all of their body below the rim of the burrow, but still visible. For the purpose of this part of the study both Basking and At Burrow have been grouped together and is described below as InActive (Figure 2-9). From this, there appears to be a clear bimodal activity pattern as has been seen in other parts of this research project (see Chapter 3 and 5). In tandem with this, it

also shows a trimodal inactivity pattern, when the animal emerges early in the morning, mid morning and then again in early afternoon (7%, 6.5% and 8.8% of its average recorded time in seconds inactive respectively). While it doesn't show when the animal enters or leaves the burrow, the highest levels of inactivity appear to be mid-morning and early afternoon where on average 8% of its observed inactive behaviours are observed, tailing off in the latter parts of the day.

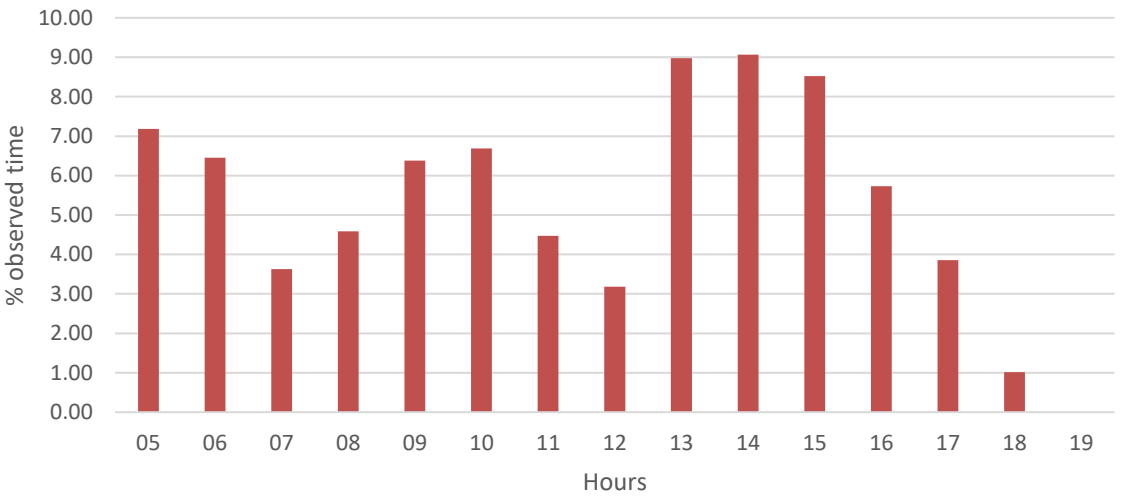


Figure 2-9. The percentage of observed time in seconds dhub (all sexes combined) were recorded as inactive (basking or at the burrow) from 05:00 through to 19:59 throughout the study period.

When some of the other behaviours are examined (Figure 2-10 a-d and Table 2-4) and the percentage of the overall time spent engaged in what could be considered interactive behaviours, there is a peak in the early morning, mid-day and afternoon, aligning with the reduced inactive periods above.

Table 2-4. The percentage of observed time dhub were engaged in an active behaviour throughout the study period. Times when the dhub were below ground have been excluded from these results.

Behaviour	Total Percentage of Observed Time
Active*	3.263
Aggressor	0.016
Aggresse	0.011
Avoidance	0.174
Breeding	0.038
Cleaning	1.264
Foraging	9.161
InActive	79.729
Interacting	0.207
Out of Sight	6.136
Safety	0.002

*Active included, Moving, Running, Walking Normal and Walking Fast.

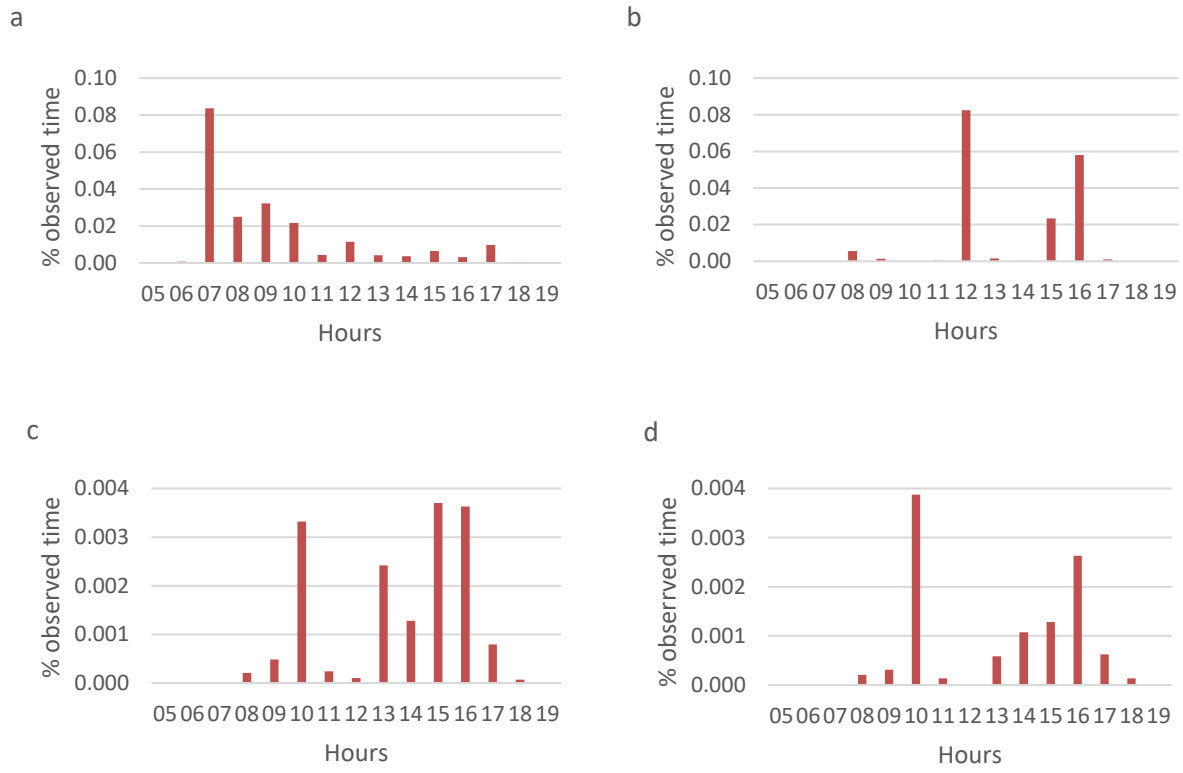


Figure 2-10. The percentage of overall time a dhub was engaged in a) Interacting; b) Avoidance; c) Aggressor and d) Aggresse behaviour. It should be noted that the percentage of observed time for Aggresse and Aggressor were two orders of magnitude smaller that when dhub were either interacting or engaged in avoidance behaviours.

Similarly, the aggressor (0.016%) and aggresse (0.011%) behaviours, while only an extremely small proportion of the overall results, suggest that there is a bimodal pattern to the time of day when this behaviour occurred. There is a more aggressive occurrences (N=18) between 16:00 and 16:59 where the mean duration was 5.83 ±0.617 seconds directed towards another dhub, but less dhub reacting to the aggression (N=13) during the same time period, but the same duration for those receiving the aggression 5.85 ±0.807 seconds was similar. The normal recipient reaction was to disappear underground so that the behaviour then stopped.

Active behaviours (Figure 2-11a) which include running, walking, moving etc (3.26 %) showed a peak in the early morning (1.27 %) with another lesser peak in mid-afternoon (0.43 %). Breeding behaviours (Figure 2-11b) were most frequent in the morning (0.02 %) and afternoon (0.02 %) but again contributed a very small proportion of the recorded time that dhub were engaged in above ground behaviours. Dhubs' reactions to predators, which were usually avian, corresponded with their sedentary behaviours above with peaks in the morning and afternoon (0.002 %). Dhub could potentially engage in burrow cleaning (Figure 2-11c) which was the 5th most common behaviour

observed, at any time of the day, but there did appear to be a peak in mid-morning just after 09:00 with 0.28% of observed behaviour time spent cleaning.

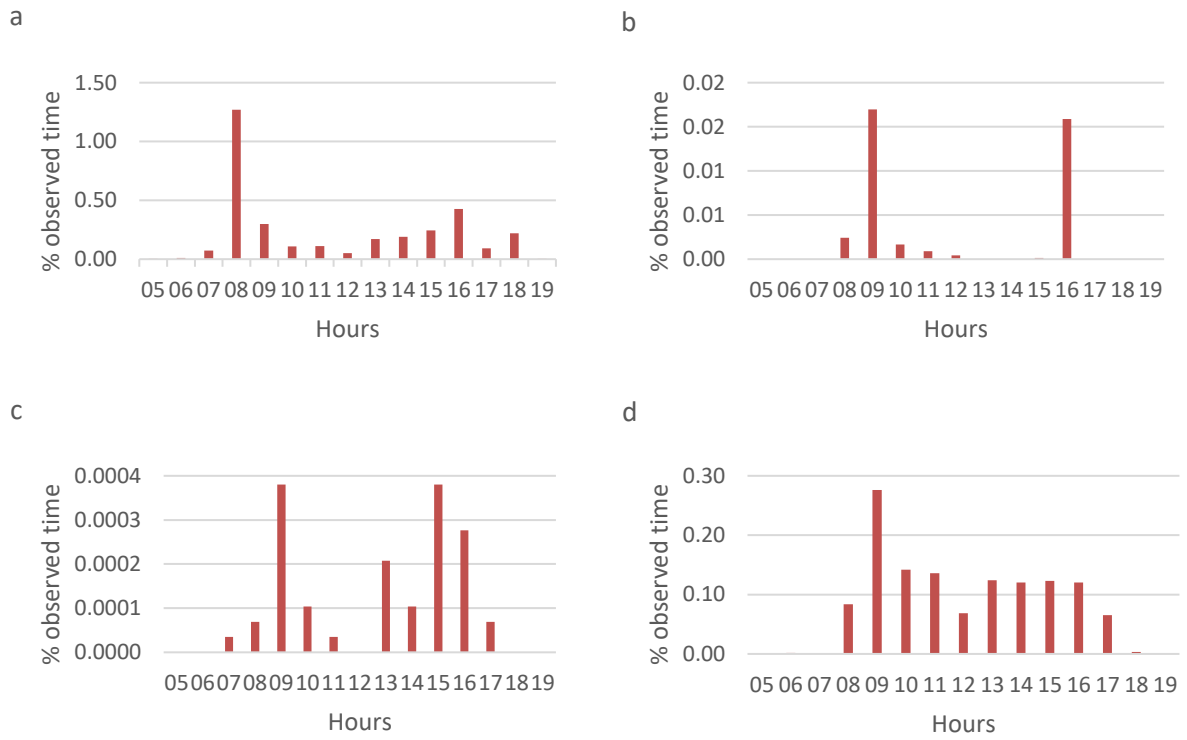


Figure 2-11. The percentage of overall time a dhub was engaged in a) Active; b) Breeding; c) Safety and d) Cleaning behaviours. It is important to note that the scale for the percentage of observed time for active behaviours a) versus cleaning d) versus b) breeding were again an order of magnitude greater than each other. Safety behaviours c) were four orders of magnitude smaller that breeding a).

2.3.4 FORAGING

An animal's ability to find food within a safe distance of its burrow is an essential component to its survival. Foraging in these dhub was predominantly observed in the afternoon (Figure 2-12a) with a peak around 16:00.

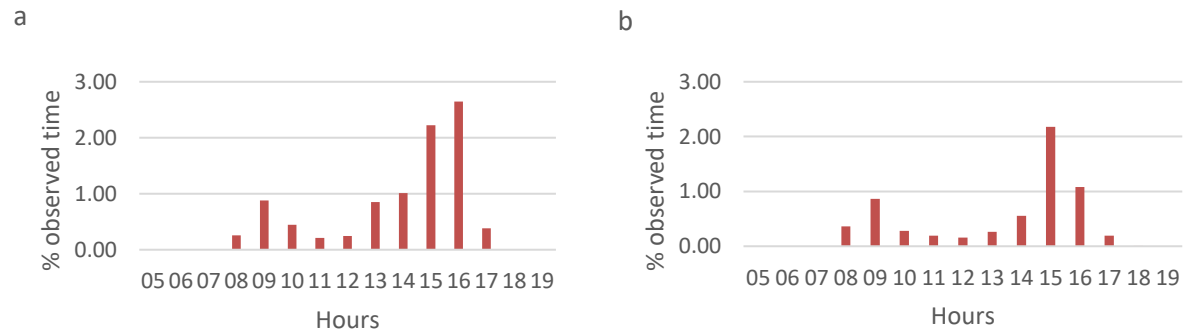


Figure 2-12. The percentage of overall time a dhub was engaged in a) Foraging and b) Out of Sight behaviours.

Males spent slightly shorter percentage of overall active behaviours (8.75%) compared to females at

(10.59%) foraging. However, the mean time spent foraging was longer for males When a dhub went out of camera view, but the initial behaviour was foraging, then that behaviour was included in the foraging group above. However, when a dhub actively went out of camera view and had not initiated foraging (Figure 2-12b) it was considered to be Out of Sight (6.136 % of observed time). These behaviours and times were slightly less than that of the foraging behaviours (9.161%) with a peak an hour earlier than the foraging behaviour. To determine whether the amount of time a dhub was out of sight might be related to its foraging or whether there was a significant difference between sexes, both the difference in sex * foraging and sex*out of sight were analysed in an ANOVA.

The one-way ANOVA ($\alpha = p < 0.05$) revealed that there was no statistically significant difference in mean foraging time between the sexes ($F(2, 631) = [2.48]$, $p = 0.085$). However, when one looks at the ANOVA for Out of Sight, there was a statistically significant difference between the sexes ($F(2, 144) = [3.62]$, $p = 0.029$). A Tukey pairwise comparison (Table 2-5) showed a link between the unknown sex and Males as well as unknown sex and Females. There was a significant difference between males and females for the mean amount of time they spent out of sight as suggested by (Figure 2-13).

Table 2-5. Grouping information using the Tukey method and 95% confidence showing the similarity around the means for each sex and those non recorded.

Sex	N	Mean	Grouping	
M	31	1806	A	
NR	60	1122	A	B
F	56	966		B

Means that do not share a letter are significantly different.

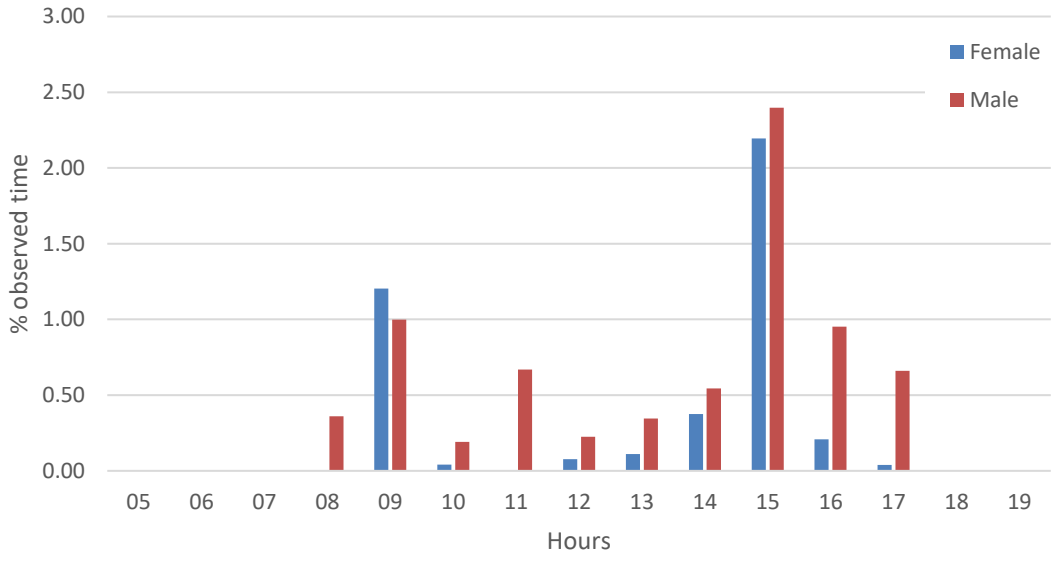


Figure 2-13. Percentage of observed times males and females were away from the burrow and out of the camera frame (OOS-Other) for all seasons combined at Mugatrah, UAE.

2.3.5 SEASON

Males were generally observed (Figure 2-14) most active in the spring (M=182.1 ± SE=37.5) and autumn (M=332.7 seconds ± SE=64.4) compared to females (M= 10.5 seconds ± SE=17.3) and (M=158.7 seconds ± SE=21.7), while females (M=187.5 seconds ± SE=56.4) were recorded slightly more active in the Summer than males (M=164.4 seconds ± SE=31.2). It should be noted that while there are over 4,000 hours of data analysed, there are only two confirmed males, while there are eight confirmed females.

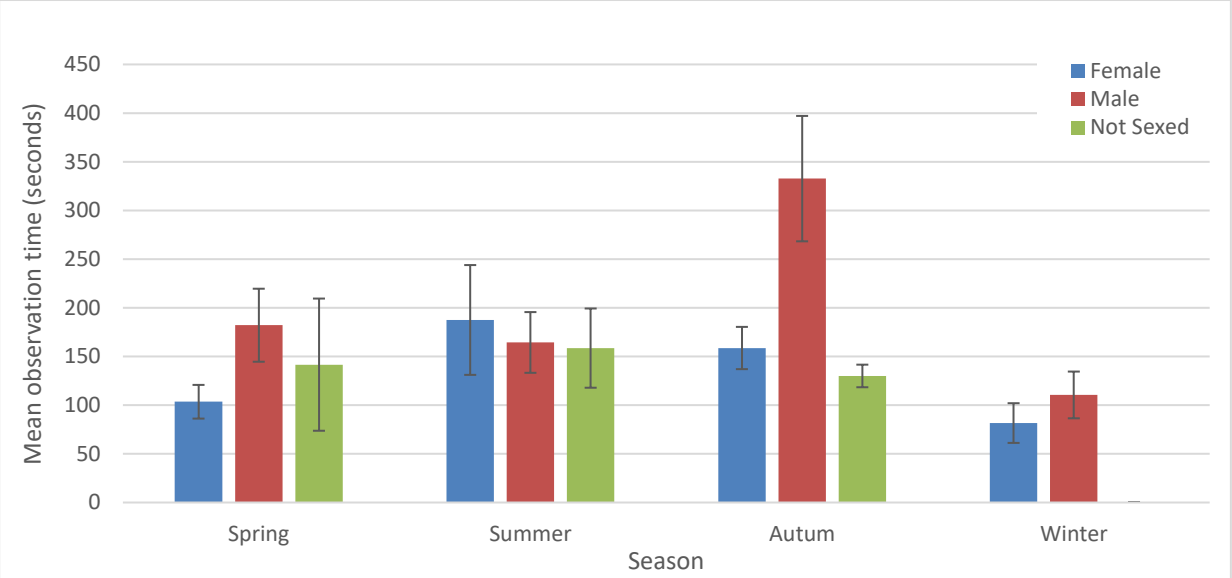


Figure 2-14. Mean observation time (seconds) recorded with SE Mean for males, females and non-recorded animals over each season for active behaviours only at Mugatrah, UAE.

When the mean times that dhub spend in a sedentary behaviour (Figure 2-15) are looked at, by far the least active time is winter females (M=1912 seconds ± SE=623) and males (M=2155 seconds ± SE=288). Females were recorded as sedentary more often in three out of the four seasons than males, with very slightly (M=362.7 seconds ± SE=68.6) more time sedentary in the summer than males (M=333.4 seconds ± SE=82.7).

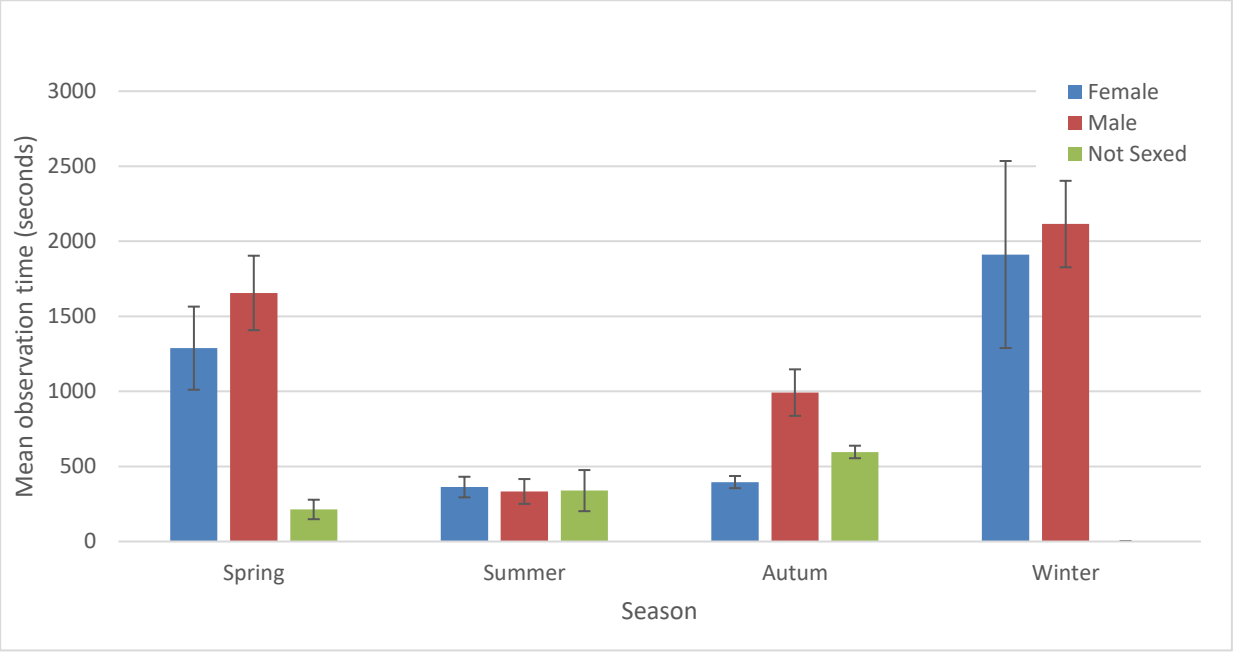


Figure 2-15. Mean observation time (seconds) recorded with SE Mean for males, females and non-sexed (Not Recorded) animals over each season for sedentary behaviours including when the animal was not visible in the burrow.

Cleaning of the burrows is an important task with females spending on average 1:37 (± SE=0:24) minutes and males 1:49 (± SE=0:36) minutes cleaning throughout the year. There was no statistical difference between females and males $F(1,174)=0.67$, $p=0.414$. However, there was a statistical difference when one looked at the mean time spent cleaning throughout the different seasons $F(3,171)=3.0$, $p=0.032$. Using the Tukey pairwise comparison suggested that the mean time spent cleaning in Winter and Spring was similar, while there was a definite difference between summer and autumn (Figure 2-16).

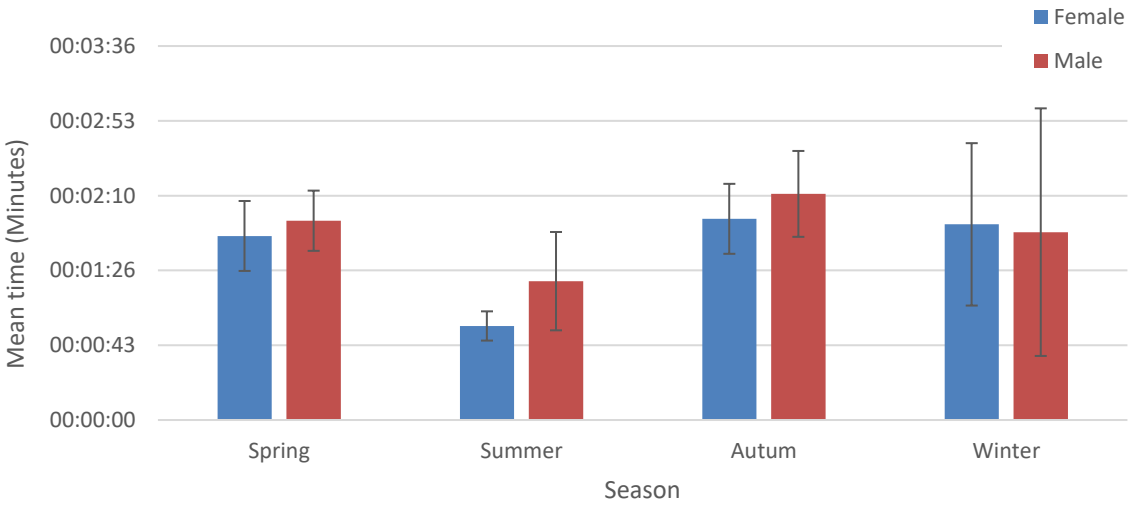


Figure 2-16. Mean observed time (minutes) either sex were observed cleaning their burrows with the SE Mean for each season. Animals whose sex could not be identified were excluded.

2.3.6 MONTHLY

Results from the RFID traps (Figure 2-17) which were analysed in detail in Chapter 3 suggest that dhub were more active during March, April and May

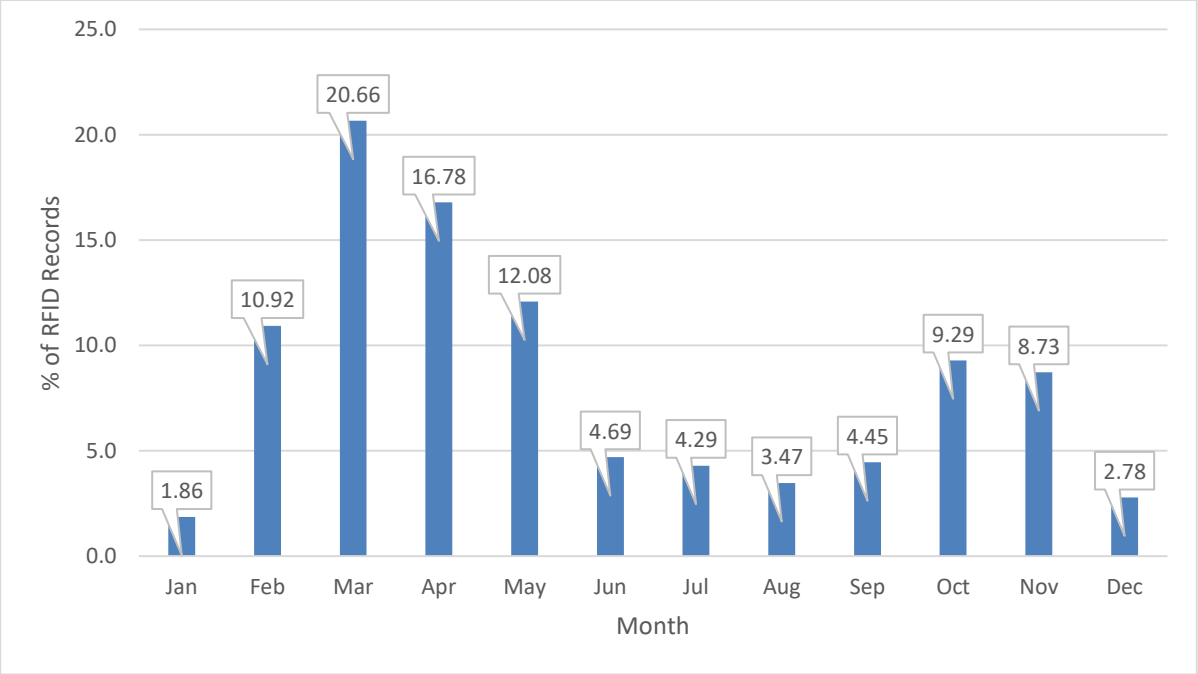


Figure 2-17. Percentage of time an animal emerged from its burrow between March 2015 and Jan 2019 and recorded on the RFID trap.

while the results from the behavioural observations (Figure 2-18) suggests that the majority of activity for both females and males was August, while August was one of the quietest months for the RFID data.

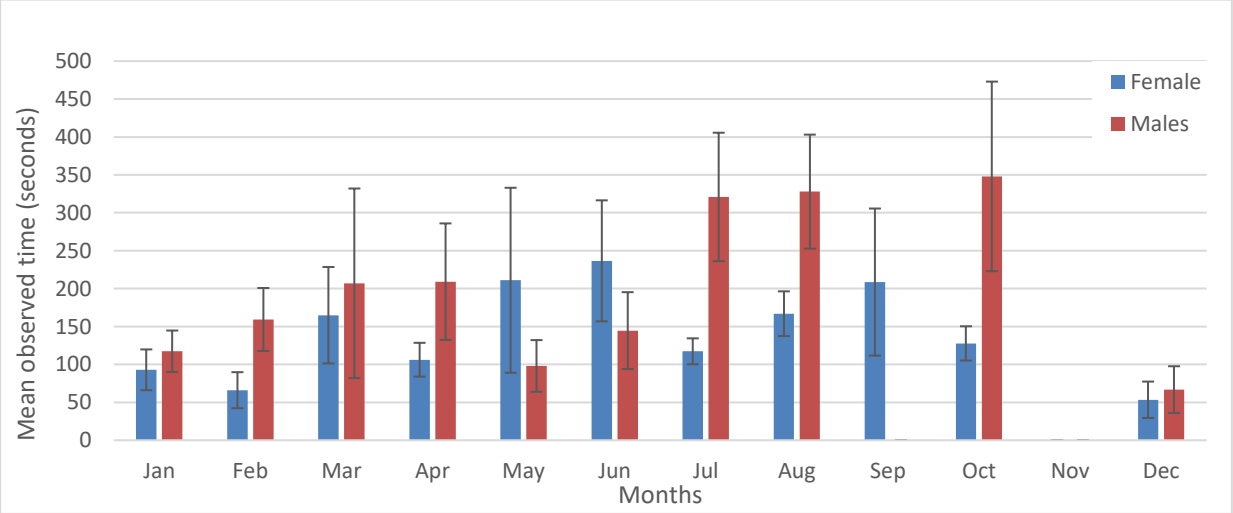


Figure 2-18. Mean observed times males and females were observed in an active behaviour with the SE Mean for each month. These data exclude times when dhub were in the burrows.

However, as these were limited to two males and eight females, then caution should be taken when any sex related inferences are taken from the data.

2.4 DISCUSSION

The current study supported the findings of some authors about the bimodal pattern of dhub (Wilms *et al*, 2009; Al-Sayegh *et al*, 2020) but adds to this, in that males in general appeared to be more active than females. It does suggest, contrary to the two others (Bouskila, 1986; Wilms et al, 2009), that dhub are active during the Winter months, in the sense that they do emerge from their burrows, but do not spend much time in any other behaviour apart from sedentary behaviours, i.e. basking. While broad behavioural categories might impair rigorous data analysis, the current study was designed in such a way that these broad categories could be broken into more specific individual behaviours which accurately represented some of the finer elements of dhub behaviour. The fact that males contributed to more of the analysed time (40%) during this study compared to the mean number of observations (18%) was a reflection on their movements and activity when compared to those of females. This might suggest that females are a little more sedentary than males and were certainly more cautious spending a much larger proportion of their time either at or in the burrow than males.

2.4.1 ANTI-PREDATORY BEHAVIOUR

The behaviour data collected from Mugatrah reinforces the reliance of the dhub on their burrows as a source of refuge. Females, which are on average 50% lighter than males (see Chapter 3) were observed more frequently at the cusp or inside the rim of the burrow than males. This would allow them the opportunity to flee down the burrow almost as soon as a predator or perceived threat was observed. Males, being on average 1.94 Kg (see Chapter 3), were less cautious and, while still being in the vicinity of the burrow, were observed more frequently than females basking away from the burrow. However, only 0.1% of recorded behaviours were considered to be females fleeing to escape a predator while 0.3% of male recorded behaviours were of them fleeing, perhaps again reflecting the more active nature of the males. It might also reflect the fact that fleeing from a basking position a metre or so from the burrow is far more noticeable than if the animal were at the burrow entrance. During the study, the primary anti-predator response was elicited from an aerial source, suggesting that birds of prey or raptor like passerines would be their main threat. Yosef & Yosef (2010) reported on the cooperative hunting techniques of brown-necked ravens (*Corvus ruficollis*) on dhub in Israel. Cunningham & Aspinall (2001) have shown that the little owl (*Athene noctua*) are active predators of young dhub and the grey shrike (*Lanius excubitor*) is also considered a potential predator of young dhub. The appearance of grey shrike have been shown to cause dhub to retreat quickly when they approach (pers *obs*), while Cunningham (2009a) saw grey shrike eating an adult rough tailed gecko (*Cyrtopodion scabrum*) and Figure 2-19 suggests that reptile species within the study site were also prey for this species.



Figure 2-19. Great grey shrike (*Lanius excubitor*) with Hadramaut sand lizard (*Mesalina adramitana*) (left) it had just caught in MUG while the desert lark (*Ammomanes deserti*) does not cause any negative reaction from the dhub (right).

There have been observations during the study of dhub actively chasing another dhub (Figure 2-20), particularly young naïve animals. This young animal outran the resident but returned a short time later to continue its investigation of the burrow.



Figure 2-20. Resident dhub chasing young dhub from its burrow.

Evidence also suggests *(pers obs*) that desert monitors (*Varanus griseus*) will enter dhub burrows and spend some time inside as observed during the current study. They could potentially take associated species such as *Hemidactylus robustus* (Heyden's gecko) or *Cyrtopodion scabrum* (rough tailed bow foot gecko) for example. In no instance was there any evidence of them catching dhub, who would utilise their antipredator defence mechanisms within the burrow (Cooper & Al-Johany, 2005) and in a number of cases, while dhub were more vigilant, they did not flee from the monitor. There was one recorded sequence where the resident dhub actively chased a monitor from its area (Figure 2-21).



Figure 2-21. Resident dhub chasing desert monitor.

All of these incidents were short bursts, lasting only several seconds and were also extremely infrequent. but recorded as part of the of the data.

2.4.2 Intra Specific Interactions

There is very little data or reports on dhub intraspecific interactions available, with which to compare these results and while dhub would not be considered to be social and seek out or interact in a sociable manner with other dhub, males did engage in interactive behaviours more frequently than females. This interaction would generally be the male approaching the female burrow without entering and scent marking or investigating the outside of the burrow for a short period before leaving again.

Most of the interactive behaviours occurred in a bimodal fashion with behaviours occurring up to 10.00 am and then again after 13.00 with a peak between 15.000 and 16.00. This is similar to the findings of Al-Sayegh *et al* (2020), but differs from Wilms *et al* (2009) who suggest that while dhub show a bimodal activity pattern, it occurs at later time periods than the current study.

Leading up to the breeding season in May, males would visit burrows more frequently with increased head bobbing and very few attempts to enter the burrow. During the breeding season, male protective behaviours (ensuring females remained in their burrows), which would involve a considerable energy expenditure by the male, focused on the male not wanting the females to leave the burrow with entry to the burrow by the male more frequent. One male in Site 02 could be seen expending a lot of energy going from one female burrow to the other each time they emerged from

the burrow. Females, however, were recorded on average interacting longer (01:15 minutes) than males (00:26 minutes) which would potentially link in with the observations from Chapter 3, where multiple females were recorded on the same day in different burrows. Ruby (1978) found that with male Yarrow's spiny lizard (*Sceloporus jarrovii*) male aggression and territoriality increased during the breeding season which was similar to Jenssen *et al* (1995) and the current study.

2.4.3 FORAGING

Obtaining adequate nutrition is among the most fundamental challenges affecting fitness in reptiles, particularly in unpredictable environments such as the desert. Both males and females were recorded an equal number of times (8.5%) foraging, however, males foraged for a slightly longer amount of time (average 9:08 minutes) compared to females (06:35 minutes) yet there was no statistical difference between the sexes. Bouskila (1986) recorded a mean foraging time for dhub of 9 minutes but did not differentiate between sex. Foraging bouts showed a bimodal pattern with early in the morning for males (09:00 to 10:00) and late afternoon (15:00 to 17:00) for both males and females being the most frequent time dhub were observed feeding. On many occasions during the study, males would spend a considerable amount of time foraging then stopping to look around while females appeared to be more direct. While females were extremely vigilant, they were not seen to be observing with the same detail as males. The average dhub track length in Mugatrah was 109 m during the Winter and 171 m during the rest of the year (see Chapter 3 and 4). Both males (7.34 %) and females (4.26 %) were recorded out of sight at almost the same rate, yet males on average spent almost twice as much time (30:06 minutes) out of sight. As this category was when the animal simply left the burrow and went away from the camera (Figure 2-22), usually at pace, indicating the animal had a purpose, it was not deemed to be a foraging behaviour. When an animal went out of sight after it had started foraging this time was included in the foraging times.



Figure 2-22. Example of demeanour of dhub when they were recorded (after they left the camera view) and went out of sight.

In the case of males, it could potentially be a means of surveying/patrolling their territory while in females it could potentially be a means by which they source alternative food or explore other burrows. During the tracking part of this study, there were many non-resident dhub visiting different burrows as captured on the RFID traps. Some of these would travel over 100 m from what was considered their home burrow. This is similar to other studies (Wilms *et al*, 2009) which has also suggested that animals move between burrows.

2.4.4 Active and Cleaning Behaviours

Males were recorded more frequently engaged in active behaviours than females. While these included the subtle shifting of an animal from one position to another either for security or potential phototaxis, thermoregulatory requirements, it also included when animals were running and walking, which would again link in with the males longer out of sight times and the interactions described above.

Active did not include time spent cleaning of burrows, which is a very important requirement for dhub. If burrows remained inactive (no resident dhub) for more than a month, the entrance quickly closed up or reduced in size considerably due to windblown sand. As such, burrow excavation was an important behaviour engaged in by dhub. While females were observed cleaning their burrows slightly more often than males, the average time spent cleaning was very similar for males and females at almost 2 minutes and there was no significant difference between the sexes. The actual cleaning duration was most likely much longer, as this behaviour was based on the observation of the animal using both front and hind legs to push the sand away from the burrow. Usually when the animal went into the burrow,

dust could be seen emanating from the entrance signifying it was still engaged in the behaviour. It is believed that the behaviour continued when the dhub was deep inside the burrow, however, this could not be guaranteed so the recording of the length of the behaviour stopped when it could not be confirmed that the animal was cleaning. Bouskila (1985) suggested that August was the most active time for cleaning in his study whereas the current study demonstrated that while cleaning was observed in each month that the animals were recorded as being active, March (03:25 minutes) and September (05:15 minutes) were the months where the mean time devoted to cleaning was greatest. Cleaning was seen to be undertaken opportunistically with only a slight increase in the percentage of observed times at 09:00 compared to the other times with no cleaning observed after 18:00.

2.4.5 TIME AND SEASON

Neither this behavioural chapter, nor the data collected during the use of the RFID traps have shown dhub to emerge at night. As such, a dhub's potential day is described as being between 05:30 to 19:30 varying throughout the year dependent on sunrise and sunset but would not be earlier nor later than those times. As has been reported, a considerable proportion of this time is spent underground (≥75%) throughout the year yet this behaviour only contributed on average 14% to the overall behaviour count. When the time spent subsurface was removed, the greatest amount of time was still spent in sedentary behaviours where the dhub was either baking or sat at the burrow entrance. The time spent in these sedentary behaviours are essential to a desert living reptile such as the dhub. The subtle shuffling and repositioning of the animals which were included in the sedentary behaviours are most likely a form of heliothermy, facilitating the correct thermoregulation for the animal as first described by Cowles & Bogert (1944).

As would be expected, Spring and Winter were the seasons where most time was spent sub surface , supporting the findings of Bouskila (1986) and Wilms et al (2009). Removing these subsurface times, females were generally more active during the Summer than males who were most active in the other three seasons. With respect to month, August, October and May respectively were the most active months in terms of recorded active behaviours. A potential suggestion why October was the second most active month could be a mechanism whereby dhub foraging increases, (7.8% of all recorded behaviours were foraging during October), in preparation for the winter, less active period. Similarly, Hussein *et al* (1978) suggested a seasonal difference in the thymus and as a result, the immunological capabilities of dhub, with both being reduced in the Winter period studied.

2.5 CONCLUSION

Dhub are inherently a sedentary species, spending over 80% of their time sub-surface in their burrow throughout the study period and a further 14% of the observed time in sedentary behaviours when they were above the surface. As the energy expended in locomotion is a significant portion of the energy budget of lizards this might suggest why so little time is spent engaged in the other behaviours, with foraging being the behaviour with the greatest benefit to dhub being the next greatest time allocation at 2%.

Interestingly, for the animals recorded in both locations, the activity periods do not tally with the RFID traps where March was the most active and August one of the least active months, based on the number of recorded trap records. The reason for this is most likely the fact that only 47 hours of data was analysed for March compared to over 900 for August. This is an issue which does need to be addressed in the future when analysing these data further.

While the potential consequences of urbanisation is the driver for the current study, Moule *et al* (2016) have found with the delicate skink, (*Lampropholis delicata*) in Australia, where urbanisation has occurred relatively recently, that the changes in behaviour might be related to the degree of urbanisation that has occurred.. This is not the case in this study as it was a private reserve, but the author has noted that in areas of more frequent human contact, dhub have moved out or been extirpated completely.

Although other factors such as space, humidity, and nutrition are involved in captive management of reptiles, thermal distribution patterns and substrate materials, particularly in outdoor enclosures, are important factors to be taken into account in reptile husbandry (Meek, 1995). When any translocation is to be considered, these issues along with the seasonal requirements of the dhub are paramount. Now that this research has provided the most detailed study of the daily and seasonal activity patterns of dhubs (females, males and unknown sex) in the UAE, the basic building blocks of a successful captive management programme prior to translocation have been developed in relation to the behavioural requirements of the species.

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APPENDIX 2-1: HOURLY BEHAVIOURS FOR EACH MONTH

Table 2-6. Breakdown of hourly behaviours for January, for all sexes from 05:00 through to 19:59 for Mugatrah, UAE.

Month	Behaviour	Total Hours	Time														
			05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
January	Active	00:23:48	-	-	-	-	-	00:00:29	00:02:42	00:03:24	00:04:30	00:05:56	00:06:00	00:00:14	00:00:33	-	-
	At Burrow	56:15:24	-	-	-	-	-	11:24:42	08:23:08	04:43:39	09:55:11	10:09:25	10:20:24	01:18:55	-	-	-
	Avoidance	00:00:02	-	-	-	-	-	-	-	-	-	00:00:02	-	-	-	-	-
	Basking	19:26:38	14:00:00	-	-	-	-	-	-	01:02:59	02:01:53	02:04:09	00:17:37	-	-	-	-
	Cleaning	00:09:16	-	-	-	-	-	-	-	00:01:40	00:00:37	00:03:59	00:03:00	-	-	-	-
	Foraging	02:41:48	-	-	-	-	-	-	-	-	01:02:16	01:04:08	00:35:24	-	-	-	-
	In Burrow	795:03:04	727:10:01	-	-	-	-	10:38:52	-	03:31:33	00:13:20	19:33:15	08:16:41	11:46:25	13:52:57	-	-

Table 2-7. Breakdown of hourly behaviours for February, for all sexes from 05:00 through to 19:59 for Mugatrah, UAE.

Month	Behaviour	Total Hours	Time														
			05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
February	Active	00:35:00	-	-	-	-	00:00:50	00:01:06	00:00:46	00:01:14	00:27:07	00:01:15	00:01:35	00:01:07	-	-	-
	At Burrow	80:12:22	-	-	-	00:15:13	10:09:59	16:00:29	05:02:52	04:09:06	21:34:52	10:29:31	08:12:56	04:17:24	-	-	-
	Avoidance	00:01:00	-	-	-	-	-	-	-	-	00:00:40	-	00:00:20	-	-	-	-
	Basking	02:21:27	-	-	-	-	-	00:55:48	-	00:37:58	00:47:41	-	-	-	-	-	-
	Cleaning	00:16:59	-	-	-	-	-	-	00:02:31	00:04:04	00:04:29	00:00:27	00:05:28	-	-	-	-
	Foraging	02:42:44	-	-	-	-	-	-	-	-	01:42:56	00:17:23	00:42:25	-	-	-	-
	In Burrow	305:01:42	245:42:22	-	-	-	00:45:00	01:31:21	00:42:12	01:13:48	08:55:57	00:34:12	09:49:58	22:01:15	13:45:37	-	-
	Interacting	00:00:24	-	-	-	-	-	-	-	-	00:00:24	-	-	-	-	-	-
	Out of Sight	00:56:42	-	-	-	-	-	-	-	-	00:56:42	-	-	-	-	-	-
	Safety	00:00:04	-	-	-	-	00:00:01	-	-	-	00:00:03	-	-	-	-	-	-
	Active																

Table 2-8. Breakdown of hourly behaviours for March, for all sexes from 05:00 through to 19:59 for Mugatrah, UAE.

Month	Behaviour	Total Hours	Time														
			05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
March	Active	00:20:00	-	-	-	-	-	-	00:02:33	00:03:11	00:06:01	00:05:30	00:02:45	-	-	-	-
	Aggressor	00:00:54	-	-	-	-	-	-	-	00:00:03	00:00:49	00:00:02	-	-	-	-	-
	Agressee	00:00:12	-	-	-	-	-	-	-	-	00:00:02	00:00:10	-	-	-	-	-
	At Burrow	11:36:16	-	-	00:04:35	01:41:06	-	01:26:42	02:00:09	01:31:21	01:31:20	02:52:08	00:27:02	00:01:53	-	-	-
	Avoidance	00:39:47	-	-	-	-	-	-	-	00:39:47	-	-	-	-	-	-	-
	Basking	01:00:43	-	-	-	-	-	00:01:11	00:06:14	00:07:07	00:42:00	00:02:16	00:01:55	-	-	-	-
	Cleaning	00:23:59	-	-	-	-	-	00:07:57	00:03:43	00:07:11	-	00:02:48	00:02:20	-	-	-	-
	Foraging	00:53:15	-	-	-	-	-	00:01:38	-	00:19:38	00:26:46	00:05:13	-	-	-	-	-
	In Burrow	30:16:53	18:29:45	-	00:53:24	-	-	-	02:41:12	00:01:15	00:00:57	00:11:11	04:40:37	03:18:32	-	-	-
	Interacting	00:05:04	-	-	-	-	-	-	-	00:05:04	-	-	-	-	-	-	-
	Out of Sight	02:17:06	-	-	-	-	-	-	-	00:28:42	00:31:03	01:14:00	00:03:21	-	-	-	-
	Safety	00:00:01	-	-	-	-	-	-	00:00:01	-	-	-	-	-	-	-	-

Table 2-9. Breakdown of hourly behaviours for April, for all sexes from 05:00 through to 19:59 for Mugatrah, UAE.

Month	Behaviour	Total Hours	Time														
			05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
April	Active	00:54:25	-	-	00:00:29	00:03:49	00:01:05	00:04:15	00:01:39	00:02:44	00:02:06	00:01:59	00:15:23	00:07:24	00:13:26	00:00:06	-
	Agressee	00:00:01	-	-	-	-	-	-	-	-	00:00:01	-	-	-	-	-	-
	At Burrow	26:15:22	-	-	-	03:38:37	00:28:58	02:03:20	03:58:25	01:08:32	01:14:09	04:21:55	03:37:40	05:04:27	00:39:19	-	-
	Avoidance	00:00:09	-	-	-	-	-	-	00:00:09	-	-	-	-	-	-	-	-
	Basking	39:43:41	28:00:00	-	01:12:06	00:15:19	01:04:46	01:32:20	01:28:16	00:06:43	00:09:39	01:17:04	02:59:30	00:29:52	01:07:37	00:00:29	-
	Breeding	00:00:26	-	-	-	-	-	-	00:00:26	-	-	-	-	-	-	-	-
	Cleaning	00:34:28	-	-	-	-	-	00:04:49	00:03:30	00:10:24	00:06:32	00:06:22	00:01:16	00:01:35	-	-	-
	Foraging	04:23:31	-	-	-	-	-	-	-	00:46:06	01:16:42	01:24:14	00:33:11	00:17:56	00:05:22	-	-
	In Burrow	66:54:45	40:07:50	-	-	-	-	00:36:39	01:03:45	03:05:22	02:19:17	02:08:13	02:05:21	00:43:44	12:15:02	02:29:32	-
	Interacting	00:06:43	-	-	-	-	-	00:02:04	00:01:11	-	-	00:00:39	-	-	00:02:49	-	-
	Out of Sight	02:23:23	-	-	-	-	00:44:20	00:07:15	00:54:41	00:16:17	00:16:19	-	00:04:31	-	-	-	-

Table 2-10. Breakdown of hourly behaviours for May, for all sexes from 05:00 through to 19:59 for Mugatrah, UAE.

Month	Behaviour	Total Hours	Time														
			05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
May	Active	11:16:36	-	00:02:44	00:28:20	09:28:54	00:11:32	00:12:48	00:05:50	00:00:06	00:19:49	00:16:03	00:03:35	00:03:55	00:02:09	00:00:51	-
	Aggressor	00:02:12	-	-	-	-	00:00:07	00:01:02	-	-	00:00:11	00:00:29	-	00:00:03	00:00:20	-	-
	Agressee	00:01:12	-	-	-	-	-	00:00:17	-	-	00:00:14	00:00:21	-	00:00:02	00:00:18	-	-
	At Burrow	14:59:04	-	00:50:30	02:04:56	02:12:16	01:39:15	01:22:36	01:20:15	00:19:25	00:54:36	00:21:45	00:31:24	01:11:22	02:09:19	00:01:25	-
	Avoidance	00:00:53	-	-	-	00:00:44	-	-	-	-	-	-	00:00:09	-	-	-	-
	Basking	15:54:01	-	04:37:59	01:35:33	02:51:39	03:02:07	01:30:30	00:01:43	-	00:04:01	00:22:46	00:34:28	00:14:21	00:58:54	-	-
	Breeding	00:09:18	-	-	-	00:00:33	00:07:57	00:00:48	-	-	-	-	-	-	-	-	-
	Cleaning	00:20:05	-	00:00:45	-	-	00:07:42	00:01:35	00:00:13	-	00:00:56	00:01:00	-	00:06:59	00:00:55	-	-
	Foraging	08:00:49	-	00:04:28	-	01:13:28	00:27:14	01:04:03	00:47:00	-	00:23:47	00:35:32	01:16:48	01:33:11	00:35:18	-	-
	In Burrow	158:51:23	94:22:24	04:00:27	-	01:35:39	05:02:48	16:58:32	06:25:27	02:41:05	04:56:11	02:54:43	10:06:12	05:51:41	01:31:54	02:24:20	-
	Interacting	01:18:26	-	00:00:21	00:40:21	00:12:02	00:12:04	00:07:43	00:00:14	-	00:01:37	00:00:32	00:01:29	00:01:10	00:00:53	-	-
	Out of Sight	01:43:04	-	-	-	-	00:34:26	-	-	-	-	-	00:42:11	00:25:18	-	00:01:09	-

Table 2-11. Breakdown of hourly behaviours for June, for all sexes from 05:00 through to 19:59 for Mugatrah, UAE.

Month	Behaviour	Total Hours	Time														
			05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
June	Active	01:10:31	-	00:00:19	00:00:11	00:11:10	00:36:22	00:01:36	00:00:10	-	00:00:42	00:01:47	00:05:44	00:10:29	00:01:36	00:00:17	00:00:08
	At Burrow	18:50:52	-	00:03:13	01:32:00	00:01:36	07:23:48	06:12:45	-	-	00:06:51	01:32:49	00:11:54	00:27:21	01:06:20	00:12:15	-
	Basking	09:49:29	-	02:06:09	00:31:39	02:31:10	00:43:53	00:01:51	-	-	00:07:16	01:21:13	00:42:01	00:48:39	00:02:18	00:53:20	-
	Cleaning	00:08:13	-	-	-	00:00:26	00:02:32	00:03:42	-	-	-	-	00:00:53	00:00:34	00:00:06	-	-
	Foraging	11:21:50	-	-	-	00:25:57	02:18:31	00:02:35	00:03:38	-	-	00:08:41	02:07:36	06:14:52	-	-	-
	In Burrow	93:11:36	36:55:25	-	-	04:51:19	11:29:28	10:58:43	04:01:25	-	01:10:59	00:43:05	03:11:23	10:56:18	07:46:48	00:58:26	00:08:17

Table 2-12. Breakdown of hourly behaviours for July, for all sexes from 05:00 through to 19:59 for Mugatrah, UAE.

Month	Behaviour	Total Hours	Time														
			05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
July	Active	01:22:33	00:00:02	-	00:00:28	00:01:57	00:03:29	00:04:17	00:00:16	00:00:22	00:00:06	00:01:30	00:04:25	00:11:52	00:05:47	00:47:55	00:00:07
	Aggressor	00:01:00	-	-	-	-	-	00:00:34	-	-	-	-	-	00:00:26	-	-	-
	Agressee	00:01:50	-	-	-	-	-	00:01:35	-	-	-	-	-	00:00:15	-	-	-
	At Burrow	19:41:14	04:08:10	00:42:49	02:32:52	01:21:38	00:37:41	01:25:40	00:55:46	00:00:16	00:01:01	00:41:05	01:42:53	01:38:01	02:45:49	01:07:33	-
	Avoidance	00:27:02	-	-	-	-	00:00:04	-	-	-	-	-	-	00:26:58	-	-	-
	Basking	04:52:24	00:14:00	-	-	00:42:33	00:43:32	00:09:38	-	00:00:02	-	00:00:31	00:02:56	00:30:08	00:45:53	01:43:11	-
	Breeding	00:00:14	-	-	-	-	00:00:14	-	-	-	-	-	-	-	-	-	-
	Cleaning	00:35:59	-	-	-	00:08:13	00:06:23	00:04:05	-	-	-	00:00:37	00:06:46	00:03:31	00:06:24	-	-
	Foraging	10:10:04	-	-	-	00:08:09	01:07:13	00:57:41	00:08:38	00:14:01	00:05:21	00:25:47	01:17:01	05:26:40	00:19:33	-	-
	In Burrow	285:47:00	144:04:00	-	02:54:39	05:32:42	26:38:25	36:43:27	05:18:01	01:30:52	02:30:22	08:53:14	10:33:10	18:12:27	21:07:12	01:07:13	00:41:16
	Interacting	00:04:27	-	-	-	-	00:02:24	00:00:41	-	-	-	-	00:00:55	-	00:00:27	-	-
	Out of Sight	04:12:27	-	-	-	-	01:44:14	-	-	-	-	00:05:15	00:41:47	01:33:05	00:08:06	-	-

Table 2-13. Breakdown of hourly behaviours for August, for all sexes from 05:00 through to 19:59 for Mugatrah, UAE.

Month	Behaviour	Total Hours	Time														
			05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
August	Active	06:03:19	00:00:13	00:01:02	00:04:52	00:23:14	01:18:20	00:11:50	00:02:26	00:00:13	00:00:12	00:04:52	00:28:09	02:18:47	00:11:53	00:57:16	-
	Aggressor	00:03:08	-	-	-	00:00:06	00:00:07	-	-	-	-	-	00:01:47	00:01:03	00:00:03	00:00:02	-
	Agressee	00:01:21	-	-	-	00:00:06	00:00:09	-	-	-	-	-	00:00:10	00:00:52	-	00:00:04	-
	At Burrow	66:00:09	03:12:07	28:09:06	08:57:10	05:21:22	01:00:34	00:16:58	00:08:58	-	00:06:10	00:42:52	03:39:59	05:34:39	06:15:17	02:34:57	-
	Avoidance	00:14:06	-	-	-	00:01:57	00:00:35	-	-	-	-	-	00:10:43	00:00:47	00:00:04	-	-
	Basking	49:20:12	07:55:31	08:15:37	08:31:26	08:53:12	01:48:30	00:46:12	00:06:51	-	00:04:33	00:29:58	02:10:04	01:48:26	06:55:09	01:34:43	-
	Breeding	00:08:14	-	-	-	00:00:37	-	-	-	-	-	-	-	00:07:37	-	-	-
	Cleaning	03:18:14	-	-	-	00:31:35	01:17:58	00:07:32	00:01:30	-	-	00:05:44	00:37:39	00:23:25	00:11:16	00:01:35	-
	Foraging	16:18:49	-	-	-	00:16:31	03:08:35	00:22:26	00:28:35	00:05:20	00:10:46	01:01:12	05:23:54	03:26:19	01:52:19	00:02:52	-
	In Burrow	764:34:39	310:12:11	-	09:17:56	52:22:03	117:39:44	55:52:01	26:17:24	02:32:08	02:22:16	12:52:26	52:23:04	82:37:53	31:23:57	08:12:01	00:29:35
	Interacting	00:02:07	-	-	-	-	00:01:03	-	-	-	-	-	00:00:25	00:00:20	-	00:00:19	-
	Out of Sight	30:09:07	-	-	-	02:55:09	05:37:52	02:07:11	-	-	-	00:58:47	11:23:20	05:42:54	01:23:54	-	-
	Safety	00:00:08	-	-	-	00:00:01	00:00:07	-	-	-	-	-	-	-	-	-	-

Table 2-14. Breakdown of hourly behaviours for September, for all sexes from 05:00 through to 19:59 for Mugatrah, UAE.

Month	Behaviour	Total Hours	Time														
			05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
September	Active	00:56:32	-	00:00:25	00:00:33	00:06:58	00:00:26	00:00:38	00:00:20	00:00:07	00:01:28	00:26:51	00:08:40	00:07:02	00:03:04	-	-
	Aggressor	00:00:15	-	-	-	-	-	-	-	-	00:00:10	-	-	00:00:05	-	-	-
	Aggressee	00:00:28	-	-	-	-	-	-	-	-	-	-	00:00:23	00:00:05	-	-	-
	At Burrow	24:15:25	00:11:00	04:13:13	00:27:22	00:02:07	00:22:58	00:05:59	00:03:43	00:41:38	07:13:34	03:10:18	02:26:06	02:23:49	02:53:29	00:00:09	-
	Basking	13:37:45	-	00:00:24	00:14:39	00:33:41	01:37:26	00:02:03	-	00:17:00	00:30:40	04:15:03	02:23:52	00:55:31	02:47:26	-	-
	Cleaning	01:24:02	-	-	-	-	00:21:58	-	00:34:52	00:02:02	00:19:57	00:05:04	-	00:00:09	-	-	-
	Foraging	03:55:56	-	-	-	-	00:01:13	00:42:48	-	00:02:08	00:08:03	00:01:47	00:59:46	01:49:51	00:10:20	-	-
	In Burrow	160:36:44	95:30:55	09:24:23	00:00:53	11:50:40	09:55:50	02:15:18	03:33:51	04:21:39	02:32:43	02:32:38	-	07:21:17	08:43:16	02:33:21	-
	Out of Sight	00:23:15	-	-	-	00:02:20	-	-	-	-	-	-	-	00:20:55	-	-	-
	Safety	00:00:10	-	-	00:00:01	00:00:01	-	00:00:03	-	-	-	-	-	00:00:04	00:00:01	-	-

Table 2-15. Breakdown of hourly behaviours for October, for all sexes from 05:00 through to 19:59 for Mugatrah, UAE.

Month	Behaviour	Total Hours	Time														
			05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
October	Active	03:11:09	-	-	-	00:02:28	00:12:08	00:13:00	00:36:25	00:13:07	00:18:26	00:24:40	00:41:29	00:23:59	00:05:26	00:00:01	-
	Aggressor	00:00:21	-	-	-	-	-	-	00:00:07	-	-	00:00:06	-	00:00:08	-	-	-
	Aggresse	00:00:10	-	-	-	-	-	-	00:00:04	-	-	-	00:00:04	00:00:02	-	-	-
	At Burrow	60:39:45	-	02:51:48	01:22:55	05:26:58	05:43:12	00:49:56	01:35:12	02:09:26	03:29:24	07:17:58	12:43:14	15:04:20	02:05:22	-	-
	Avoidance	00:00:45	-	-	-	-	-	-	-	-	00:00:03	-	00:00:03	00:00:13	00:00:26	-	-
	Basking	92:02:06	-	-	-	01:07:57	14:49:18	06:00:57	08:16:52	08:31:37	18:08:33	17:22:28	13:07:54	04:12:15	00:24:15	-	-
	Breeding	00:00:18	-	-	-	-	-	-	-	00:00:12	-	-	00:00:04	00:00:02	-	-	-
	Cleaning	02:57:59	-	-	-	-	00:16:26	00:38:37	00:19:20	00:07:48	00:27:20	00:31:57	00:01:58	00:21:47	00:12:46	-	-
	Foraging	12:46:04	-	-	-	-	-	00:22:28	00:12:54	00:30:47	01:13:44	03:03:51	04:54:18	02:27:39	00:00:23	-	-
	In Burrow	525:21:26	310:22:19	-	05:58:20	04:46:43	05:56:57	15:03:22	24:13:11	09:12:44	11:35:57	25:24:03	25:05:29	40:30:33	45:42:25	01:29:23	-
	Interacting	00:02:33	-	-	-	-	-	-	00:00:40	00:00:28	-	00:00:34	00:00:19	-	00:00:32	-	-
	Out of Sight	08:58:50	-	-	-	-	-	-	00:38:57	00:30:58	00:23:54	02:10:08	04:35:13	00:39:40	-	-	-
	Safety	00:00:24	-	-	-	-	00:00:03	-	-	-	00:00:02	00:00:03	00:00:11	00:00:04	00:00:01	-	-

Table 2-16. Breakdown of hourly behaviours for November, for all sexes from 05:00 through to 19:59 for Mugatrah, UAE.

Month	Behaviour	Total Hours	Time														
			05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
November	In Burrow	14:00:00	14:00:00	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 2-17. Breakdown of hourly behaviours for December, for all sexes from 05:00 through to 19:59 for Mugatrah, UAE.

Month	Behaviour	Total Hours	Time														
			05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
December	Active	00:06:39	-	-	-	-	-	00:01:37	00:00:28	00:00:29	00:01:19	00:01:34	00:00:32	00:00:40	-	-	-
	At Burrow	14:07:24	-	-	-	-	-	01:34:42	02:25:44	00:28:01	03:27:17	03:56:19	02:13:27	00:01:54	-	-	-
	Basking	00:02:17	-	-	-	-	-	-	-	-	00:02:17	-	-	-	-	-	-
	Foraging	00:20:29	-	-	-	-	-	-	-	-	00:20:29	-	-	-	-	-	-
	In Burrow	457:56:57	419:35:53	-	-	08:37:14	-	-	-	00:29:15	00:03:06	14:42:38	07:52:21	06:36:30	-	-	-
	Safety	00:00:01	-	-	-	-	-	-	-	-	00:00:01	-	-	-	-	-	-

APPENDIX 2-2: DESCRIPTIVE STATISTICS FOR EACH BEHAVIOUR FOR EACH MONTH

Table 2-18. Descriptive statistics for all active behaviours, for each month. The No. is the number of times that behaviour was recorded for each month. The percentage refers to the percentage of all observations for that month. All other data are recorded as seconds the behaviour was observed.

	No	%	Mean	SE Mean	StDev	Min	Median	Max	Total Time
Jan	66	4.6	21.6	2.3	18.5	2.0	16.5	116.0	0:23:48
Feb	88	6.1	23.9	10.3	96.5	1.0	10.0	907.0	0:35:00
Mar	25	1.7	19.3	4.1	19.9	2.0	15.0	102.0	0:07:44
Apr	124	8.6	25.9	6.6	73.2	1.0	10.0	609.0	0:53:30
May	223	15.5	164.0	143.0	2124.0	1.0	10.0	31658.0	10:05:23
Jun	145	10.0	26.7	12.7	152.2	0.0	9.0	1827.0	1:04:03
Jul	134	9.3	34.6	21.2	245.8	2.0	10.0	2856.0	1:17:12
Aug	427	29.8	40.3	13.7	283.2	1.0	10.0	3526.0	4:46:34
Sep	19	1.3	18.0	4.9	21.4	2.0	9.0	93.0	0:05:41
Oct	162	11.3	14.0	0.9	11.5	1.0	11.0	68.0	0:37:45
Nov									0:00:00
Dec	21	1.5	19.0	4.8	21.9	2.0	12.0	97.0	0:06:39

Table 2-19. Descriptive statistics for all aggressor behaviours, for each month. The No. is the number of times that behaviour was recorded for each month. The percentage refers to the percentage of all observations for that month. All other data are recorded as seconds the behaviour was observed.

	No	%	Mean	SE Mean	StDev	Min	Median	Max	Total Time
Jan									
Feb									
Mar	1	2.9	3.0			3.0	3.0	3.0	0:00:03
Apr									0:00:00
May	12	34.3	11.0	3.5	12.1	2.0	6.5	45.0	0:02:12
Jun									
Jul	6	17.1	10.0	4.8	11.9	4.0	5.0	34.0	0:01:00
Aug	12	34.3	12.3	6.6	22.7	2.0	6.0	84.0	0:02:28
Sep	1	2.9	5.0			5.0	5.0	5.0	0:00:05
Oct	3	8.6	6.3	0.3	0.6	6.0	6.0	7.0	0:00:19
Nov									
Dec									

Table 2-20. Descriptive statistics for all aggresse behaviours, for each month. The No. is the number of times that behaviour was recorded for each month. The percentage refers to the percentage of all observations for that month. All other data are recorded as seconds the behaviour was observed.

	No	%	Mean	SE Mean	StDev	Min	Median	Max	Total Time
Jan									
Feb									
Mar									
Apr									
May	9	50.0	6.0	2.0	5.9	1.0	2.0	17.0	0:00:54
Jun									
Jul	2	11.1	30.5	25.5	36.1	5.0	30.5	56.0	0:01:01
Aug	3	16.7	5.0	1.5	2.7	3.0	4.0	8.0	0:00:15
Sep	1	5.6	5.0	*	*	5.0	5.0	5.0	0:00:05
Oct	3	16.7	3.3	0.7	1.2	2.0	4.0	4.0	0:00:10
Nov									
Dec									

Table 2-21. Descriptive statistics for at burrow behaviours, for each month. The No. is the number of times that behaviour was recorded for each month. The percentage refers to the percentage of all observations for that month. All other data are recorded as seconds the behaviour was observed.

	No	%	Mean	SE Mean	StDev	Min	Median	Max	Total Time
Jan	89	6.6	2276.0	284.0	2680.0	2.0	1082.0	10994.0	56:15:24
Feb	116	8.6	2475.0	315.0	3397.0	5.0	749.0	14072.0	79:45:18
Mar	33	2.4	1072.0	266.0	1528.0	50.0	373.0	6066.0	9:49:38
Apr	113	8.4	836.0	134.0	1421.0	0.0	317.0	7895.0	26:14:05
May	178	12.8	265.3	44.0	579.1	0.0	65.0	5202.0	12:45:04
Jun	46	3.3	1495.0	746.0	5006.0	1.0	60.0	25552	18:41:09
Jul	168	12.3	407.4	89.6	1154.5	1.0	74.0	8472.0	18:47:15
Aug	391	29.0	395.2	59.0	1165.8	1.0	36.0	9988.0	42:55:21
Sep	22	1.6	999.0	569.0	2667.0	1.0	40.0	12205.0	6:06:10
Oct	157	11.6	680.0	104.0	1295.0	1.0	253.0	9764.0	29:27:42
Nov									
Dec	37	2.6	1453.0	273.0	1613.0	16.0	1033.0	6210.0	14:07:24

Table 2-22. Descriptive statistics for the avoidance behaviours, for each month. The No. is the number of times that behaviour was recorded for each month. The percentage refers to the percentage of all observations for that month. All other data are recorded as seconds the behaviour was observed.

	No	%	Mean	SE Mean	StDev	Min	Median	Max	Total Time
Jan	1	3.7	2.0	*	*	2.0	2.0	2.0	0:00:02
Feb	2	7.4	30.0	10.0	14.1	20.0	30.0	40.0	0:01:00
Mar	3	11.1	796.0	409.0	709.0	1.0	1024.0	1362.0	0:39:47
Apr	1	3.7	9.0	*	*	9.0	9.0	9.0	0:00:09
May	3	11.1	17.7	7.2	12.5	9.0	12.0	32.0	0:00:53
Jun									0:00:00
Jul	2	7.4	235.0	231.0	326.0	4.0	235.0	465.0	0:07:49
Aug	13	48.1	64.5	48.0	173.0	1.0	7.0	631.0	0:13:59
Sep									0:00:00
Oct	2	7.4	19.5	6.5	9.2	13.0	19.5	26.0	0:00:39
Nov									
Dec									

Table 2-23. Descriptive statistics for the basking behaviours, for each month. The No. is the number of times that behaviour was recorded for each month. The percentage refers to the percentage of all observations for that month. All other data are recorded as seconds the behaviour was observed.

	No	%	Mean	SE Mean	StDev	Min	Median	Max	Total Time
Jan	36	4.0268	1944	1395	8367	15	164	50400	19:26:38
Feb	31	3.4676	274	110	615	4	61	3348	2:21:27
Mar	10	1.1186	72.2	15.6	49.2	4	67.5	127	0:12:02
Apr	102	11.4094	1402	696	7025	1	40	50400	39:43:41
May	183	20.2461	171.9	34.3	461.2	0	38	4215	8:38:38
Jun	101	11.1857	330	98.1	981.2	1	45.5	7569	9:10:04
Jul	73	8.1655	226.6	70.5	602.2	0	25	3552	4:35:39
Aug	259	28.9709	542.2	96.9	1558.7	1	41	10565	39:00:25
Sep	15	1.6779	994	402	1555	4	236	5350	4:08:28
Oct	83	9.2841	368.8	94.5	861	1	81	4899	8:30:14
Nov									
Dec	1	0.1119	137			137	137	137	0:02:17

Table 2-24. Descriptive statistics for the breeding behaviours, for each month. The No. is the number of times that behaviour was recorded for each month. The percentage refers to the percentage of all observations for that month. All other data are recorded as seconds the behaviour was observed.

	No	%	Mean	SE Mean	StDev	Min	Median	Max	Total Time
Jan									
Feb									
Mar									
Apr	1	5.3	26.0			26.0	26.0	26.0	0:00:26
May	13	63.2	46.5	14.5	50.1	8.0	24.0	160.0	0:09:18
Jun									
Jul	1	5.3	14.0			14.0	14.0	14.0	0:00:14
Aug	4	21.1	123.5	74.1	148.1	37.0	56.5	344.0	0:08:14
Sep									
Oct									
Nov									
Dec									

Table 2-25. Descriptive statistics for the cleaning behaviours, for each month. The No. is the number of times that behaviour was recorded for each month. The percentage refers to the percentage of all observations for that month. All other data are recorded as seconds the behaviour was observed.

	No	%	Mean	SE Mean	StDev	Min	Median	Max	Total Time
Jan	5	2.8	111.2	34.3	76.6	37.0	100.0	200.0	0:09:16
Feb	9	5.1	113.2	19.8	59.5	27.0	98.0	189.0	0:16:59
Mar	7	4.0	205.6	50.5	133.5	86.0	151.0	477.0	0:23:59
Apr	26	14.8	79.5	20.6	104.9	9.0	63.0	549.0	0:34:28
May	16	9.1	72.4	22.9	91.8	14.0	35.0	392.0	0:19:18
Jun	7	4.0	18.9	3.8	10.1	5.0	23.0	29	0:02:12
Jul	31	17.6	63.8	10.7	59.8	2.0	44.0	209.0	0:32:59
Aug	59	33.5	99.2	11.5	88.3	5.0	84.0	448.0	1:37:35
Sep	2	1.1	659.0	347.0	491.0	312.0	659.0	1006.0	0:21:58
Oct	14	8.0	130.8	28.4	106.4	13.0	107.5	402.0	0:30:31
Nov									
Dec									

Table 2-26. Descriptive statistics for the foraging behaviours, for each month. The No. is the number of times that behaviour was recorded for each month. The percentage refers to the percentage of all observations for that month. All other data are recorded as seconds the behaviour was observed.

	No	%	Mean	SE Mean	StDev	Min	Median	Max	Total Time
Jan	37	7.9	262.4	47.6	289.2	6.0	122.0	941.0	2:41:48
Feb	26	5.6	376.0	105.0	538.0	11.0	96.0	1845.0	2:42:44
Mar	2	0.4	638.0	540.0	764.0	98.0	638.0	1178.0	0:21:16
Apr	53	11.3	298.3	76.9	559.5	3.0	50.0	2191.0	4:23:31
May	60	11.6	397.0	100.0	736.0	2.0	151.0	3859.0	5:57:44
Jun	45	9.6	852.0	251.0	1681.0	7.0	369.0	10214	10:39:05
Jul	78	16.7	447.5	70.7	624.0	6.0	169.5	2704.0	9:41:43
Aug	108	23.1	447.6	63.6	661.4	3.0	185.0	4489.0	13:25:41
Sep	13	2.8	465.0	256.0	922.0	13.0	97.0	3018.0	1:40:50
Oct	39	8.4	353.1	81.7	510.1	8.0	117.0	1838.0	3:49:32
Nov									
Dec	6	1.3	204.8	54.2	132.8	35.0	210.5	354.0	0:20:29

Table 2-27. Descriptive statistics for the in burrow behaviour, for each month. The No. is the number of times that behaviour was recorded for each month. The percentage refers to the percentage of all observations for that month. All other data are recorded as seconds the behaviour was observed.

	No	%	Mean	SE Mean	StDev	Min	Median	Max	Total Time
Jan	89	10.5	31027.0	2014.0	19005.0	23.0	34368.0	50400.0	767:03:04
Feb	63	7.5	16656.0	2184.0	17332.0	24.0	9890.0	50400.0	291:28:46
Mar	16	1.9	5050.0	1811.0	7246.0	64.0	711.0	20136.0	22:26:38
Apr	62	7.3	3885.0	847.0	6670.0	12.0	993.0	31773.0	66:54:24
May	77	8.9	5367.0	819.0	7090.0	1.0	2069.0	33713.0	111:48:56
Jun	41	4.6	7435.0	1273.0	7950.0	246.0	3506.0	36602	80:32:28
Jul	117	13.6	7700.0	911.0	9772.0	7.0	2971.0	36895.0	245:58:13
Aug	233	27.5	8753.0	715.0	10886.0	4.0	3340.0	38127.0	564:03:19
Sep	21	1.9	10022.0	3176.0	12705.0	53.0	4084.0	37129.0	44:32:31
Oct	79	9.2	10713.0	1522.0	13442.0	0.0	5472.0	50400.0	232:06:23
Nov	1	0.1	50400.0			50400.0	50400.0	50400.0	14:00:00
Dec	46	5.4	35840.0	2527.0	17139.0	186.0	50400.0	50400.0	457:56:57

Table 2-28. Descriptive statistics for the interacting behaviours, for each month. The No. is the number of times that behaviour was recorded for each month. The percentage refers to the percentage of all observations for that month. All other data are recorded as seconds the behaviour was observed.

	No	%	Mean	SE Mean	StDev	Min	Median	Max	Total Time
Jan									0:00:00
Feb	1	0.9	24.0	*	*	24.0	24.0	24.0	0:00:24
Mar	3	2.7	101.3	78.3	135.7	21.0	25.0	258.0	0:05:04
Apr	14	12.5	28.8	11.1	41.4	9.0	14.5	169.0	0:06:43
May	81	72.3	53.5	27.6	248.5	1.0	18.0	2251.0	1:12:12
Jun									0:00:00
Jul	8	6.3	33.6	15.7	41.5	7.0	15.0	122.0	0:03:55
Aug	5	4.5	21.6	2.4	5.3	14.0	21.0	28.0	0:01:48
Sep									
Oct									
Nov									
Dec									

Table 2-29. Descriptive statistics for the out of sight behaviours, for each month. The No. is the number of times that behaviour was recorded for each month. The percentage refers to the percentage of all observations for that month. All other data are recorded as seconds the behaviour was observed.

	No	%	Mean	SE Mean	StDev	Min	Median	Max	Total Time
Jan									
Feb	7	7.4	486.0	175.0	464.0	0.0	430.0	1046.0	0:56:42
Mar	2	1.1	1722.0			1722.0	1722.0	1722.0	0:28:42
Apr	11	10.6	826.0	275.0	869.0	0.0	489.0	2660.0	2:17:35
May	7	6.4	1031.0	432.0	1058.0	4.0	866.0	2313.0	1:43:04
Jun									
Jul	6	5.3	662.0	119.0	266.0	315.0	724.0	995.0	0:55:08
Aug	37	38.3	1749.0	374.0	2245.0	100.0	1271.0	13258.0	17:29:37
Sep									
Oct	24	23.4	1102.0	227.0	1066.0	25.0	947.0	4578.0	6:44:14
Nov									
Dec									

Table 2-30. Descriptive statistics for the safety behaviours, for each month. The No. is the number of times that behaviour was recorded for each month. The percentage refers to the percentage of all observations for that month. All other data are recorded as seconds the behaviour was observed.

	No	%	Mean	SE Mean	StDev	Min	Median	Max	Total Time
Jan									
Feb	2	22.2	2.0	1.0	1.4	1.0	2.0	3.0	0:00:04
Mar	1	11.1	1.0			1.0	1.0	1.0	0:00:01
Apr									
May									
Jun									
Jul									
Aug	3	33.3	2.7	0.9	1.5	1.0	3.0	4.0	0:00:08
Sep	1	11.1	1.0			1.0	1.0	1.0	0:00:01
Oct	1	11.1	1.0			1.0	1.0	1.0	0:00:01
Nov									
Dec	1	11.1	1.0			1.0	1.0	1.0	0:00:01

APPENDIX 2-3: DHUB IDENTITIES AND THE HOURS OF OBSERVATION

Table 2-31. Dhub Identities and the number of hours observation completed for each month in 2014 and 2015

	Sex	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15
AQ01	F						04:35:05								
S1A1	F	14:00:00	13:32:54	37:08:01	56:00:00	70:00:24	17:18:18	28:00:00	14:00:00	168:00:00	203:30:00	112:00:00	14:00:00	28:01:07	28:00:00
S1A2B	F														14:00:00
S1A3	F	09:42:39		20:31:45	53:36:34	70:00:00	10:33:24	28:00:00		84:00:00	221:30:00	84:00:30	06:06:14	28:00:00	
S1A4	F		05:16:06	14:00:00	66:19:11	84:34:00		14:00:00		98:00:00	203:30:00	84:00:00		28:00:00	27:56:52
S1A5	F						24:29:02								
S2A1	F		07:43:12	18:13:35	14:00:00	112:00:00		54:04:17							
S2A2	F		18:10:38	10:53:17	14:00:00	112:01:00		81:34:20							
S2A4	F		04:14:14		05:10:32	69:58:36		00:02:09		17:00:25					
S1A2	M	04:17:21	02:21:58	04:44:50	56:00:30	55:20:00		28:00:00		89:00:00	217:30:00	98:06:01	14:28:40	29:07:25	28:00:52
S2A3	M		03:26:50	14:37:33	16:55:21	109:51:24		48:06:44		16:33:22					
UnkMale	M											00:01:53			
Juv_Unk	U						03:15:06								
Juv_Unk02	U												03:30:03		
JuvB06	U						67:43:13								
S1A6	U						28:00:00	421:58:52							
S1B03B	U												09:29:13		
S2A3U01	U				00:51:46	28:00:00									
S2A5	U		09:15:06	14:00:00	00:31:39										
S2A7	U				14:00:00	112:01:58									
S2A8	U				14:00:00	112:00:00									
S3A1	U		06:45:56												
Unk	U		04:05:04	00:23:30	00:05:35	00:25:30	48:52:32	02:15:28			28:00:00				
UR	U		07:58:54		14:00:00									00:08:22	00:38:45
URC5	U		03:09:42												
Number of hours		28:00:00	86:00:34	134:32:31	325:31:08	936:12:52	204:46:40	706:01:50	14:00:00	472:33:47	874:00:00	378:08:24	47:34:10	113:16:54	98:36:29

*Where sex is M=Male, F=Female and U=Not recorded

Table 2-32. Percentage of time (4,419 hours) dhub were observed engaged in the different behaviours throughout the study period from 05:00 through to 19:59.

	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	Total Time
Active	0.00	0.00	0.01	0.23	0.05	0.02	0.02	0.01	0.03	0.03	0.04	0.08	0.02	0.04	0.00	0.59
Aggressor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agressee	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
At Burrow	0.17	0.83	0.38	0.45	0.61	0.96	0.58	0.34	1.11	1.02	1.03	0.83	0.40	0.09	0.00	8.80
Avoidance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.03
Basking	1.12	0.34	0.27	0.38	0.53	0.25	0.22	0.24	0.51	0.61	0.50	0.20	0.29	0.09	0.00	5.56
Breeding	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Cleaning	0.00	0.00	0.00	0.02	0.05	0.03	0.02	0.01	0.02	0.02	0.02	0.02	0.01	0.00	0.00	0.23
Foraging	0.00	0.00	0.00	0.05	0.16	0.08	0.04	0.04	0.15	0.18	0.40	0.48	0.07	0.00	0.00	1.65
In Burrow	55.04	0.30	0.43	2.01	3.98	3.37	1.66	0.64	0.82	2.03	3.00	4.70	3.50	0.43	0.03	81.95
Interacting	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
Out of Sight	0.00	0.00	0.00	0.07	0.19	0.05	0.03	0.03	0.05	0.10	0.39	0.19	0.03	0.00	0.00	1.14
Safety	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 2-33. Number of hours of observations for each of the behaviours. Total analysed 4,419:15:19

Mth	Total Time	Active	Aggressor	Agressee	At Burrow	Avoidance	Basking	Breeding	Cleaning	Foraging	In Burrow	Interacting	Safety
Jan	874:00:00	00:23:48			56:15:24	00:00:02	19:26:38		00:09:16	02:41:48	795:03:04		
Feb	378:08:24	00:35:00			79:45:18	00:01:00	02:21:27		00:16:59	02:42:44	291:28:46	00:00:24	00:00:04
Mar	47:34:10	00:20:00	00:00:54	00:00:12	11:36:16	00:39:47	01:00:43		00:23:59	00:53:15	30:16:53	00:05:04	00:00:01
Apr	141:16:54	00:54:25		00:00:01	26:15:22	00:00:09	39:43:41	00:00:26	00:34:28	04:23:31	66:54:45	00:06:43	
May	184:37:03	11:16:36	00:02:12	00:01:12	14:59:04	00:00:53	15:54:01	00:09:18	00:20:05	08:00:49	130:51:23	01:18:26	
Jun	134:32:31	01:10:31			18:50:52		09:49:29		00:08:13	11:21:50	93:11:36		
Jul	325:31:08	01:22:22	00:01:00	00:01:50	19:40:57	00:27:02	04:52:24	00:00:14	00:35:59	10:10:04	285:46:36	00:04:27	
Aug	936:12:52	06:03:19	00:03:08	00:01:21	66:00:09	00:14:06	49:20:12	00:08:14	03:18:14	16:18:49	764:33:58	00:02:07	00:00:08
Sep	204:46:40	00:48:50	00:00:15	00:00:28	24:14:15		13:30:38		01:24:02	03:55:56	160:31:11		00:00:10
Oct	706:01:50	03:11:09	00:00:21	00:00:10	60:39:45	00:00:45	92:02:06	00:00:18	02:57:59	12:46:04	525:21:26	00:02:33	00:00:24
Nov	14:00:00										14:00:00		
Dec	472:33:47	00:06:39			14:07:24		00:02:17			00:20:29	457:56:57		00:00:01

APPENDIX 2-4: MEAN TIME DHUB WERE OBSERVED COMPLETING A BEHAVIOUR FOR EACH MONTH

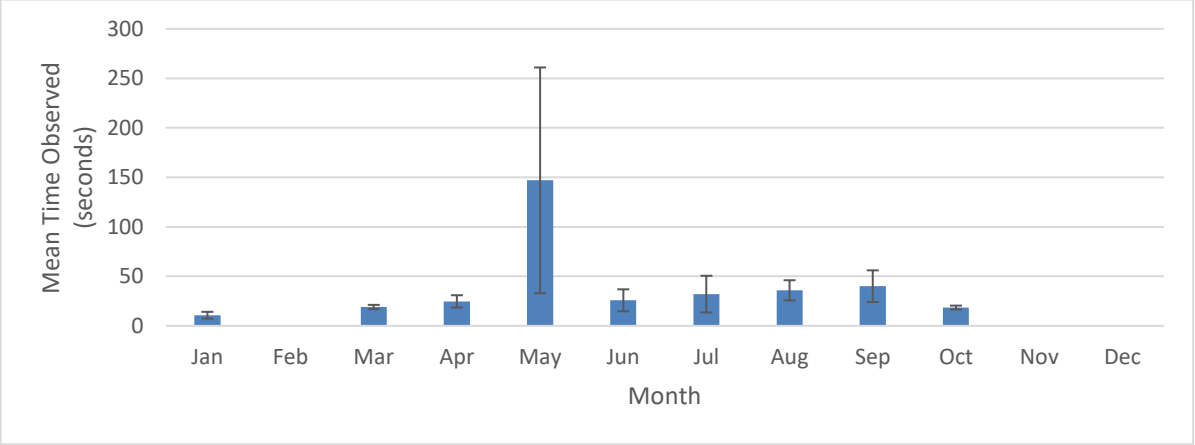


Figure 2-23. Mean time (±SE) in seconds dhub were observed active. (There were no data for February, November and December)

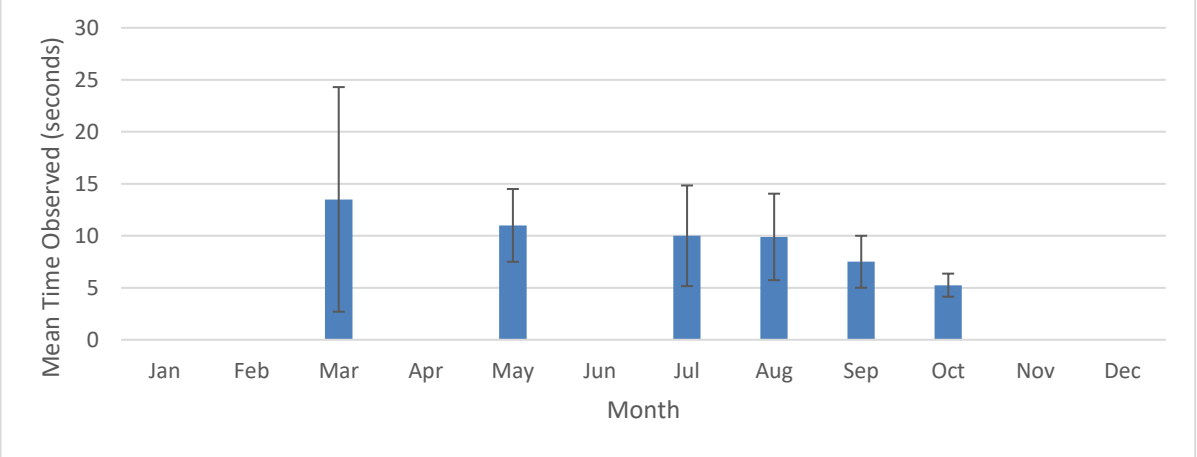


Figure 2-24. Mean time (±SE) in seconds dhub were observed moving towards another dhub in an aggressive manner. (There were no data for February, November and December)

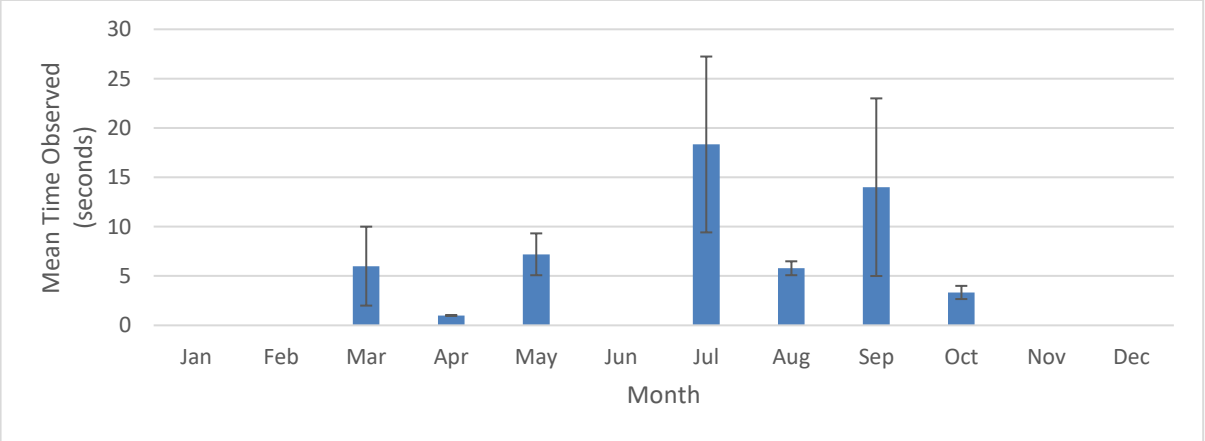


Figure 2-25. Mean time (±SE) in seconds dhub were observed moving away and seeking refuge from an aggressive dhub. (There were no data for February, November and December)

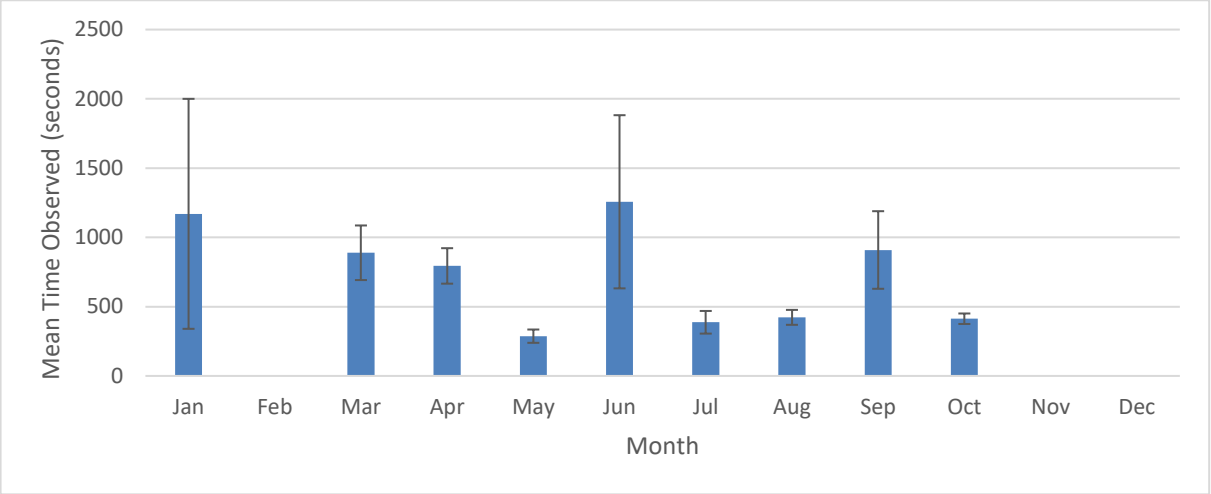


Figure 2-26. Mean time (±SE) in seconds dhub were observed at their burrows. (There were no data for February, November and December)

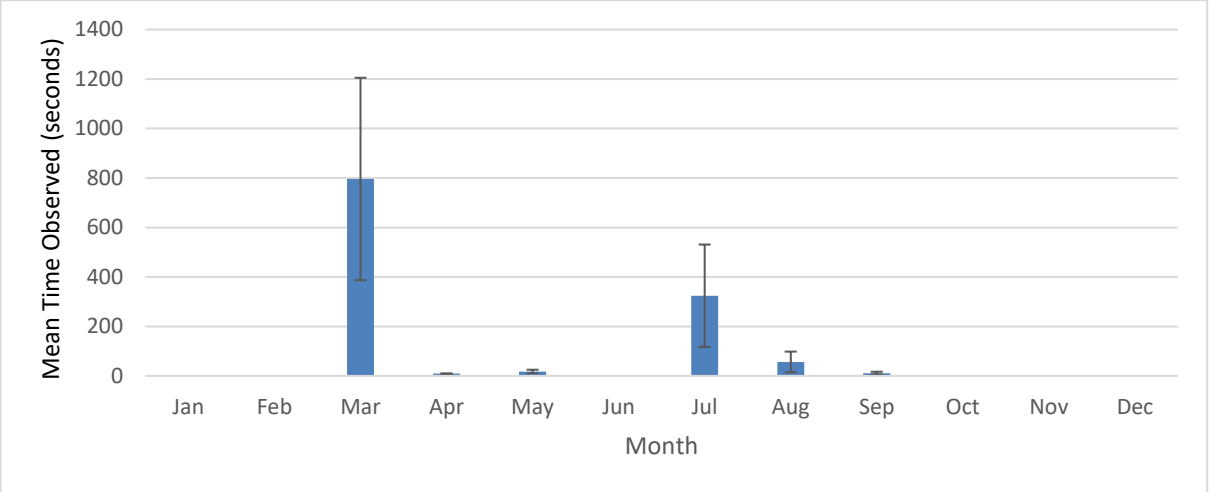


Figure 2-27. Mean time (±SE) in seconds a dhub actively avoided another dhub by moving away or directly returning to its burrow as a result. (There were no data for February, November and December)

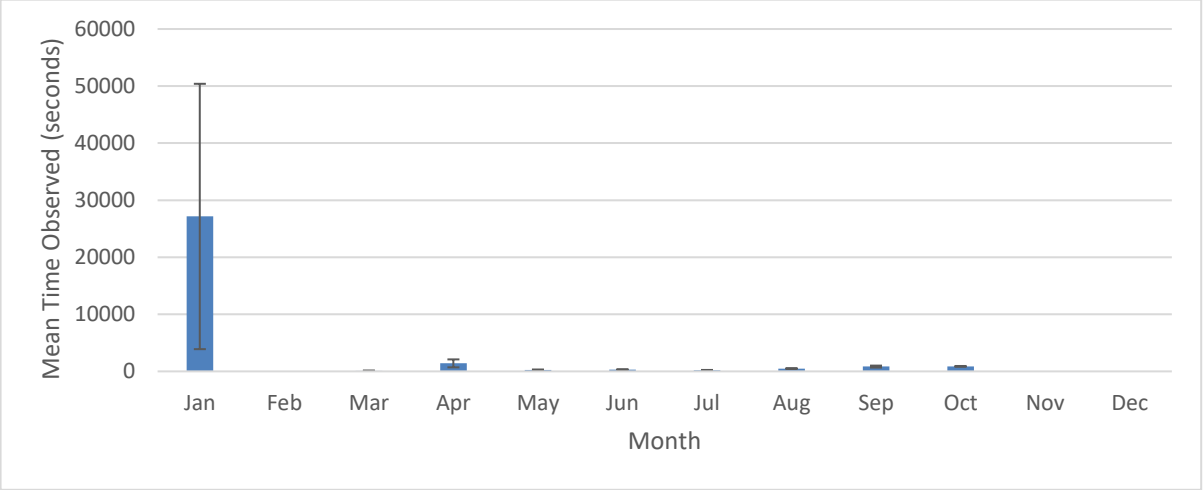


Figure 2-28. Mean time (±SE) in seconds dhub were observed basking in an area away from their burrow. (There were no data for February, November and December)

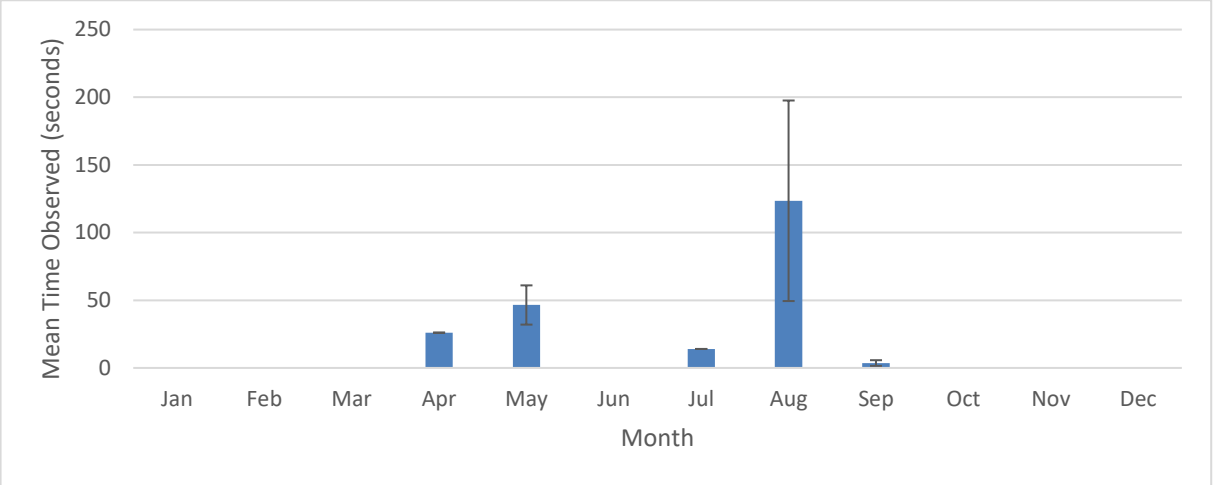


Figure 2-29. Mean time (±SE) in seconds dhub were observed completing breeding behaviours. (There were no data for February, November and December).

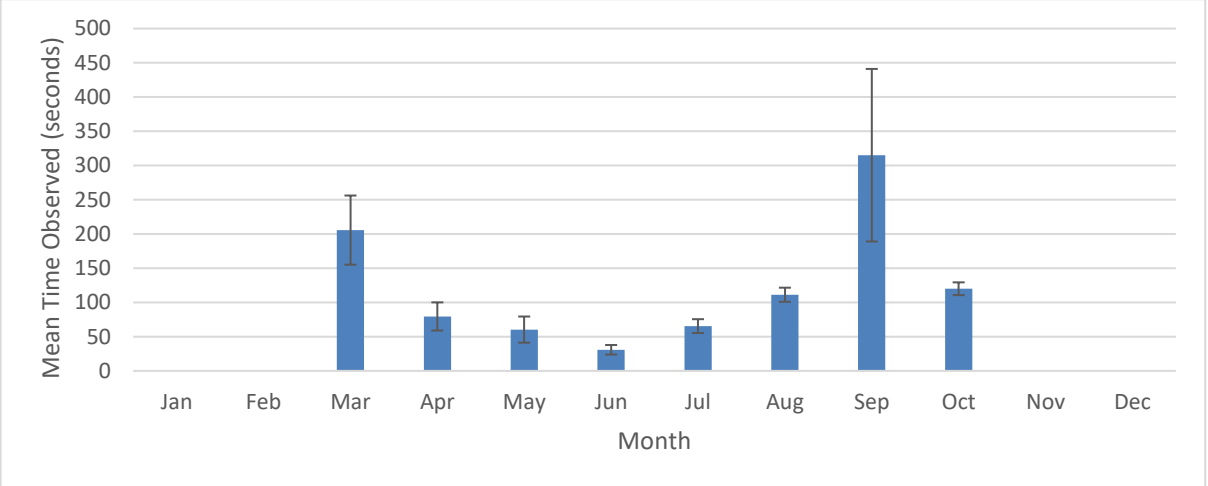


Figure 2-30. Mean time (±SE) in seconds dhub were observed engaged in cleaning behaviours in their burrows. (There were no data for February, November and December).

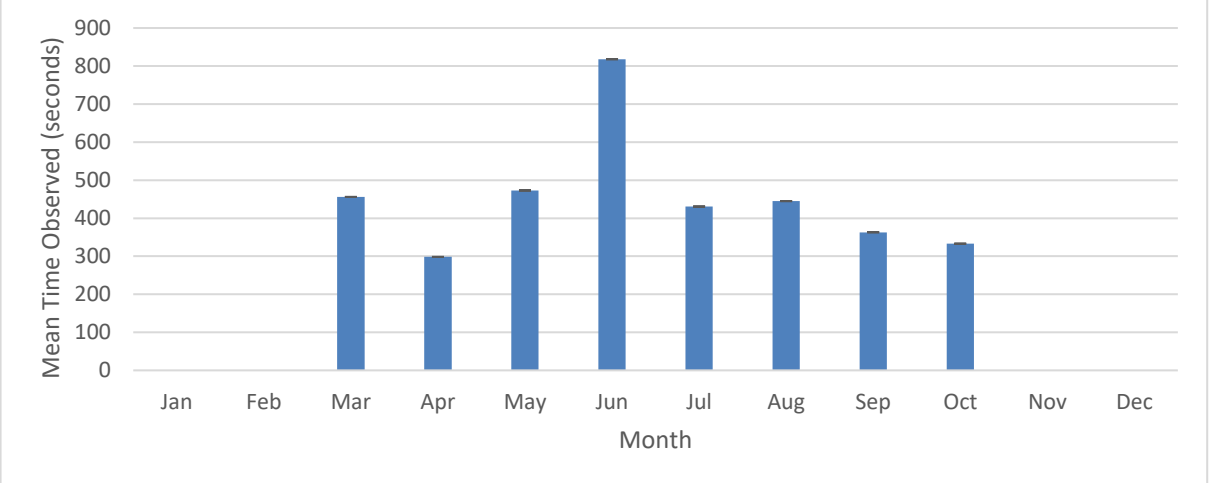


Figure 2-31. Mean time (±SE) in seconds dhub were observed engaged in foraging behaviours. (There were no data for February, November and December).

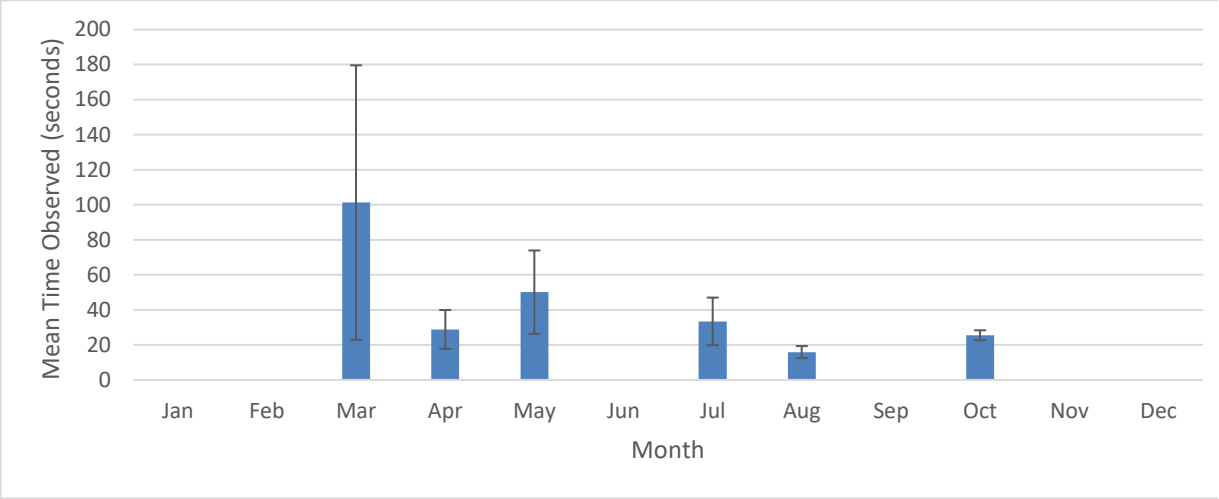


Figure 2-32. Mean time (±SE) in seconds dhub were observed engaged in behaviours where they interacted with other dhub. (There were no data for February, November and December).

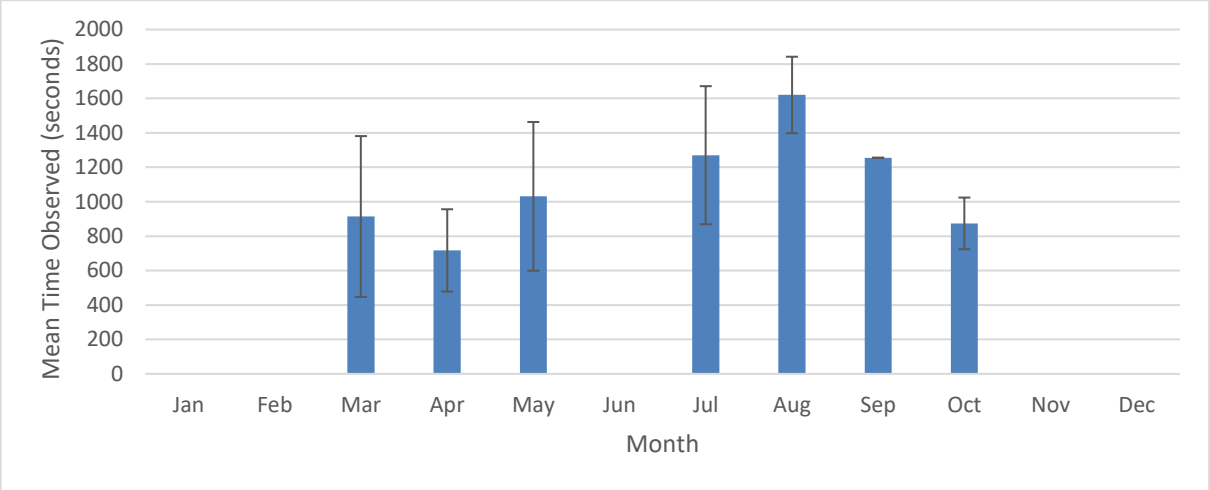


Figure 2-33. Mean time (±SE) in seconds dhub were observed going out of sight of the camera, but were not foraging. (There were no data for February, November and December).

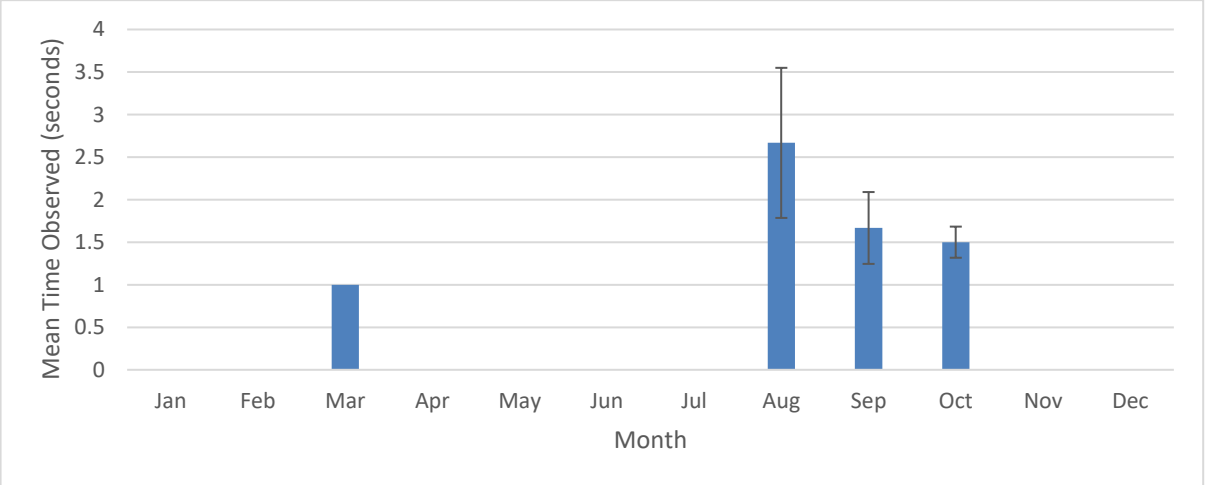


Figure 2-34. Mean time (±SE) in seconds dhub were observed escaping into their burrows to avoid a person or predator. (There were no data for February, November and December).

CHAPTER 3: TEMPERATURES AND BURROWS

3.1 INTRODUCTION

3.1.1 THERMOREGULATION

Reptiles move/react along a thermal gradient to control their body temperatures. The biological significance of this temperature regulation for ectothermic animals was first suggested by Cowles & Bogert (1944). They were again some of the first to suggest that reptiles have sophisticated behavioural mechanisms (thermotaxis) that allow them to precisely regulate their body temperatures within a fairly wide range of ambient conditions.

Kearney *et al* (2009) suggested that for most ''cold-blooded'' terrestrial animals, particularly in tropical and desert areas, where ectotherm biodiversity is greatest (Allen *et al*, 2007; Deutsch *et al*, 2008; Amarasekare & Simon, 2020), the primary thermal challenge is not to attain high body temperatures but to stay cool. As most terrestrial ectotherms are mobile, they can behaviourally exploit local heterogeneity (thermotaxis) to regulate body temperatures somewhat independently of local environmental temperatures by basking, shading, varying their position and height from the ground, etc. Many organisms have therefore adapted specific thermal preferences within their fundamental niche, for example, by shifting time (e.g., day/night) or place of activity (e.g., open habitat, shade, or burrows) (Huey & Kingsolver, 1989; Michelangeli *et al*, 2018) that allow the maintenance of physical function (Cox *et al*, 2018). Many ectotherms who can have a body temperature that is markedly different from air temperature use this behavioural thermoregulation to avoid heat death in the warmest times (Sunday *et al*, 2014; Muñoz & Losos, 2018). The difference between the air temperature that a species experiences and the maximum air temperature that the species can tolerate is called the "thermal-safety margin" (Sunday *et al*, 2014). Behavioural plasticity of habitat use and the energetic consequences of thermal retreats are therefore critical aspects of species' normal physiological processes as well as its vulnerability to climate warming and extreme events (Beaupre *et al*, 1993; Ferguson *et al*, 2003; Herczeg *et al*, 2006; Herczeg *et al*, 2008; Kearney *et al*, 2009; Barrows, 2011; Sunday *et al*, 2014).

Understanding how organisms (Figure 3-1) respond to temperature is a key step to predict, amongst other things, translocation potential or climate change, as any changes in the environment will obviously be compounded by responses to local change or a new location which would be filtered through complex non-linearities of environment–organism interactions (Paaijmans *et al*, 2013; Woods *et al*, 2015). The benefits of movement to suitable less severe environments, in an attempt to escape climate change, are particularly limited in the tropics, where fitness impacts will be most severe (Buckley *et al*, 2013) and where tropical ectotherms are reportedly the organisms most at risk from

climate warming (Zeh *et al*, 2012), through the reduction of "thermal safety margins". As such, understanding the thermal preferences of the species under consideration is very important (Rubalcaba *et al*, 2019). Angilletta & Werner (1998) posit that thermoregulatory behaviour allows animals to function over a range of body temperatures (T_b) that are conducive to the requisite physiological processes (e.g., locomotion, digestion). In fact, Wapstra *et al* (2004) indicate that basking in the spotted skink (*Niveoscincus ocellatus*) females can influence the sex of her young. While, Acierno *et al* (2008) found that there were significant differences in the plasma concentration of 25-hydroxyvitamin D_3 concentrations in corn snakes (*Elaphe guttata*) exposed to increased levels of UVB. Furthermore, numerous studies (Ferguson *et al*, 2003; Ferguson *et al*, 2005; Ferguson *et al*, 2010) propose that some reptiles might actively bask to increase low levels of Vitamin D.

While T_b is the body temperature of the animal, the operative temperatures (T_e) is the predicted equilibrium temperatures of non-regulating ectotherms i.e. body temperatures that non-regulating animals would achieve (Hertz *et al*, 1993) and models for these have been used for more than 40 years (Stevenson, 1985b; Wilms *et al*, 2011; Sinclair *et al*, 2016; Rubalcaba *et al*, 2019). T_e estimates an ectotherm's steady-state body temperature and is a more biophysically (the physical properties of biological processes) accurate index of microclimates experienced by ectotherms. T_e can be estimated either with physical models placed in the environment or by mathematical models. The benefit of T_e models lies in the fact that they take a multivariate problem, involving inputs of air temperature, ground temperature, solar radiation, and wind speed, and map them into a single thermal metric on a spatial scale appropriate for the animal. Many authors (Hertz *et al*, 1993; Dzialowski, 2005; Wilms *et al*, 2009; Wilms *et al*, 2011) have explained the methods of calculating the T_e of ectotherms and how these values can be utilised with body temperature (T_b) to establish the thermal safety margins of a species. The most reliable T_e models utilise copper casts that mimic the morphology and absorptivity of an animal (Dzialowski, 2005). Other authors (Hertz *et al*, 1993) use a cylindrical copper tube as an animal analogue. These usually have a temperature logger in the lumen of the pipe to record temperatures at a given frequency. Wilms *et al* (2011) have demonstrated that copper analogues produced reliable data for the estimation of the thermal environment for the lizard *Uromastyx aegyptia* by comparing temperatures recorded in the copper analogue to those of animals which had inter coelomic transponders fitted under the exact same conditions.



Figure 3-1. *Uromastyx aegyptia leptieni* basking on a rock. Note the behavioural thermotaxis of having the mouth open and the body slightly raised from the substrate to assist cooling. This animal has also changed from the slate grey to yellow/ochre colour since emerging from its burrow (pers. obs.) as another heat protection mechanism.

By comparing the physiological limits to operative body temperatures, Sunday *et al* (2014) determined that most ectotherms are incapable of surviving in open habitats through physiological thermal tolerance alone and thus must have access to thermal refugia to survive. They found that this requirement was greatest in the tropics, empirically corroborating the theoretical findings of Kearney *et al* (2009), who used generic thermal-tolerance limits and T_e to show that behavioural avoidance of high body temperatures is necessary in the tropics.

3.1.2 BURROWING REPTILES AND THEIR BIOLOGICAL AND BEHAVIOURAL NEEDS

The fundamental differences that exist between reptiles, (for example, their lower food requirements and lower activity levels), and mammals have probably led to an underestimate of their required biological and behavioural needs. In the captive situation, recognised abnormal repetitive behaviours (ARBs) or stereotypies are infrequently observed and sometimes difficult to identify in amphibians and reptiles (Rose *et al*, 2017; Benn *et al*, 2019), the main type seen is glass climbing in lizards, but the problems of apathy and lethargy are common (Warwick *et al*, 2013; Warwick *et al*, 2017). It has been suggested that amphibians and reptiles are far less familiar to humans than mammals and having species-specific thermal, hydrological, dietary and behavioural requirements most owners of captive individuals lack a basic understanding of their needs in captivity. Herpetofauna may also be feared or disliked in the general population and in many cases the two groups have been rarely the focus of living zoological collections (Hawkins & Willemsen, 2004) and have been shown to suffer an excessively

high mortality rate when kept as pets (Warwick *et al*, 2017). It has been suggested that to get a greater understanding of some of these requirements and to maximise the use of enrichment for reptiles an understanding of how the basic needs of reptiles, heat, light, food, water, substrate and furniture, can be manipulated to provide a more stimulating environment is required (Hawkins & Willemsen, 2004; Grant *et al*, 2017). We are fortunate that research in these areas is increasing, however, even less is known about many reptile and amphibian behaviours and requirements in the wild. As part of any dhub translocation, the capture and possible housing of *Uromastyx aegyptia* might be a requirement. It is imperative, therefore, that their basic dietary and refuge requirements is better understood.

Voorhies (1975) suggests that there are three ethological categories of burrowing reptiles:

1. Those that dig and inhabit a permanent burrow e.g. *Uromastyx* spp. (Figure 3-2).



Figure 3-2. Burrow of dhub showing the shape, position and space that the animal takes up within the burrow more than 2 metres into an active burrow.

2. Those that burrow through loose sand in search of food e.g. *Scincus mitranus* (Figure 3-3) and
3. Those that are permanent underground foragers such as the amphisbaenians.



Figure 3-3. Eastern sand fish (*Scincus mitranus*) on a rare occasion that it emerged from the sand at WAS site. Note the chiselled snout and elongated body to enable the animal move freely through the sand.

3.1.3 BURROW SHAPE AND SIZE

Many semi fossorial reptile species have varying sized and shaped burrows. The deepest recorded was that of the yellow spotted monitor (*Varanus panoptes*) which ranged from 0.95 to 3.6 m in depth (Doody *et al*, 2015). The reasons why animals utilise burrows are multi-faceted, but they primarily provide safety from predation, as well as a stable thermic and hydric environment for the resident. While there is not a lot known about the internal shape, size and thermal characteristics of dhub burrows it is a very important facet in any translocation project involving *Uromastyx aegyptia* (see Chapter 6 Translocation). While most *Uromastyx* species have being described as utilising burrows e.g. *Uromastyx acanthinura* (Kechnebbou *et al*, 2019), detailed reports on burrow characteristics have been minimal (e.g. *Uromastyx hardwickii* (Ramesh & Sankaran, 2013; Ali *et al*, 2020)), with a number of authors describing the size, structure, length and depth of dhub burrows (Bouskila, 1983; Cunningham, 2001a; Wilms *et al*, 2009; Wilms *et al*, 2010) but not many have focused on the interactions between dhub and their burrows.

3.1.4 BURROW ORIENTATION

For *Uromastyx aegyptia*, Bouskila (1983) showed that there was no significant direction with regards to the orientation of the burrows that he studied, while Cunningham (2001b) described a primarily southerly orientation and Wilms *et al* (2009) showed a similar south east to south west orientation. While there were different results with regard to the orientation of dhub burrows, the datasets used in these observations were small. One of the objectives of the current study was thus to look at a larger number over a much wider area than previous studies. With regard to other reptile species, McCoy *et al* (1993) suggested that gopher tortoise (*Gopherus polyphemus*) and Maia-Carneiro & Rocha (2013) Lutz's tree iguana (*Liolaemus lutzae*) do not orient their burrows in a particular direction, rather, more in line with topographic features. Souter *et al* (2004) found the use of supplemental burrows (similar to adding nest boxes for hole nesting birds) was beneficial for blue tongued lizards (*Tiliqua adelaidensis*).

3.1.5 SPECIES OTHER THAN DHUB ASSOCIATED WITH DHUB BURROWS

Some authors comment on the importance of mammalian and avian burrows to other vertebrate associates in different ecotypes (Williams *et al*, 1999; Connior *et al*, 2008; Grillet *et al*, 2010; Corkery *et al*, 2014; Corkery *et al*, 2015). *Uromastyx aegyptia leptieni* is one of the many semi fossorial squamate species which provides important refugia for other reptile species as well as many avian species (Williams *et al*, 1999). Dhub burrows are not only a thermal refugia for themselves, but they also act as protection from predators as well as being a source of refuge for other species (Figure 3-45 and Figure 3-46) including a refuge for potential predators such as *Varanus griseus*. However, some

associated species can be adversely affected by factors which affect the primary occupant, as in the case of the ocellated lizard (*Timon lepidus*) and the European rabbit (*Oryctolagus cuniculus*), where a reduced rabbit population is reducing refugia available to the ocellated lizard (Grillet *et al*, 2010). The benefit of shared burrows, in the form of kleptothermy, has been described by Corkery *et al* (2014).

3.1.6 OBJECTIVES OF THE CURRENT STUDY:

Little is known about the burrow and thermal characteristics of natural populations of *U. a. leptieni*, which are fundamental prerequisites to allow successful translocations. Thus, the objectives of this part of the research were:

- To identify the most accurate way to determine the maximum effective temperature (T_e) for the dhub in current locations.
- To determine the preferred orientation, shape and size of the burrow.
- To determine burrow philopatry.
- Following on from the above, and utilising the information obtained, the current study then looked briefly at the creation of supplemental burrows, as a potential conservation measure, thereby potentially increasing the availability of suitable burrows for the study species.

3.2 MATERIALS AND METHODS

3.2.1 SITE SURVEY

Trial site surveys were conducted initially in late 2013 and 2014. In 2014, 10 Km^2 of Site 1 and 1 Km^2 of Site 2 have been extensively surveyed. 50 m transects were driven using a Polaris Ranger (Polaris, US) and burrow locations were recorded using a Garmin 62 SC handheld GPS (Figure 3-4). The orientation, location, burrow height and width, signs of activity and vegetation status around the burrow were also recorded on a Samsung Galaxy Note 8 (Samsung Electronics, Korea) and a Memento Database (Luckydroid, http://mementodatabase.com/) self-designed for the data capture (Figure 3-5) .



Figure 3-4. Polaris was pulled to each site (A) on the back of a trailer and loaded with whatever equipment was required for the survey. At times the sand was so soft the Polaris got stuck (B).

Following the early sample surveys and from 2014 through to the end of 2016 ten different sites were surveyed at different times of the year. This resulted in a total survey area of approximately 10,700 Ha and a total of 4,869 burrows surveyed with 1,611 distinct burrows identified.

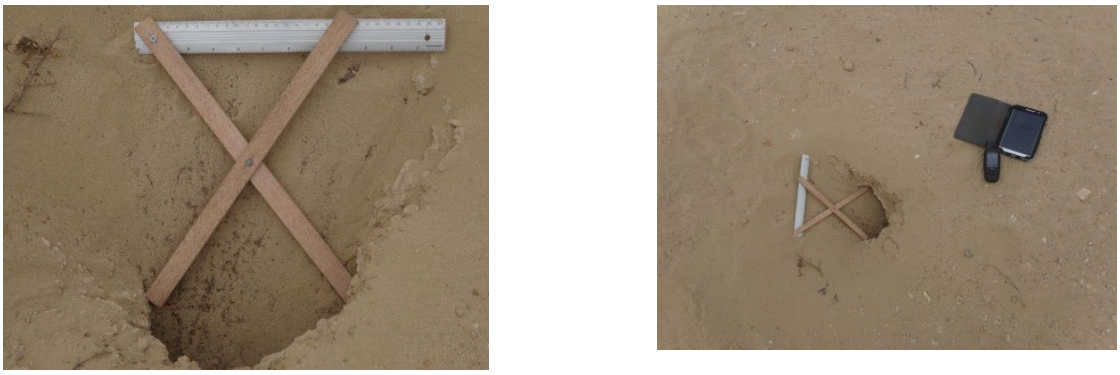


Figure 3-5. Site survey equipment showing a home-made callipers to accurately measure the burrow width and height as well as the Garmin gps and data collection tablet.

The initial GPS positions of the tagging sites, burrows, feeding tracks and other important landmarks like the transect dimensions were documented with a handheld GPS receiver (Garmin GPSMAP®62; http://www.garmin.com). In March 2016 a Trimble Geo 7X GNSS (Trimble US, https://geospatial.trimble.com) handheld unit with Dubai Municipality VRS correction enabled was

used to re-record all GPS positions giving a positional accuracy of ± 10 cm. From March 2016, the Geo 7 GPS was used to record all GPS positions and as it had the ability to create bespoke data collection forms, it was used for all subsequent survey work.

3.2.2 Maximum effective temperatures (*Te*) for dhub

To determine the maximum effective temperature (T_e) for dhub, temperature data were collected by selecting three random burrows located in Mugatrah (as per Figure 3-6) at the end of December 2013 and deploying loggers beside them. Mugatrah was chosen as it had a Davis Weather Station located on the property to use for comparisons. All surveyed burrows were assigned a sequential number, three random numbers within this range were then selected as the location where the temperature loggers would be placed.

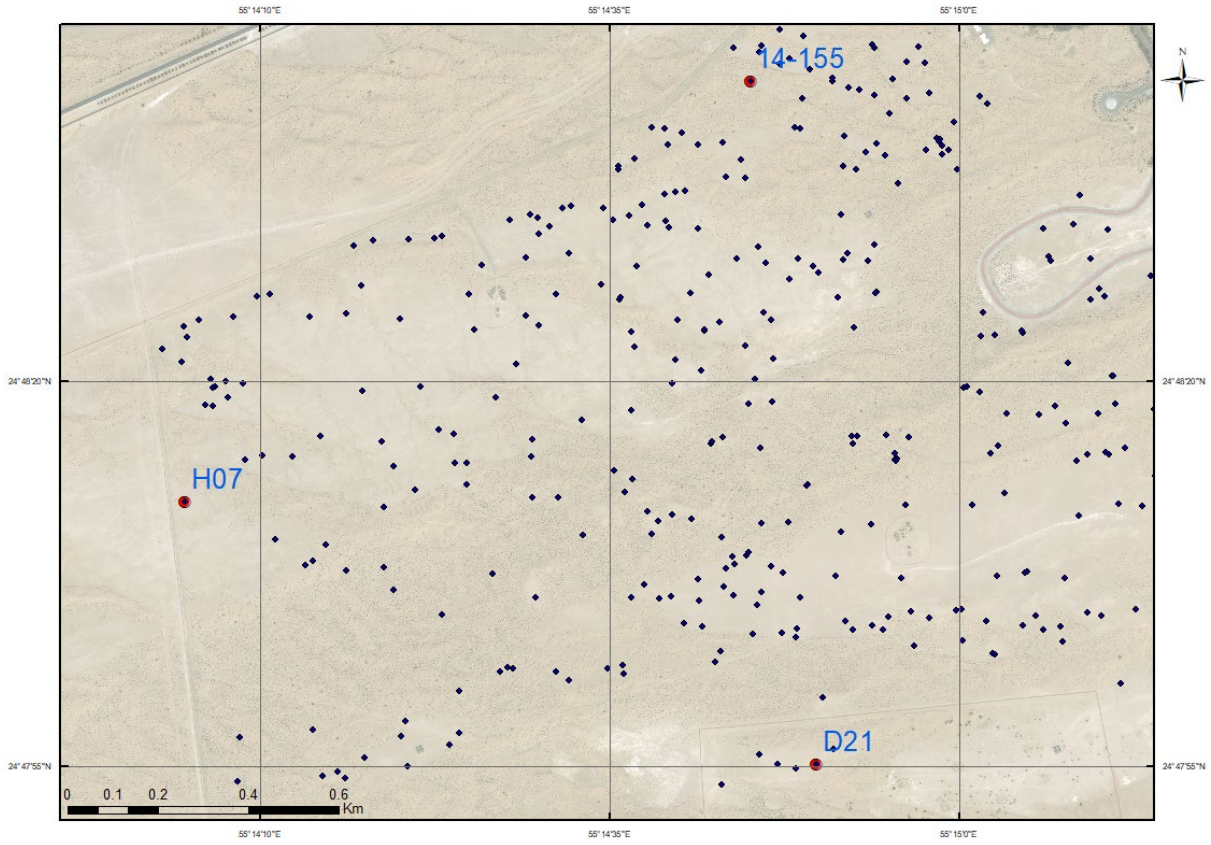


Figure 3-6. Location of the three burrows (14-155, H07 and D21) with the temperature recorders. Purple dots are the other burrows recorded throughout the survey period.

iButton data recorders (Embedded Data Systems, Lawrenceburg, KY., US) for temperature (Thermochron DS1922 (company declared accuracy of ± 0.0625 °C)) were used in copper pipe analogues (Figure 3-7) and Thermochron DS1923 temperature/humidity recorder (company declared accuracy of ± 0.0625°C / ±0.6 %RH), were suspended 10 cm above the ground (Figure 3-8). This was to extrapolate the "operative temperature" (T_e). The iButtons were set to record every 20 minutes with rollover (if the data were not retrieved, the logger would continue recording) from December 2013

through to March 2018. Data were retrieved from the loggers at two-month intervals.

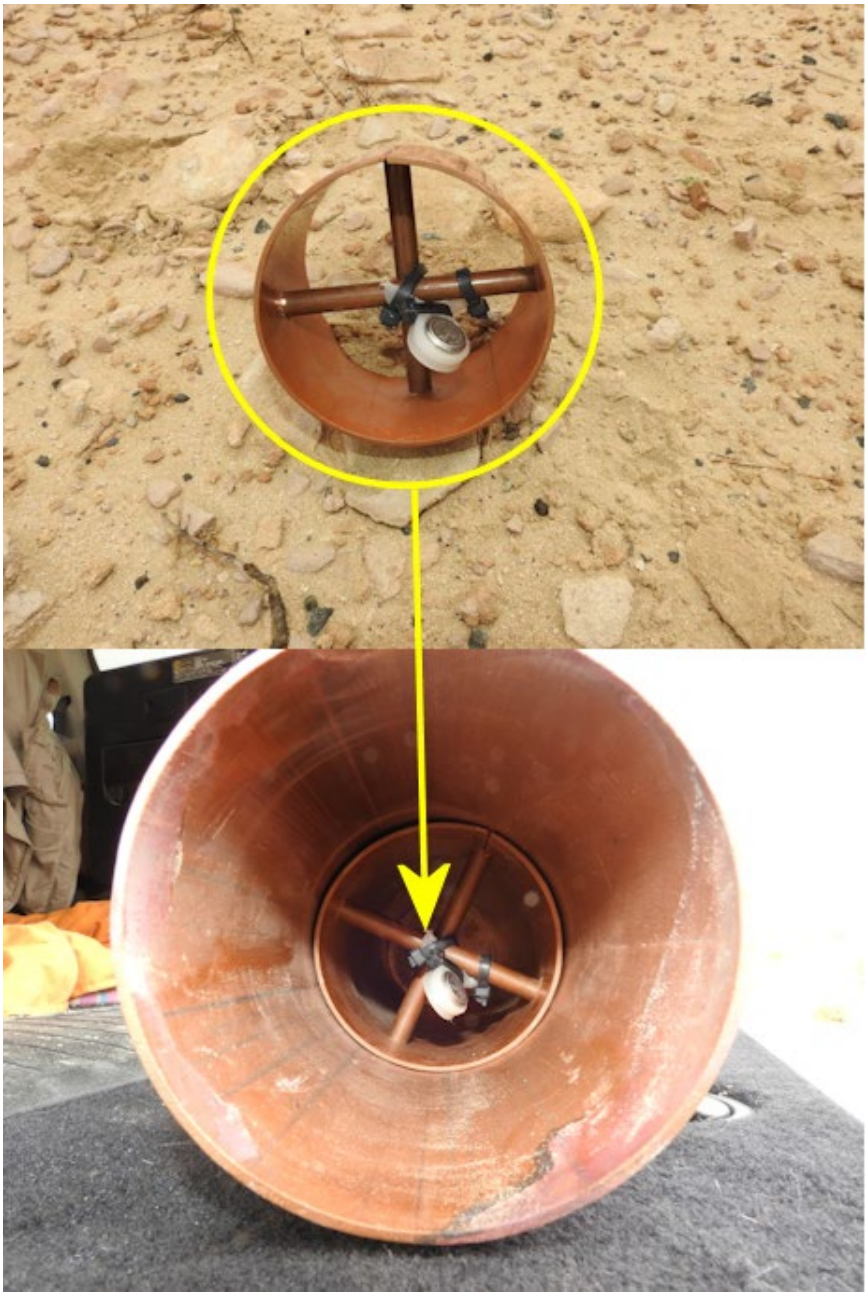


Figure 3-7. 500 mm long x 100 mm wide x 0.6mm thick wall, copper animal lumen analogue with insert holding iButton DS1922.

Further environmental data were collected using a Vantage Pro2 weather station (Davis Instruments, US) with the recording interval set to 30 minutes (Table 3-1). These data were used to compare normal air temperatures (Davis) to specific microclimatic regions (iButtons). Similar to the iButtons, weather station data were collected from December 2013 through to March 2018.



Figure 3-8. Suspended iButton and second copper pipe

Table 3-1. Davis Instruments declared accuracy for the Vantage Pro2 weather station.

Data Collected	Company accuracy
Temperature (°C)	± 0.3 °C
Humidity (%)	± 2%
Solar Radiation (W/m^2)	± 5% of full scale (0 to 1800 W/m^2)
*Ultra Violet Index	± 5% of full scale
Wind Direction (1 – 360°)	± 3°
Wind Speed (Km/h)	± 3.2 Km/h
Rainfall (0.2 mm)	For rain rates up to 100 mm/hr ±4% of total

**UV Index has been defined by Canadian scientists in 1992 and subsequently adopted by the World Health Organisation which measures the UV levels at the surface of the Earth. This gives a more easily remembered set of units, ranging from 1 to 15 and the potential of skin damage from the sun.*

Solar radiation was also measured with Solarmeter 6.5 UV Index Meter (company declared accuracy of ±10%) and Solarmeter 6.2 Sensitive UVB Meter (µW/cm² UVB with company declared accuracy of ±10%) Solar Light Company Inc, US. These data were collected every hour from 05:30 through to 19:30 daily from September 2015 through to November 2016 with extra data collected in February and March 2017. As these were handheld units, two assistants were renumerated for the data collection and funding did not allow for the continual data collection.

3.2.3 Temperatures at different heights above the ground

To examine the potential effect of dhub position in relation to the ground, in early 2018 a second pipe analogue was added to determine whether there would be any difference between the temperatures

within the pipe when it is on the ground (PG) and when it is raised (PR) 10 cm off the ground, which was considered the maximum height dhub would be capable of raising themselves from the ground to cool (Figure 3-9).



Figure 3-9. Final temperature monitoring setup. A is external thermo/hygrometer iButton; B is the lumen analogue on the ground; c is the raised lumen analogue.

3.2.4 Methods of Capture to attach data loggers

Three methods of capture to attach data loggers to measure operative body and skin temperatures as well as sampling for blood parameters were employed during the study. Originally, animals were caught using an old bedou method, which entailed placing a noose made of heavy-duty fishing line at the front of the burrow. This was unsuitable as the animals were not caught very often (catch per unit effort was very low) and it was felt that there may be an impact on the welfare of the animals. The second and most used method was to place a net over the mouth of the burrow. Generally, the animal was able to get out of the burrow and was caught on the way back into the burrow. The third method was opportunistically with a net. It was found that when one could get in front, i.e. between the animal and its burrow, it usually froze. It was then possible to use a hand net to capture it.

A trap set log was kept (APPENDIX 3-1) each time traps were set at burrows. So as not to disturb animals on the day that trapping was to be done, the nets were set late in the evening of the day before, when animals would have retreated into their burrows. The net was rolled up and placed under a stone to avoid accidental capture of any species during the night. Early in the morning, circa 06.00 to 07.00 the burrows to be trapped were visited again and the nets positioned properly. All

traps were visible from a distance with binoculars. Each burrow would be checked from a distance at least twice during the morning and afternoon periods. During the summer months, to avoid accidental capture during the hottest part of the day (circa 11.00) the traps were rolled up again and placed under the stone. They were setup again from circa 15.00 before being rolled up and placed safely after 18.00. During the cooler winter/spring the traps would be left in place during the day but checked regularly. Traps were rolled up and put away safely each night to avoid accidental capture of species at night. When an animal was caught from a burrow, the trap was removed and placed at a new location. Due to the possibility of an animal being in the net for an hour or so, internal body temperatures (T_b) were not recorded as the ability of an animal to properly thermoregulate was removed. It was believed this would influence the T_b results.

3.2.5 OPERATIVE BODY AND SKIN TEMPERATURES

The current study used copper analogues similar to the ones used in the study by Wilms *et al* (2011). During the initial restraint of survey animals, internal body temperatures (T_b) were also taken. However, these data were not used as an estimate of T_b since it was believed that they would not be representative of true T_b of a free ranging animal due to the capture method. While the actual T_b of dhub were not determined as had been done with *Varanus* sp. previously (Christian & Weavers, 1996), skin temperature (T_{sk}) was investigated as a possible accurate measure of T_b. As there were a number of iButtons lost during the initial setup phase of the T_{sk} study, a bespoke saddle (Figure 3-10) was used instead to hold both the iButton and radio transmitter securely on the animal.

Calculated set-points (T_{set}), determined to be the optimum T_b which this species sought to achieve, for *Uromastyx aegyptia microlepis*, (taken from the literature) from Saudi Arabia were established to be 38 °C (Zari, 1991) and 36.1 °C (Al-Johany, 2003). These points were used as a comparison throughout the current study.

3.2.6 TEMPERATURE DATA FROM ANIMAL TRACKING AND MONITORING PHASE OF THE STUDY

During the animal tracking and monitoring phase of the study, temperature data were collected from 20 different animals (Table 3-2). This was collected with an iButton Data Logger attached to the bespoke saddle made for the animals (Figure 3-10). Although all of the 169 animals caught and individually identified were available to study, only 20 animals were fitted with VHF trackers which allowed the animals to be recaught and data downloaded. As there were limited number of VHF transmitters not all data overlapped the same months and years.

Table 3-2. List of animals tracked with sex, catch burrow, date first caught, weight and length.

Animal ID	Sex	Burrow	Catch Date	Weight (gr)	Length (mm)
AQ01†	Female	NR*	30/08/2014	630	475
WAS 001	Male	447	04/10/2014	990	530
WAS002	Female	14-450	06/10/2014	830	490
WAS003	Female	14-S3B1	12/10/2014	970	530
WAS004	Male	14-449	19/10/2014	820	458
S2B07†	Female	S2B07	03/03/2015	850	530
MUG001	Male	14-198	08/03/2015	1370	591
WAS 006	Female	Dhub257	08/03/2015	780	504
MUG 004†	Male	S1B02	11/03/2015	1830	636
MUG 005†	Male	14-120	11/03/2015	1700	600
MUG 021	Male	14-197	31/05/2015	1709	640
WAS 027	Male	Dhub043	25/06/2015	1581	578
WAS 056	Male	LC18	13/10/2015	1602	620
WAS 058	Male	14-523-G	13/10/2015	1766	631
WAS 059	Male	14-519-R	13/10/2015	1965	649
WAS 060	Female	14-521-G	13/10/2015	817	498
WAS 061	Female	Hassan01	13/10/2015	833	497
WAS 063	Male	Hassan04	13/10/2015	679	480
WAS 064	Male	LC20	13/10/2015	1422	616
WAS 065	Male	14-502-R	14/10/2015	1477	596

**NR=Not recorded. She was a translocated animal. †Individuals selected for detailed analysis.*

Not all of these dhubs data were used in the analysis as some were being tracked as part of the translocation phase of the study (see Chapter 6). As such, due to the nature of the translocation the data were considered to be unreliable and were excluded from the final analysis (Table 3-3).

Table 3-3. The translocated animals whose data was considered unreliable and were excluded from this part of the study.

Animal ID	Sex	Burrow	Catch Date	Weight (gr)	Length (mm)
WAS002	Female	14-450	06/10/2014	830	490
WAS004	Male	14-449	19/10/2014	820	458
WAS 061	Female	Hassan01	13/10/2015	833	497
WAS 063	Male	Hassan04	13/10/2015	679	480
WAS 064	Male	LC20	13/10/2015	1422	616
WAS 065	Male	14-502-R	14/10/2015	1477	596

While the remaining individuals data were used for general analysis, due to loss of iButtons, inability to retrieve data for long periods of time and other unforeseen circumstances, only four individuals (S2B07, AQ01, S1B02 and MUG005 highlighted above†) were selected for more detailed analysis. These individuals were chosen as they had almost a complete years worth of data each.

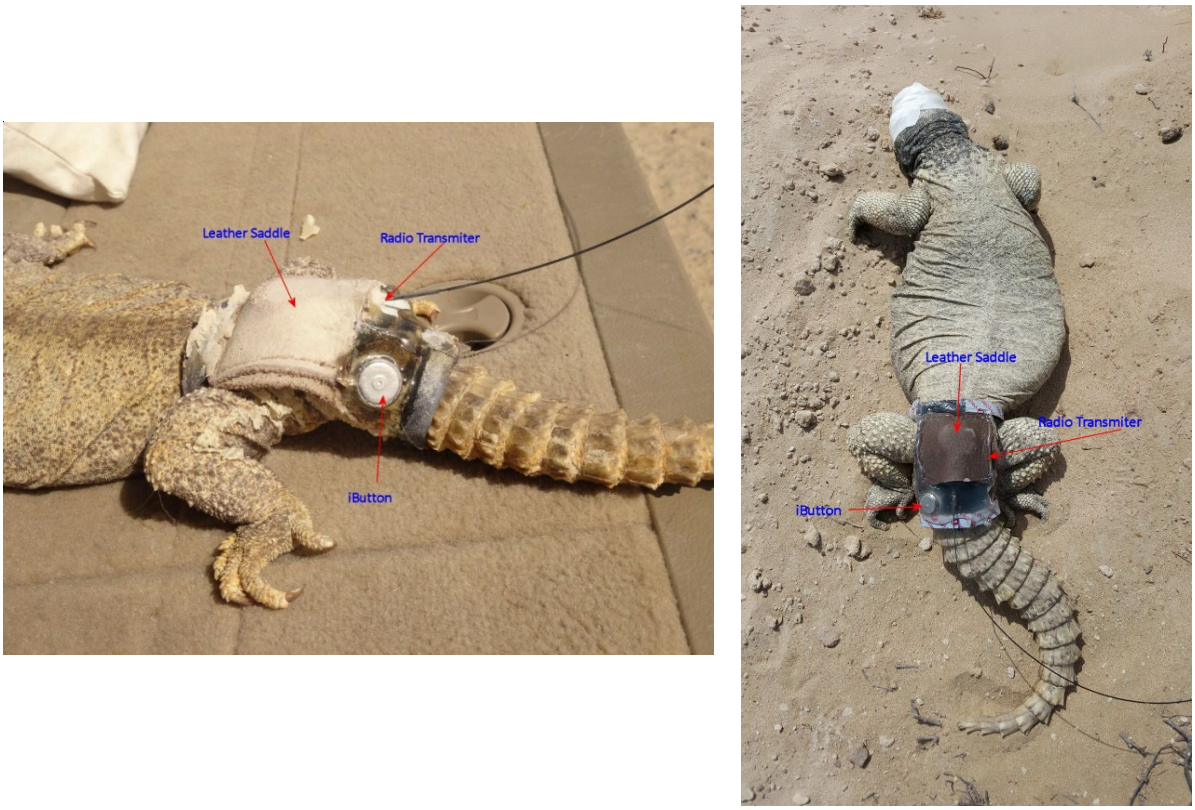


Figure 3-10. iButton and transmitter equipment as it was placed onto the study animals.

3.2.7 BURROW FIDELITY

Burrow fidelity was estimated through video capture (see Chapter 2 for details with regards to video recording), but also using Radio Frequency Identification Device detection equipment (RFID Traps) which recorded the individual RFID tag which had been implanted in each of the 20 animals during the capture phase of the study. (Permission from Minister of Finance, UAE)

The bespoke RFID traps were designed based on the RFIDRW-E-232 RFID reader module, (Priority 1 Design, Melbourne, Australia), see Figure 3-11. These allowed animals entering the monitored burrow to be identified via the RFID implanted at the time of capture (Figure 3-12 and Figure 3-13). When caught accidentally during the trapping phase, other reptile species, such as *Varanus varanus*, were opportunistically identified with an RFID (Figure 3-12).

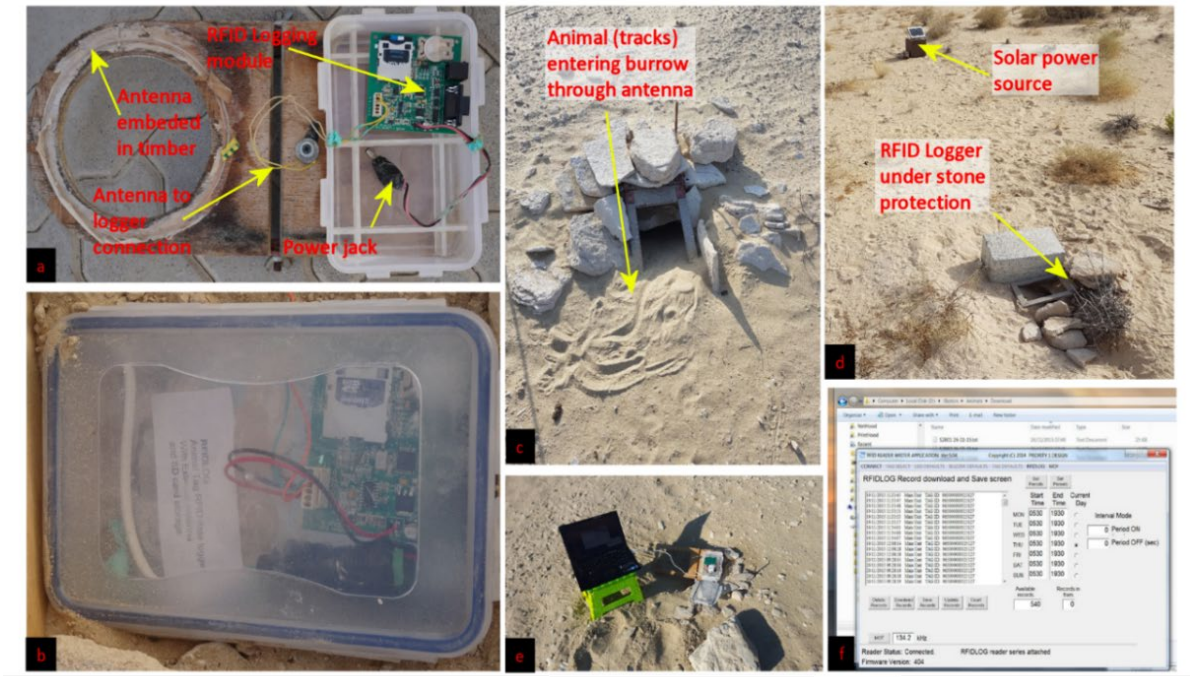


Figure 3-11. RFID logging equipment. a. RFID reader placed inside waterproof box. b. Unit is covered and sealed on top to avoid any moisture. c. Tracks leading through antenna. d. Unit in place with power source in the background. e. Logger connected for download. f. Download and configuration screen for RFID logger.

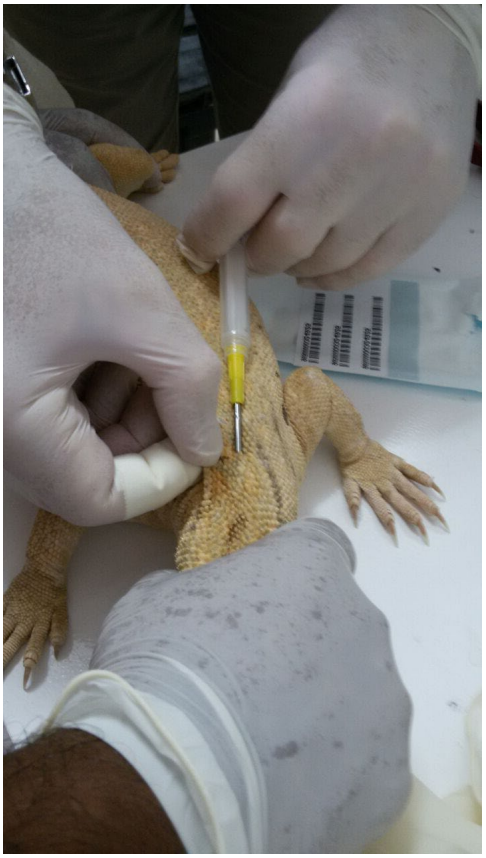


Figure 3-12. RFID being implanted in the nuchal area of a desert monitor lizard (*Varanus griseus*) captured lizard



Figure 3-13. Corresponding identifying number of implanted desert monitor lizard

The data with the identification, weight, location etc of each animal captured were stored in a bespoke MS Access database with specific queries developed to manipulate the data.

3.2.8 BURROW ORIENTATION, SHAPE AND SIZE

Burrow orientations were divided into eight general 'directions' as shown on the Trimble Geo 7 GPS: NE (= 22.5-67.5°), E (= 67.5-112.5°), SE (= 112.5-157.5°), S (= 157.5- 202.5°), SW (= 202.5-247.5°), W (= 247.5-292.5°), NW (= 292.5-337.5°), and N (= 337.5-22.5°). (See Figure 3-54 in APPENDIX 3-4).

Along with the orientation, the width and height of the burrow was recorded, together with the substrate and topography on which it was located, whether there was any faecal material present, any fresh tracks from the burrow, whether the animal was seen and the status of the burrow (active, inactive or abandoned). With regards the burrow status, active was when there were obvious signs of the animal being present, inactive was when the burrow shape was obvious but was filled with sand and abandoned was when the burrow opening was visible but there were no obvious attempts at maintaining the burrow by an animal.

3.2.9 SPECIES, OTHER THAN DHUBS, ASSOCIATED WITH DHUB BURROWS.

Other species associated with the burrows in the period December 2013-March 2018, were recorded and identified to the lowest possible taxonomic level.

3.2.10 DETERMINATION OF SEASON

Although there is no data to suggest definitive seasons within the UAE, the current study took seasons to be as per Table 3-4 based on dhub activity patterns.

Table 3-4**.** Seasonal breakdown used throughout the study.

Survey Period	Dates
Spring	1st Feb to 30th Apr
Summer	1st May to 31st Jul
Autumn	1st Aug to 31st Oct
Winter	1st Nov to 31st Jan

Determination of Distance Travelled

The distance that an animal travelled for the feeding tracks was obtained by following the tracks leading from a burrow in the direction that the animal travelled and with the Garmin GPS creating a route of the same track. These were individually identified to allow for accurate positioning. The internal GPX file was downloaded as a CSV file and opened in MS Excel. Taking that the Excel sheet will be setup something similar to the example below (Figure 3-14)

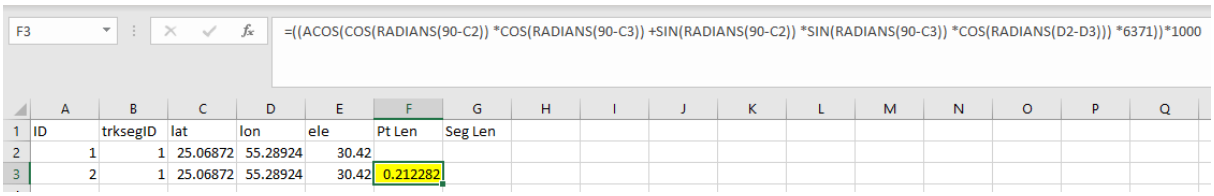


Figure 3-14. Excel table example to demonstrate the formula for distance travelled. Highlighted cell is the distance in metres travelled.

Two more columns called Point Lengths (Pt Len) and Segment Lengths (Seg Len) were created. In the second cell below the first point coordinates the formula below was entered:

=((ACOS(COS(RADIANS(90-C2)) *COS(RADIANS(90-C3)) +SIN(RADIANS(90-C2)) *SIN(RADIANS(90-C3)) *COS(RADIANS(D2-D3))) *6371))*1000

This gave the length between the two coordinates in metres. The cell reference was adjusted as necessary. The formula was copied and pasted down the full length of the recorded points. At the first point of each segment the value was deleted in the Point Length cell (it is a new segment and will not have a distance. In the cell to the right (Seg Length) sum all the distances for that segment. That is the length the animal travelled from the burrow.

When calculating the distance an animal travelled from the first burrow they were recorded in (considered their home burrow) to the RFID trap they were recorded in, an MS Access query as below was written for this:

```
SELECT
(Sin([Home_LatRad])*Sin([Visit_LatRad])+Cos([Home_LatRad])*Cos([Visit_LatRad])*Cos([Home
_LonRad]-[Visit_LonRad])) AS Expr1, IIf([Expr1]=1,Null,Atn(-[expr1]/Sqr(-
[expr1]*[expr1]+1))+2*Atn(1))*180*60/3.141592654 AS Expr2, qryBurrowVisits.AnimalID,
qryBurrowVisits.Sex, qryBurrowVisits.CountOfRecTime AS [No times],
qryBurrowVisits.CatchBurrow, qryBurrowVisits.Home_Lon, qryBurrowVisits.Home_Lat,
qryBurrowVisits.Home_Ele, qryBurrowVisits.[Burrow Visited] AS Visiting,
qryBurrowVisits.Visit_Lat, qryBurrowVisits.Visit_Lon, qryBurrowVisits.Visit_Ele,
([expr2]*1.852)*1000 AS Distance, qryBurrowVisits.First, qryBurrowVisits.Last
FROM qryBurrowVisits;
```

This produced a line-of-sight distance in metres and did not take into consideration the undulating landscape.

3.2.11 Internal Body Temperatures

While it was planned initially to take internal body temperatures with a clinical thermometer, it was decided not to continue with this as it was felt that due to the potential length of time an animal was

in a trap before being checked, it could adversely affect the results.

3.2.12 Artificial Burrows

A set of artificial burrows were designed and deployed at Nakhlee (Figure 3-15). These were hand excavated as the use of mechanical equipment would cause too much damage to the walls of the excavation.

A small shelter was put underground with a small tunnel leading to this. The shelter was protected to ensure the sand did not engulf it. The tunnel was supported by cutting a 100 cm pipe in half along the length of the pipe. This ensured that the dhub had proper traction while moving through the tunnel and also allowed the excavation of the tunnel further if required.

Unfortunately, subsequently it was not possible to use these as access to the site became restricted due to security concerns.



Figure 3-15. Construction of the artificial burrow at the Nakhlee site. (Top Left to Right) Shelter to be placed subsurface. Digging out the tunnel and area for shelter. Tunnel and shelter in place. (Bottom Left to Right). Top view of shelter. Sealing of edges to ensure sand did not engulf the shelter. Excavation filled in with burrow marker at the front.

3.3 RESULTS

3.3.1 MAXIMUM EFFECTIVE TEMPERATURE (T_E) VS AMBIENT AIR TEMPERATURES

Data for the three iButtons, which had been placed inside each analogue and the Davis weather station from December 2013 through to March 2018 (*n*=42,211 hours) were compiled into an hourly average (Table 3-5) from where the daily average temperature was calculated. It is seen (Figure 3-16 and Table 3-6) that there is a uniformity in the values from the iButtons with only a slight difference between the Weather Station and the iButtons and a very similar standard error of the mean between all of the equipment. When one then looks at the difference in recorded temperatures across the three locations, a one-way ANOVA demonstrated that there was no statistical difference between the sites for the temperatures recorded when the iButton was suspended 10 cm above ground (Table 3-7) and the Davis weather station for each month.

Table 3-5. Number of total data points and the number of hours data for the outside temperature, outside humidity, copper analogue on the ground, copper analogue raised slightly off the ground recorded between December 2013 and March 2018 for each of the three locations.

Site	Outside Temp	Outside Humidity	Copper Temp Ground	Copper Temp Raised	# Records	# Hours Data
H07	97,355	97,355	91,922	7,256	104,208	34,736
D21	93,258	93,257	113,499	Not recorded	113,499	37,833
14-155	101,318	101,310	107,818	7,258	116,235	38,745

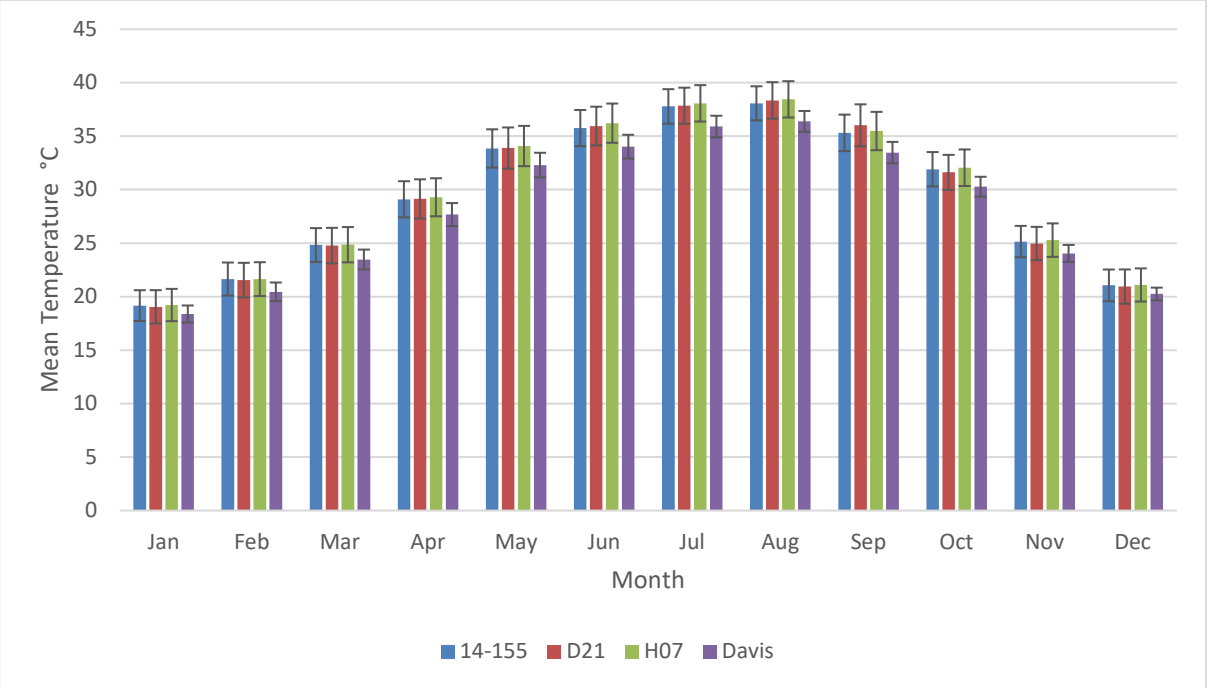


Figure 3-16. Mean (values recorded every 20 mins each day (n=72 records/day x the number of days in each month)) monthly outside temperatures for the three different burrows where the analogues were placed and the Davis weather station with error bars (SEM). Data was pooled for each month from December 2013 through to March 2018.

Table 3-6. Mean, Maximum, Minimum, Standard Deviation, Number of records and Standard Error of the Mean for each iButton and the Davis Weather Station over the full study period by each month in °C. Data was pooled for each month from December 2013 through to March 2018.

	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min	Davis	9.9	9.2	11.2	14.6	19.1	22.1	26.7	27.3	23.7	20.4	13.7	11.1
	H07	7.8	6.8	8.1	13.1	16.4	21.1	25.6	25.3	21.1	17.6	12.1	8.1
	D21	5.6	5.1	5.6	12.6	14.8	20.6	25.1	23.9	20.1	16.6	8.8	6.6
	14-155	6.6	7.1	8.1	13.6	16.3	21.1	25.6	24.8	21.4	17.6	11.4	7.6
Mean	Davis	18.4	20.5	23.5	27.7	32.3	34.0	36.0	36.4	33.5	30.2	24.1	20.2
	H07	19.2	21.7	24.8	29.3	34.2	36.2	38.2	38.5	35.5	32.0	25.3	21.1
	D21	19.1	21.6	24.7	29.1	34.0	36.0	38.0	38.4	36.1	31.6	25.0	20.9
	14-155	19.2	21.7	24.8	29.1	33.9	35.8	37.9	38.1	35.3	31.9	25.2	21.0
Max	Davis	31.8	36.7	42.3	43.3	46.2	49.5	49.1	48.7	46.7	42.3	35.6	32.7
	H07	43.1	49.0	53.0	59.0	56.5	58.5	58.7	59.5	57.7	54.5	47.1	44.1
	D21	41.6	45.1	49.6	53.0	56.5	56.0	58.5	61.0	64.0	51.1	43.6	42.6
	14-155	40.4	45.1	51.6	52.5	54.5	56.0	56.5	57.0	56.8	54.5	48.1	42.8
SEM	Davis	0.06	0.08	0.11	0.12	0.10	0.11	0.11	0.09	0.10	0.09	0.07	0.06
	H07	0.10	0.13	0.17	0.19	0.16	0.17	0.18	0.16	0.17	0.16	0.13	0.11
	D21	0.10	0.13	0.17	0.19	0.16	0.17	0.18	0.16	0.19	0.16	0.13	0.11
	14-155	0.10	0.12	0.17	0.18	0.15	0.16	0.18	0.15	0.16	0.16	0.12	0.10

Table 3-7. One way ANOVA of mean hourly temperatures recorded at four different locations. These included unshaded records from three iButtons (14-155, D21 and H07) as well as temperatures from the fan aspirated professional grade Davis weather station (n= 24 for each location, for each month).

Month	DF	Adj SS	Adj MS	F-Value	P-Value
Jan	3	10.84	3.615	0.08	0.970
Feb	3	24.27	8.091	0.16	0.921
Mar	3	32.53	10.84	0.20	0.893
Apr	3	41.02	13.67	0.22	0.885
May	3	49.38	16.46	0.23	0.873
Jun	3	71.14	23.71	0.37	0.776
Jul	3	72.95	24.32	0.43	0.730
Aug	3	66.78	22.26	0.40	0.753
Sep	3	89.03	29.68	0.45	0.717
Oct	3	47.31	15.77	0.29	0.832
Nov	3	22.68	7.559	0.16	0.920
Dec	3	11.26	3.754	0.08	0.969

These data suggest that while there is a difference in the mean temperatures across the burrow locations, it does not differ significantly (one way ANOVA p=>0.05, APPENDIX 3-2, Table 3-22) from the temperatures recorded on the professional weather station. Therefore, the suspended iButton can be used as an indicator of local microclimatic conditions faced by the dhub.

3.3.2 TEMPERATURES OF COPPER ANALOGUES AT DIFFERENT HEIGHTS ABOVE THE GROUND

As there were only two raised pipes (PR), (14-155 and H07), to mimic dhub thermotaxis (Figure 3-1), an independent samples t-test was conducted to determine if firstly there was any difference in temperatures between the pipes in the two survey locations (PG); t(9671)= 1.54, *P*=0.123 and those raised above the ground (PR); t(9664)= 1.25, *P*=0.210 for the same time periods. As there was no statistically significant difference between the data sets, the samples were pooled and means used to determine whether there were significant differences between temperatures of PG (*M*=30.8, *SD*=12.3) and PR (*M*=30.5, *SD*=12.8) sampling; t(9656)= 0.98, *P*=0.327 (Table 3-8).

Table 3-8. Independent sample t-test for temperatures between February 2018 and May 2018 for burrows 14-155 and H07.

Burrow	N	M	SD	SEM	T-Value	DF	P
14-155-PG*	4837	30.9	12.3	0.18	1.54	9671	0.123
H07-PG	4837	30.6	12.3	0.18			
14-155-PR*	4837	30.7	13.0	0.19	1.25	9664	0.210
H07-PR	4837	30.3	12.6	0.18			
Avg_PG	4837	30.8	12.3	0.18	0.98	9656	0.327
Avg_PR	4837	30.5	12.8	0.18			

*PG-Pipe on the ground, PR-Pipe raised off the ground

As there was no statistically significant difference between the pipe positions (PG v PR), it was interpreted that when determining the potential lumen temperature of the dhub using the pipe analogue, it does not matter whether the pipe is positioned on the ground or raised.



Figure 3-17a. Dhub using *Tetraena qatarense* increasing the cooling potential and b. using an old *Panicum turgidum* tuft for the same effect.

3.3.3 TEMPERATURES OF COPPER ANALOGUES

The data collected (n=45,754 20 minute temperature values) from the copper tubes used as animal analogues (Figure 3-18 and Table 3-9) suggests a similar mean temperature (°C) across the 3 locations with the mean temperature from H07 appearing to be slightly lower (summer 38.3, autumn 37.1) than those of 14-155 (summer 39.0, autumn 38.0) and D21 (summer 39.3, autumn 38.2) during the summer

and autumn periods. The standard error across all the locations was extremely small at 0.1 to 0.2 °C. Similarly, there appeared to be little difference between the standard deviation, minimum or maximum values of any of the locations.

Table 3-9 Minimum, Mean, Maximum, Standard Deviation and Standard Error of the Mean temperature (°C) for each iButton in the copper pipe analogue over the full study period by each month.

	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min	14-155	6.0	7.0	7.5	13.6	15.9	21.3	25.7	24.9	18.1	17.6	12.6	8.0
	D21	6.1	5.1	7.1	13.3	14.8	21.2	25.6	24.1	17.6	16.3	11.3	6.1
	H07	7.5	6.5	7.0	12.6	16.1	21.8	25.8	24.9	20.6	17.1	12.1	7.5
Mean	14-155	20.9	23.4	27.3	32.9	36.7	39.3	41.1	41.6	37.9	34.4	28.0	22.4
	D21	21.9	24.2	27.9	33.1	37.0	39.7	41.1	41.5	38.1	35.1	28.7	23.3
	H07	20.9	23.3	26.7	31.9	36.1	38.5	40.4	40.5	37.1	33.8	27.7	22.3
Max	14-155	51.2	55.2	58.7	62.8	65.7	66.4	68.2	67.4	66.4	61.0	53.5	50.5
	D21	50.5	56.0	61.0	66.9	67.6	69.4	67.8	69.0	67.5	62.7	56.7	52.0
	H07	50.0	55.0	58.5	63.4	66.0	65.4	66.2	67.2	64.9	59.5	54.5	49.0
SD	14-155	10.5	11.3	11.7	12.3	12.4	12.2	11.6	11.8	12.1	11.5	10.8	10.3
	D21	11.3	12.0	12.5	13.0	13.2	12.9	12.0	12.3	12.7	12.2	11.7	11.5
	H07	10.8	11.4	11.5	12.0	12.3	12.1	11.3	11.5	11.6	11.2	10.7	10.4
SEM	14-155	0.1	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2
	D21	0.1	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2
	H07	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

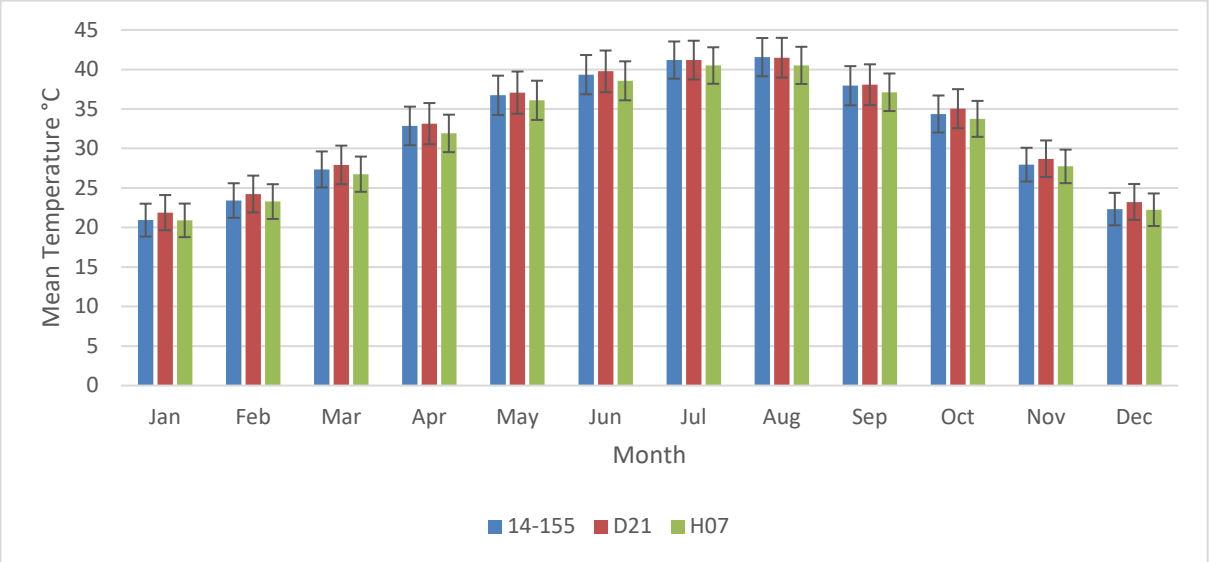


Figure 3-18. Mean monthly temperatures for the copper animal analogues (14-155, D21 and H07) which were on the ground at the three different burrows locations at with error bars (SEM). Data was pooled for each month from December 2013 through to March 2018.

To determine whether the differences were statistically significant, the data was tested for differences between the three sites. The one way ANOVA for each month suggested that there were no statistical differences between the different locations. Similar analysis of the mean maximum and mean

minimum temperatures (APPENDIX 3-2) for each of the locations suggest no significant differences between the three different sites. Hence, the data from these locations were pooled and the mean value used for comparisons against the Davis professional weather station and dhub burrow iButton data.

The mean and mean maximum temperatures for both the suspended iButton and the iButton in the copper analogue were compared (Figure 3-19). This suggests that while there was a very small SE (0.1 to 0.2), there were visible differences between the temperatures in the copper pipe and the temperature recorded while the iButton was suspended above the ground.

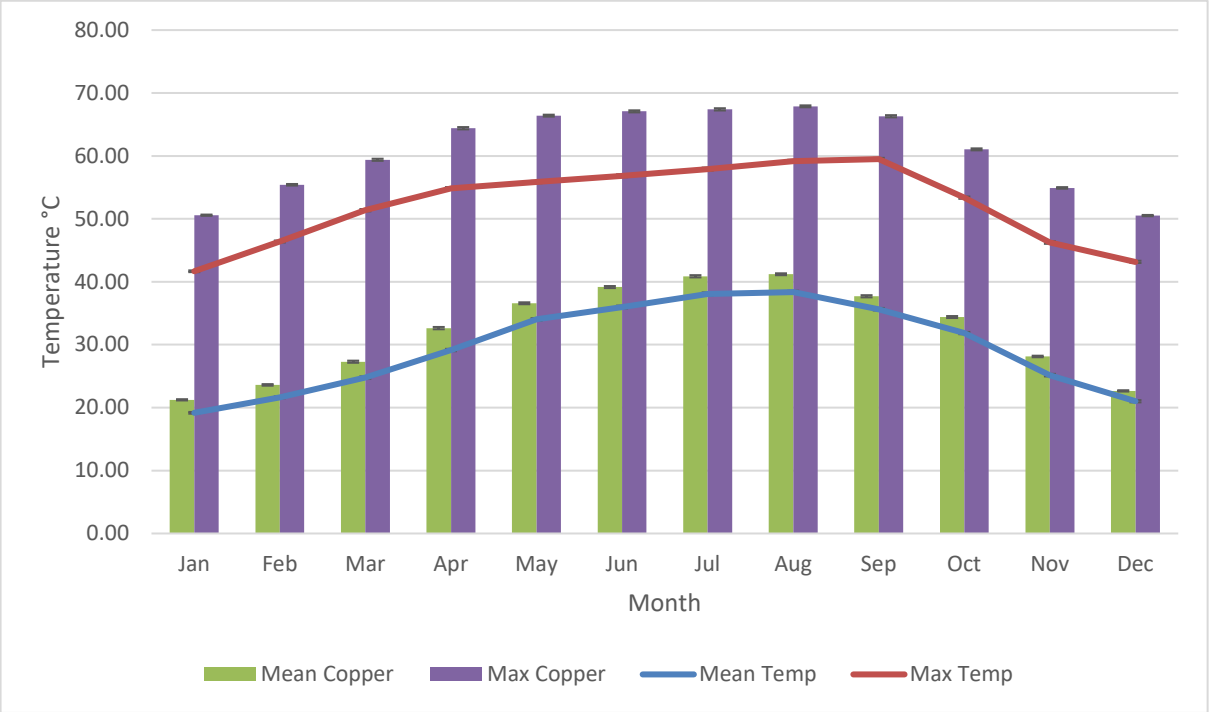


Figure 3-19. The recorded mean monthly analogue temperatures (Mean Copper) and the mean monthly maximum analogue temperatures (Max Copper) for the copper analogue compared to the mean monthly iButton temperature (Mean Temp) and mean monthly maximum iButton temperature (Max Temp) for the iButton suspended 10 cm from the ground with error bars (SEM) from 2014 through to 2018.

When these were compared in a one-way ANOVA, there was no statistical difference between the different treatments (APPENDIX 3-1).

A key finding of these data is that the animal analogue suggests that the T_e from these can be used for any of the survey animals within the Mugatrah site. It can therefore be surmised that the operative temperature T_e range was 19 °C (19 °C in winter to 38 °C in summer).

3.3.4 Temperature data from animal tracking and monitoring phase of the study

Although there were data recorded for 20 individuals, there was not data for every individual each

month. This has resulted in selected animals (those with data) being used in some of the analysis and others excluded (as per Table 3-3).

As an example, Figure 3-20 shows the temperature and humidity within the burrow of one (AQ01) of the 20 animals that was monitored during May 2015. The humidity within the burrow was relatively stable at approximately 60% while the temperatures were also constant at approximately 34 °C while the animal was within the burrow. Using a combination of the humidity (decreasing) and temperature (increasing) from the animal data logger (T_{sad}), it was possible to identify the time periods when the animals were leaving and returning to their burrows. The sudden drop in humidity suggested that they left the burrow at 07.00. At the same time there was also a shift upwards in the temperature. The subsequent increase in humidity and slight drop in temperature (9.00-14.00) were used as the indicators for the animal returning to the burrow.

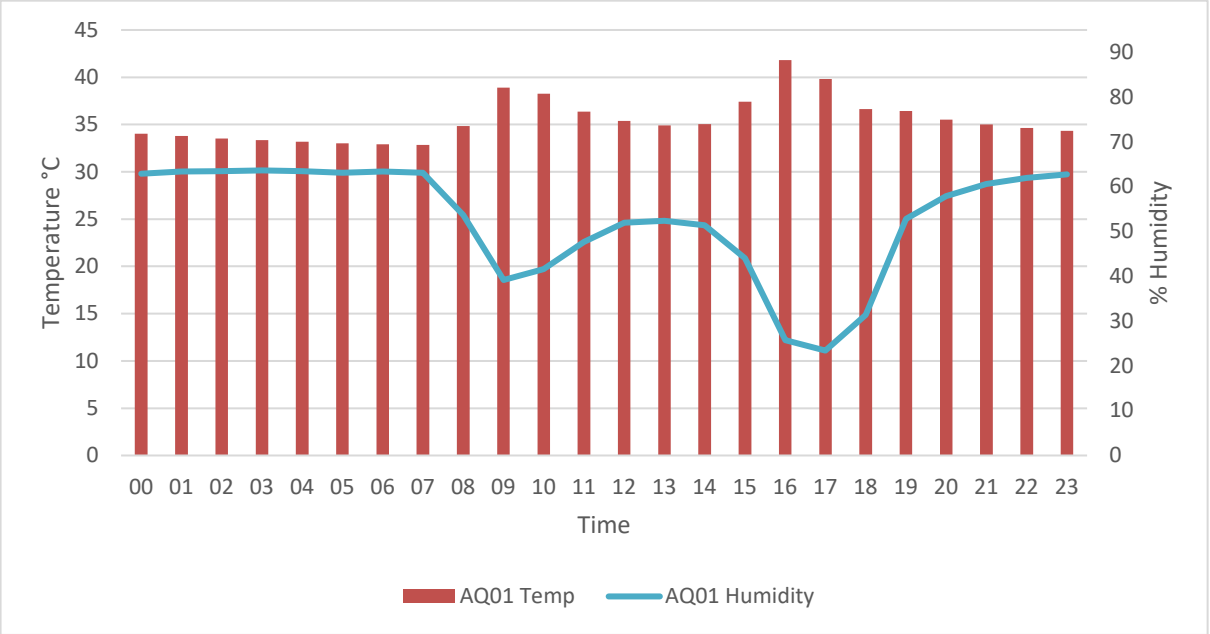


Figure 3-20. Mean hourly temperature and humidity for Animal AQ01 during May 2015.

Figure 3-20 demonstrates these changes but also suggests a bimodal emergence for this animal. Humidity begins to drop while temperatures rise at about 14.00 suggesting the animal leaves the burrow again.

This is a similar observation when 4 other animals (the only data overlapping for May 2015) are added to the analysis (Figure 3-21).

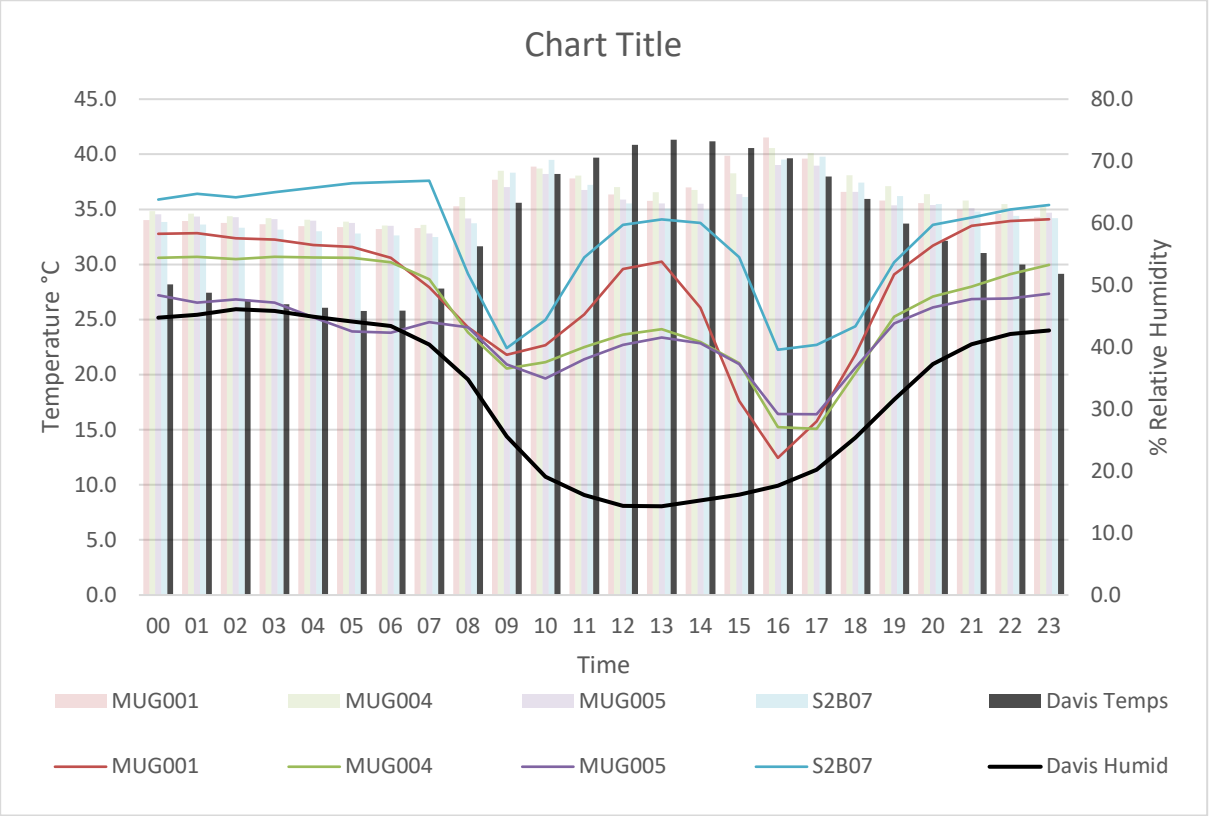


Figure 3-21. Mean hourly temperature (column) and humidity (line) recorded for four different animals (MUG001, MUG004, MUG005 and S2B07) during the month of May 2015 in Mugatrah.

While humidity and temperatures were different for each animal (Figure 3-21), the general trend of emergence and retreat back into the burrows, based on the change in humidity, was the same for all of the animals. There was no statistical difference between the mean hourly temperatures $F(3,95) = 2.21$, $p=0.092$ recorded for the animals.

Looking at the trend in greater detail for AQ01, when the outside temperatures and humidity (measured on the Davis Weather Station) are included (Figure 3-22), burrow humidity is 20% higher than the outside humidity while the temperature within the burrow is relatively stable at approximately 33.7 °Celsius with a four-degree Celsius change over the time the animal returns to the burrow and then emerges the following morning. The amount of time the animal spends outside varies as well, staying out for approximately two hours in the morning and about three and a half to four hours in the afternoon.

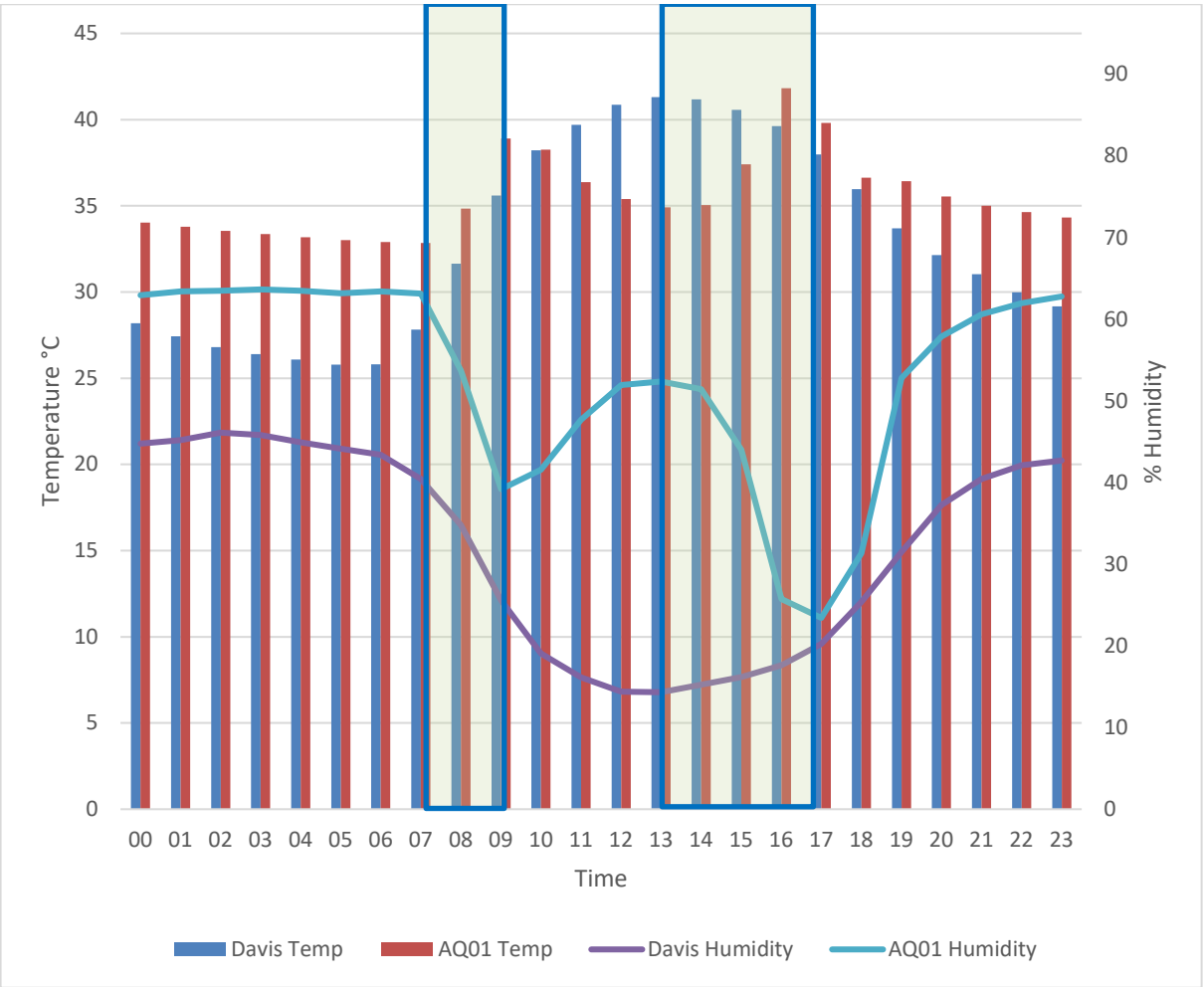


Figure 3-22. Mean hourly temperature and humidity for AQ01 (from iButton) during May 2015 with the Davis (Davis Weather Station) temperature and humidity as comparison.
*Green bands suggest when the animal emerged and re-entered the burrow.

For May 2015, there were a further two animals in WAS where data was used. When one compares the mean temperatures as recorded on $T_{(Sad)}$ for the individuals in MUG and WAS (Figure 3-23) a similar bimodal emergence is observed with 07:00 to 10:00 and 13:00 to 14:00 being the preferred times when dhub were outside their burrows. These data showed a very similar mean burrow temperature, but approximately a 10% burrow humidity difference between WAS and MUG.

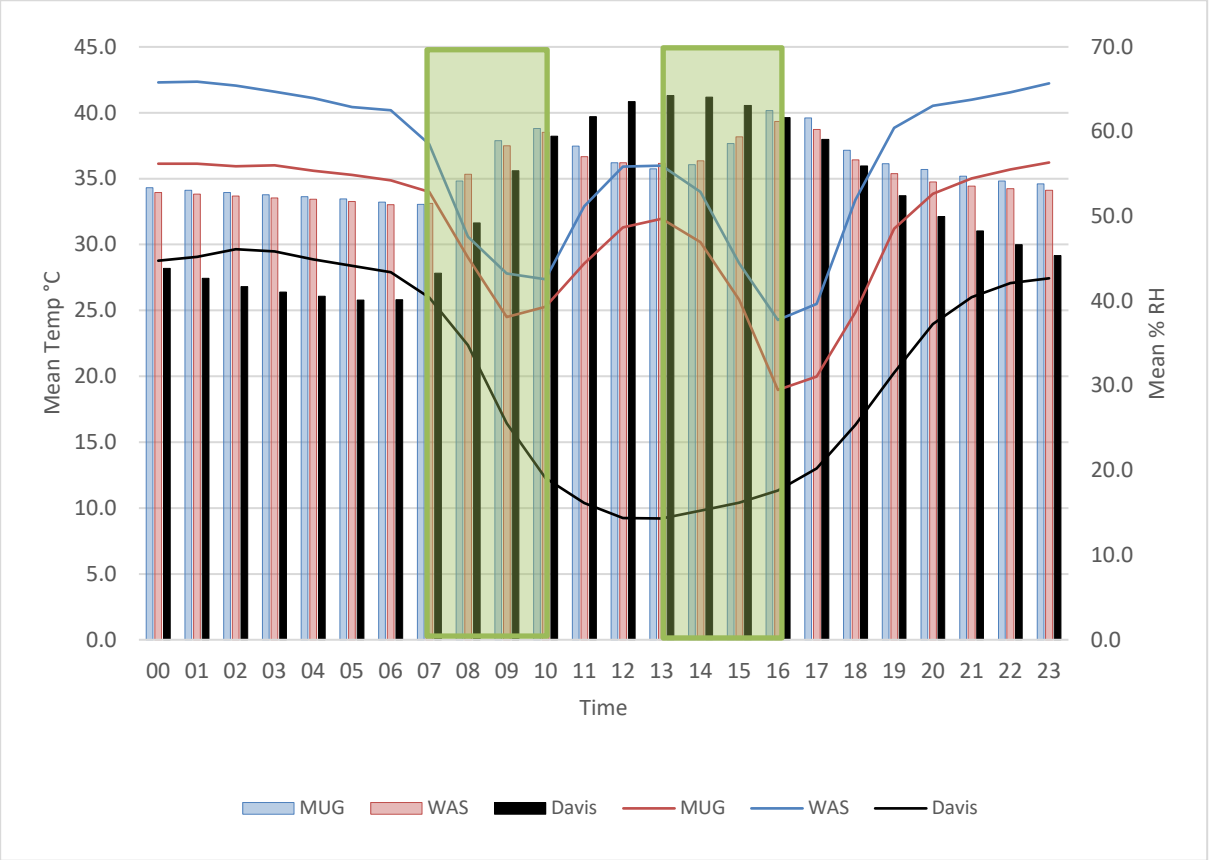


Figure 3-23. Mean hourly temperature and humidity for (MUG001, MUG004, MUG005 and S2B07) MUG and (WAS001 and WAS006) WAS (from iButton) individuals during May 2015 with the Davis (Davis Weather Station) temperature and humidity as comparison.
*Green bands suggest when the animal emerged and re-entered the burrow.

As there was a definite bimodal pattern (07:00 to 09:00 and 14:00 to 16:00-16:30) to the times when these dhub were out of their burrow (green shade on Figure 3-22 and Figure 3-23), the solar radiation was plotted against the $T_{(Sad)}$ temperatures to determine if a trend could be identified (Figure 3-24). These data suggest that the dhub retreated at about 770 W/m^2 but reappeared when the solar radiation had not receded below 873 W/m^2, suggesting that perhaps the solar radiation was not affecting their activity.

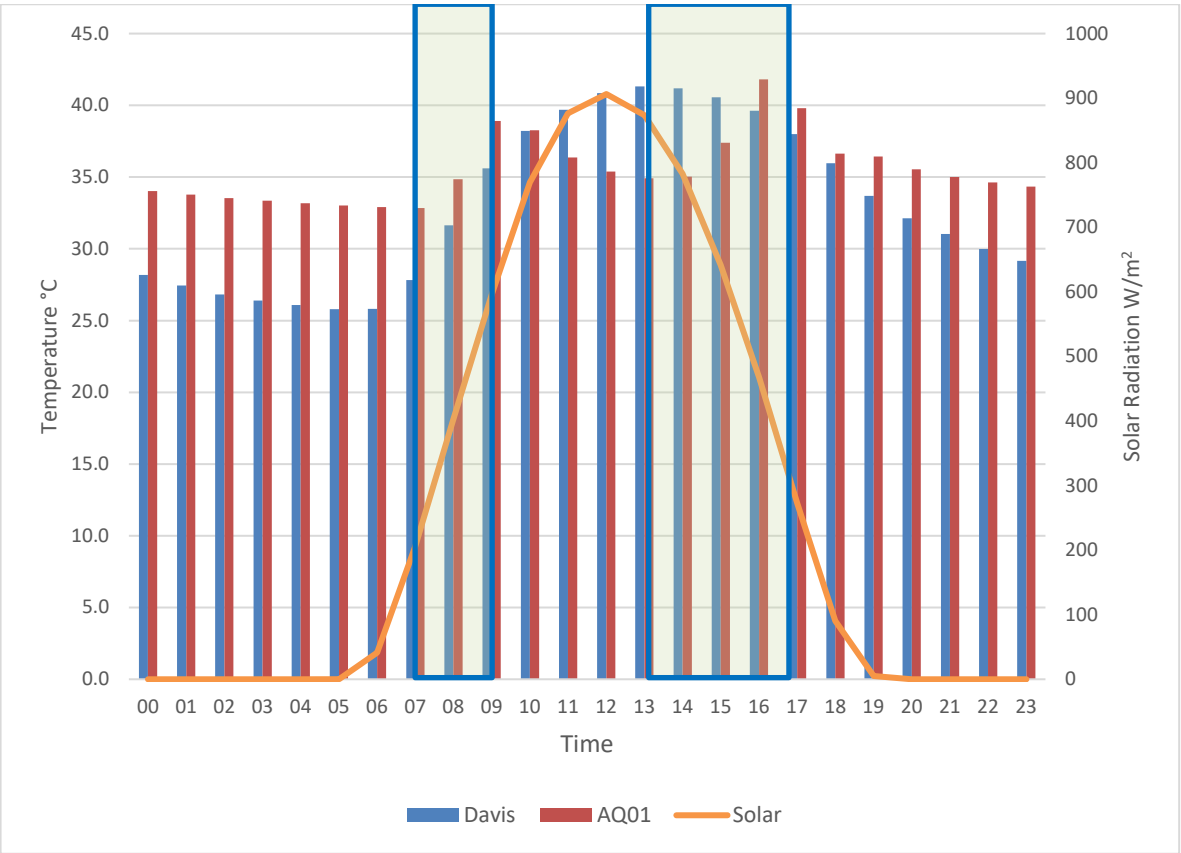


Figure 3-24. Mean hourly temperature for AQ01 during May 2015 with the solar radiation (Davis Weather Station) as comparison. *Green bands suggest when the animal emerged and re-entered the burrow.

This was repeated for all months and each dhub, but no immediately obvious link between the solar radiation recorded and the dhubs' emergence or retreat was observed to suggest triggers for the emergence or retreat of the dhub. Using the T_e determined above from the analogue and taking that the T_{set} (calculated from studies in Saudi Arabia) were established to be 38 °C (Zari, 1991) and 36.1 °C (Al-Johany, 2003) respectively, the T_e was plotted against the temperatures and humidity for AQ01 in May (Figure 3-25).

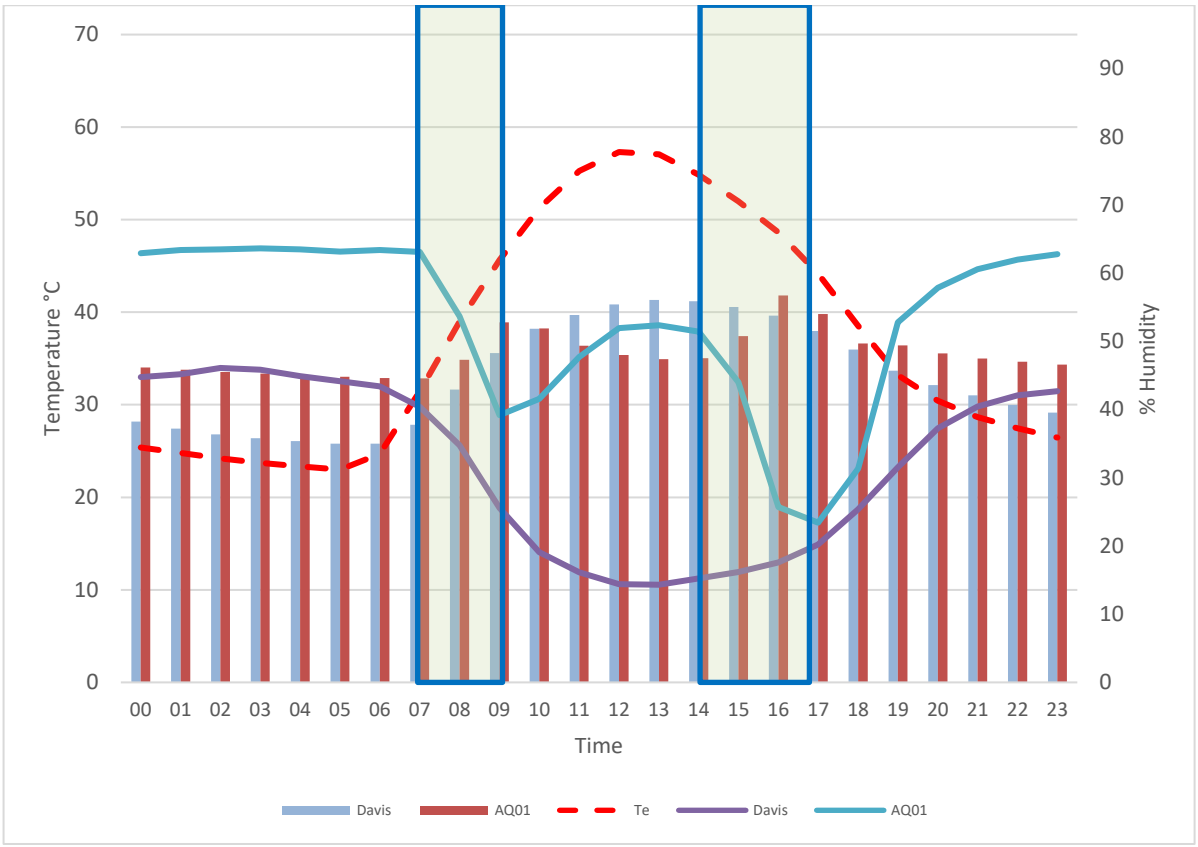


Figure 3-25. Mean hourly temperature and humidity for AQ01 (from iButton) during May 2015 with the Davis (Davis Weather Station) temperature and humidity as comparison. T_e as determined for dhub at this site is used as a comparison.

*Green bands indicate when the animal emerged and re-entered the burrow.

When one looks at these results and the point at where AQ01 returns to her burrow, it is approximately 45.6 °C (am) and 44.2 °C (pm) respectively on the T_e scale or 38.9 °C (am) and 39.8 °C (pm) according to T_{sad}. This would suggest that T_{set} would be in the region of 39 °C and 40 °C.

The striking observation from these data is the uniformity of the mean humidity (65.2 to 66.1 %, SEM 2.59 to 2.10) and temperatures (31.8 to 32.7 °C, SEM 2.056 to 2.113) while the animal is in the burrow between 21:00 until 05:00 throughout the year.

To determine if there were any significant differences between animals at the different times between 21:00 and when they would possibly emerge at 05:00, a one way ANOVA (Table 3-10) was run on each time group, comparing each animal on a monthly basis and shows a significant difference in burrow temperatures for March, April and May.

The statistically significant values $P < 0.001$ for March, April and May (Table 3-10) tie in with the dhubs most active daytime periods. It should be noted that at times the dhubs were not alone in the burrows as was evidenced from the video analysis data (Chapter 2) and there might have been some interaction between animals, moving them to suboptimal areas within the burrow. In any event, the mean

temperature that each animal was exposed to was higher than that of the outside temperature (Figure 3-26).

Table 3-10. One way ANOVA of mean temperatures from 21:00 to 05:00 recorded on different animals, for each month between 2015 and 2016.

Month	DF	Adj SS	Adj MS	F-Value	P-Value
Jan	8	4.646	0.5807	0.40	0.920
Feb	8	21.69	2.711	1.46	0.184
Mar	8	28.21	3.527	3.40	**0.002***
Apr	8	66.51	8.314	5.80	**<0.001***
May	8	48.43	6.0544	9.70	**<0.001***
Jun	8	19.32	2.415	0.73	0.661
Jul	8	15.28	1.910	0.46	0.885
Aug	8	5.853	0.7316	1.45	0.190
Sep	8	2.296	0.2870	0.31	0.959
Oct	8	27.34	3.418	0.21	0.989
Nov	8	72.31	9.039	0.67	0.719
Dec	8	4.825	0.6031	0.23	0.983

Significantly different (*p< 0.05*) statistics in bold and asterisk

	S	R-sq	R-sq(adj)	R-sq(pred)
March	1.01905	21.53%	15.19%	6.62%
April	1.19743	31.91%	26.40%	18.96%
May	0.790233	41.80%	37.49%	31.69%

When one looks at the Tukey pairwise comparison (Table 3-11) the difference between the time periods become very much more marked the closer it comes to the breeding season (May). Although there is a statistical difference across these time periods, to determine what is causing the difference is a little more difficult. To investigate this further, a general linear model

Table 3-11. Tukey Pairwise Comparisons for the 3 months which were statistically significant.

	March					April						May					
Hour	N	Mean	Group			N	Mean	Group				N	Mean	Group			
21	12	27.115	A			12	31.036	A				13	34.956	A			
22	12	26.834	A	B		12	30.592	A	B			13	34.617	A	B		
23	12	26.575	A	B		12	30.235	A	B	C		13	34.364	A	B	C	
00	12	26.330	A	B		12	29.781	A	B	C	D	13	34.052	A	B	C	D
01	12	26.125	A	B		12	29.492	A	B	C	D	13	33.809		B	C	D	E
02	12	25.957	A	B		12	29.250		B	C	D	13	33.577			C	D	E
03	12	25.827	A	B		12	29.007			C	D	13	33.361				D	E
04	12	25.649		B		12	28.807			C	D	13	33.141				D	E
05	12	25.530		B		12	28.616				D	13	32.959					E

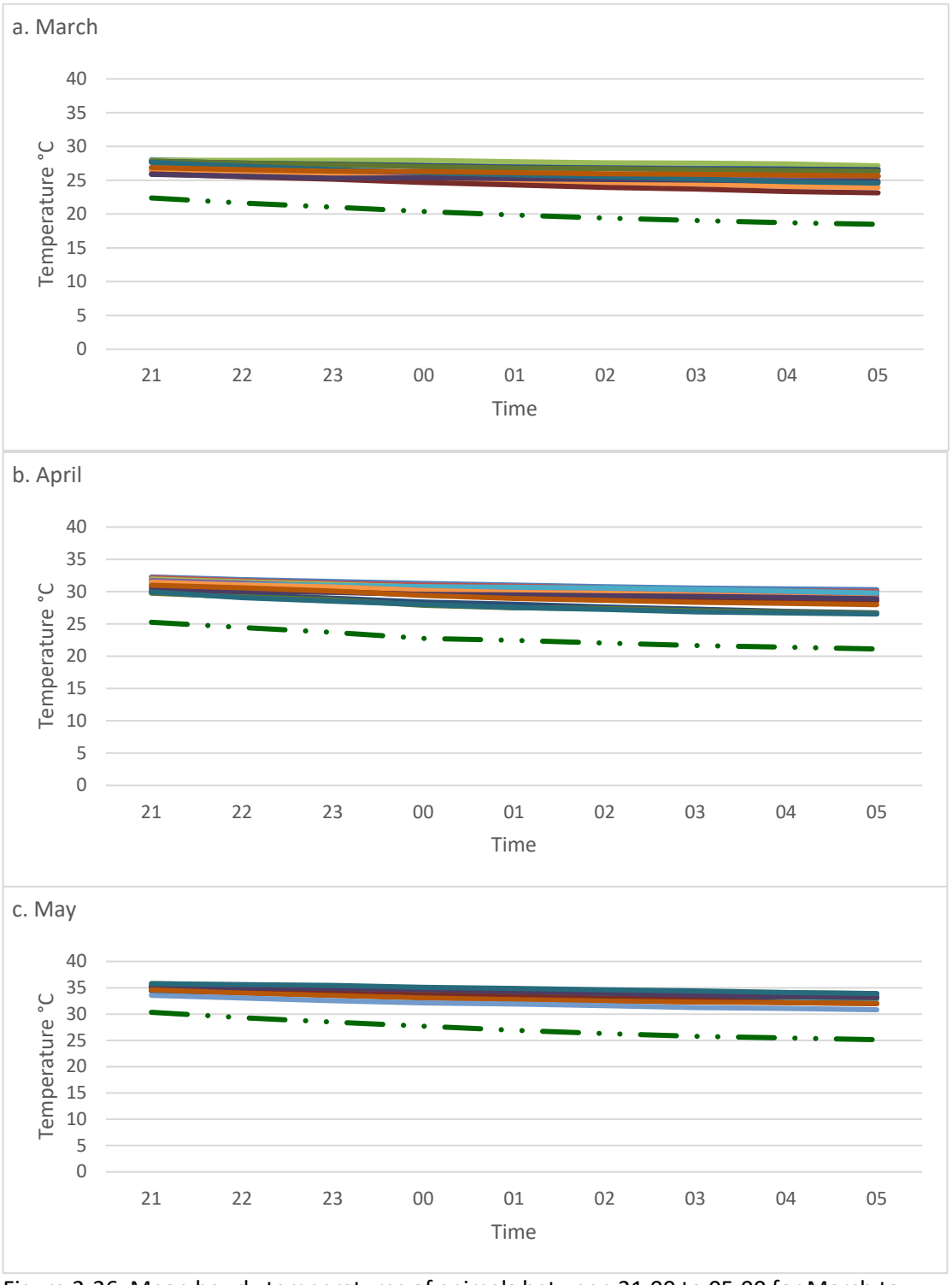


Figure 3-26. Mean hourly temperatures of animals between 21:00 to 05:00 for March to May with the mean outside temperature (Davis) as a comparison.

of Sex, Month and Sex*Month for March through to May and the same time periods was conducted. While there was no statistical difference between sex or sex*month, there was a statistical difference

(*P= <0.001*) between months. Looking at the Tukey pairwise comparison for month*sex gives an indication of the differences (Table 3-12). This suggests that while there is no statistical differences between the temperatures recorded on males and females, the month of the year has a definite effect on the temperatures within the burrows.

Table 3-12. Grouping information using the Tukey method and 95% confidence

Month*Sex	N	Mean	Grouping		
May F	4	33.217	A		
May M	9	32.844	A		
Apr F	4	29.388		B	
Apr M	8	28.231		B	
Mar F	4	25.954			C
Mar M	8	25.318			C

Means that do not share a letter are significantly different.

If one looks at the data retrieved from a "lost" saddle (Figure 3-27), i.e. one that was placed on an animal but came off within the burrow (J018) for June through September 2016 it can be seen how stable the temperatures throughout the day are within the burrow. In June, the mean temperatures for J018 was 34.8 °C ranging from 34.7 to 34.9 with a SD0.042 and a SEM of only 0.001 while from July-Sep. temperature only varied between 36.5 and 37.4°C. The slight drop in the temperature seen at 08.00 in Sept is only 0.2 °C. The humidity data inside the burrow also showed an almost identical constant level of 94.1 %, (±SE) 0.025 in June to 93.1 %, SEM 0.029 in September.

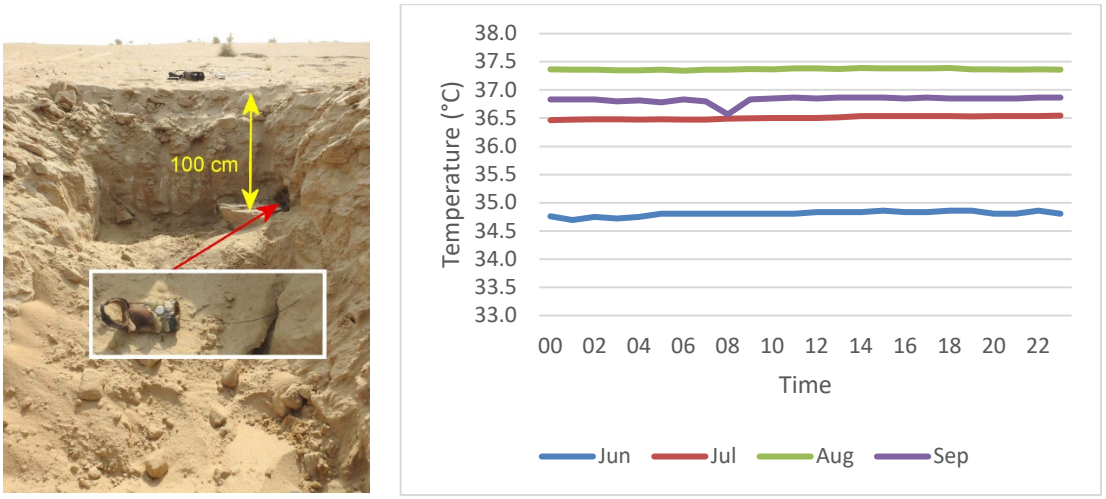


Figure 3-27. The retrieved saddle (100 cm below ground) with the mean hourly temperature data in 2016 from the iButton plotted.

3.3.5 Humidity

Humidity, according to the loggers attached to the dhubs varied between 77.1%, SEM 0.831 in March to 58.9%, SEM 0.390 in May. Apart from April, there was no statistical difference (see Table 3-13) between the mean humidity in the burrow (analysed separately for each month) from 21:00 to 05:00

for either males or females. The general linear model for Sex, Month and Sex*Month for March through to May suggests (similar to the temperature GLM) that there was no significant difference ($\alpha = p < 0.005$) between Sex for any of the times in the burrow.

Table 3-13. One way ANOVA of mean humidity from 21:00 to 05:00 recorded on different animals, for each month between 2015 and 2016.

Month	DF	Adj SS	Adj MS	F-Value	P-Value
Jan	8	7.73	0.9658	0.01	1.000
Feb	8	185.6	23.19	0.18	0.993
Mar	8	551.0	68.88	0.77	0.628
Apr	8	1010	126.31	2.42	**0.020**[*]
May	8	177.3	22.16	0.46	0.879
Jun	8	19.59	2.449	0.03	1.000
Jul	8	53.78	6.722	0.10	0.999
Aug	8	93.20	11.65	0.11	0.999
Sep	8	114.0	14.25	0.08	1.000
Oct	8	152.1	19.01	0.07	1.000
Nov	8	489.9	61.24	0.52	0.836
Dec	8	7.82	0.9780	0.01	1.000

[*]Significantly different ($p < 0.05$) statistics in bold and asterisk

3.3.6 BURROW ORIENTATION, SHAPE AND SIZE

The entrance to a dhub burrow is low and wide (Figure 3-28). From early 2013 through to the end of 2016 ten different sites (Figure 3-29 and Table 3-14) were surveyed at different times to examine burrow orientation, shape and size. This resulted in a total survey area of approximately 10,700 Ha and a total of 4,869 burrows surveyed.



Figure 3-28. Dhub burrow entrance, wide and low and 2 metres inside the burrow with the animal present. The “tight fit” aids in defence of the burrow as well as providing a thermal bridge enabling the dhub maintain the constant temperatures recorded within the burrow.



Figure 3-29. The location of the ten different sites surveyed for burrows from 2013 through to 2016 in the Emirate of Dubai.

Table 3-14. Sites surveyed with study code and numbers of burrows recorded. The GPS coordinates are to the general area where the burrow was located within the survey site.

Site	Code	Perimeter (Km)	Area (Ha)	Burrow counts	Burrow (Ha^{-1})†	Location
Al Quadra	AQ	17.3	1,435	29	0.02	N: 24.99 E: 55.28
Dubai Investment Park 1	DIP1	16.3	1,557	8	0.01	N: 24.95 E: 55.14
Global Village	GV	15.3	975	62	0.06	N: 25.07 E: 55.32
Legends	LEGE	6.47	221	4	0.02	N: 25.07 E: 55.32
Mugatrah	MUG	14.2	1,043	3002	0.82	N: 24.80 E: 55.24
Nakhlee	NAK	9.22	529	70	0.10	N: 25.09 E: 55.57
Dubai Investment Park 2	DIP2	18.8	2,106	7	0.00	N: 24.94 E: 55.19
Seeh Al Salam*	SAS	7.65	271	0		N: 24.86 E: 55.41
Plantations	PLANT	11.8	687	2	0.00	N: 25.04 E: 55.28
Wadi Al Safa	WAS	19.9	1,915	1685	0.31	N: 25.07 E: 55.26

†*These were unique burrows per site and did not include repeat surveys*

**Burrows surveyed in Seeh Al Salam, although found, were not included in the results as these animals were being actively fed by Dubai Municipality staff, as such they would not be natural populations and would likely give an incorrect density value.*

Of the 4,869 burrows sampled, there was a total of 1,611 distinct burrows identified during the study. Burrows were re-surveyed to determine whether their status would change between survey periods. Out of the 1,611 distinct burrows, approximately 60% of burrows surveyed in Wadi Al Safa (Figure 3-30) and 46% in Mugatrah (Figure 3-31) were found to be in a Westerly orientation i.e., they were facing in one of the three compass points, North West, West or South West. In WAS, South and North facing burrows were the next most frequent orientation at 23% while East facing burrows only

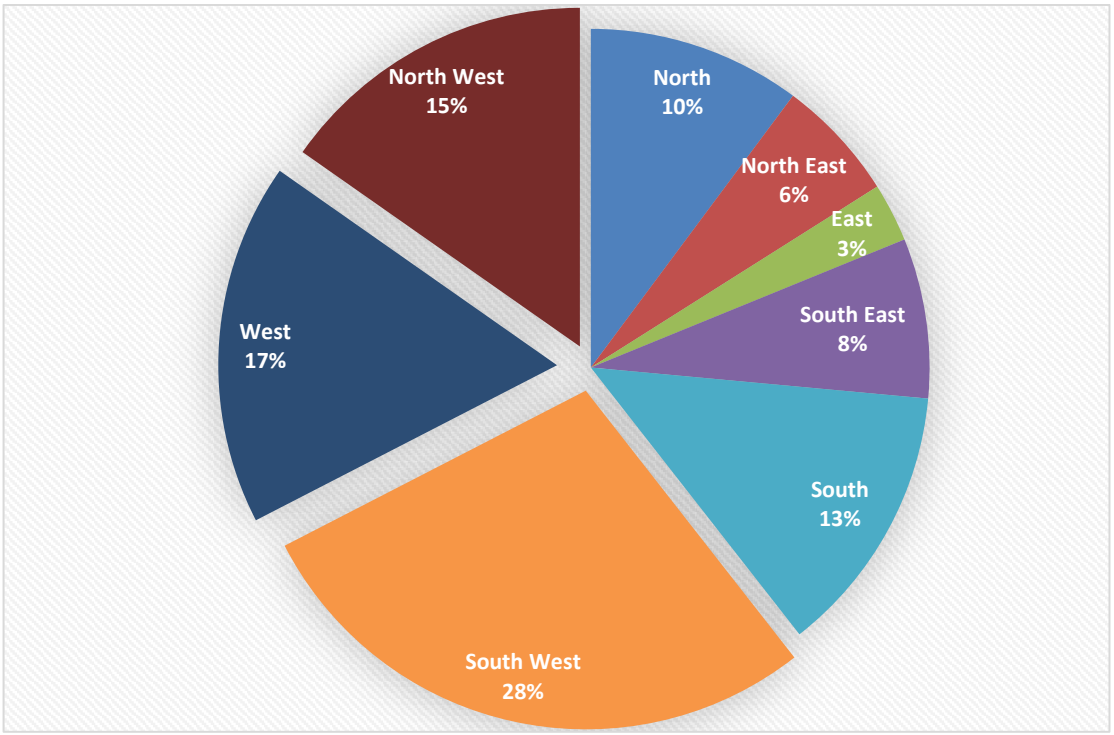


Figure 3-30. Total burrow orientation of distinct burrows in Wadi Al Safa where an orientation was recorded (*N*=393).

accounted for 17% of observed orientations. Of the unique burrows in Mugatrah, a larger proportion

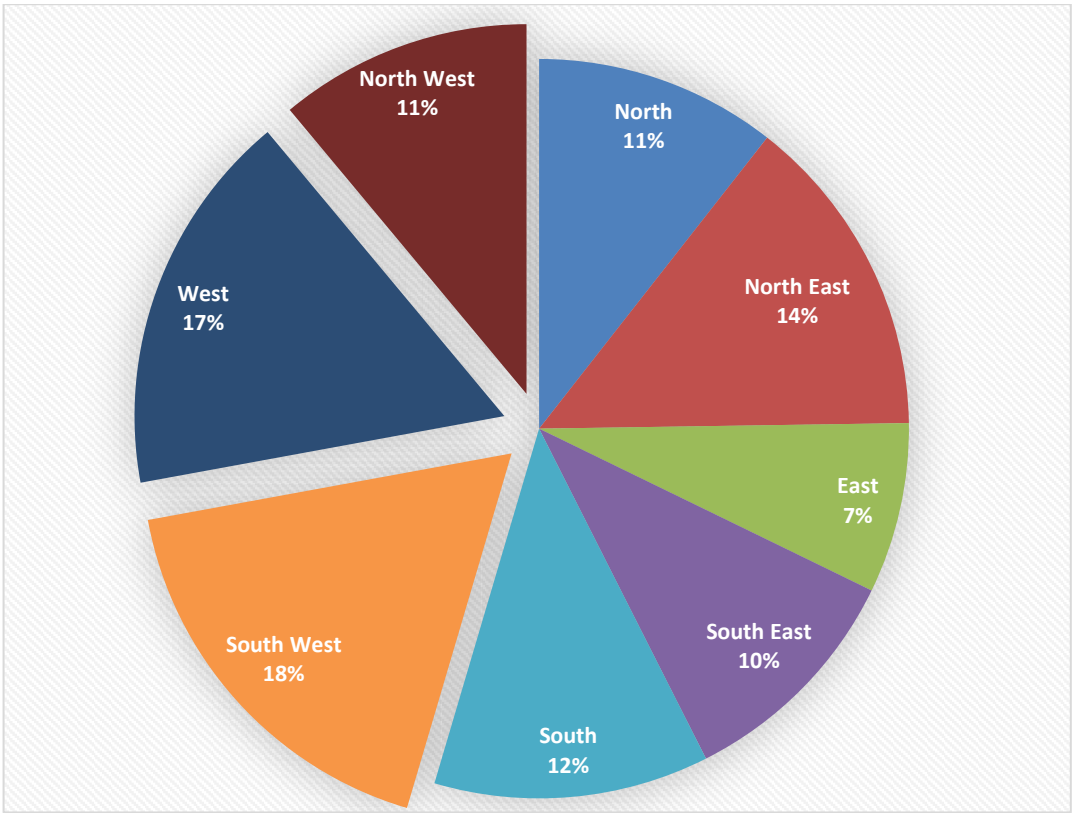


Figure 3-31. Total burrow orientation of distinct burrows in Mugatrah where an orientation was recorded (*N*=416)..

of burrows oriented towards the East at 31% than in Wadi Al Safa, with very similar percentage of

burrows oriented to the South and North in both sites.

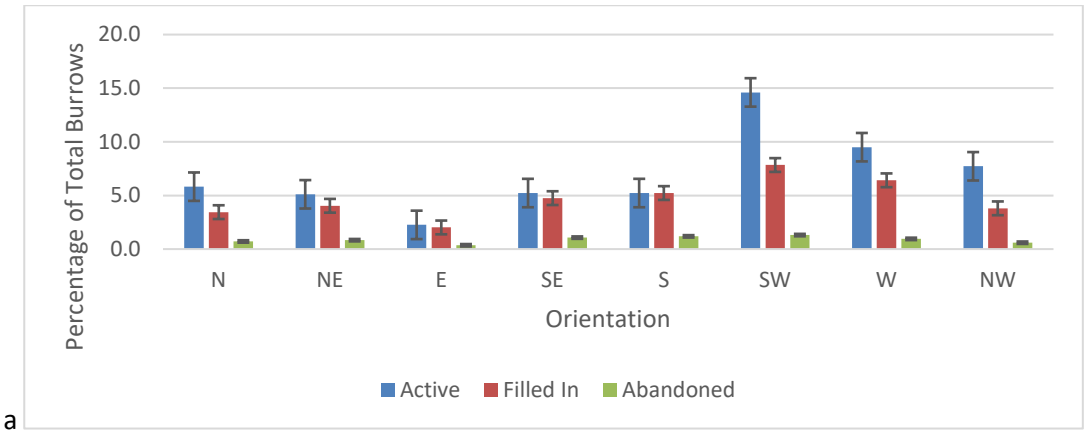
3.3.7 ORIENTATION OF BURROWS WITH SEASON

The survey period from 2013 to 2016 was divided into seasons as per Table 3-15, to see if there were any differences. Figure 3-32 demonstrates the orientations of all the active MUG and WAS burrows where most burrows had been found during these time periods. This suggests that the orientation of the active burrows to the West were again the primary orientation throughout each season. However, there did appear to be a shift to East facing active burrows during the winter, when 20.1% were in this direction. There also appeared to be proportionally less abandoned burrows during the spring than the other seasons.

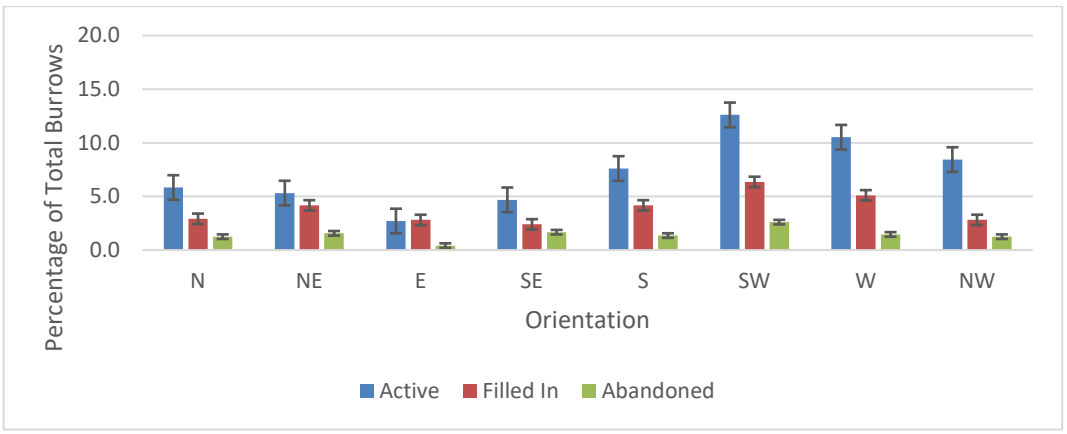
Table 3-15. Date span used for the different survey periods and the number of burrows surveyed during this time (*n=4869*)

Year	Survey Period	Dates	No. Burrows Surveyed
2013	Spring	1st Feb 2013 to 30th Apr 2013	1
	Summer	1st May 2013 to 31st Jul 2013	176
	Autumn	1st Aug 2013 to 31st Oct 2013	127
	Winter	1st Nov 2013 to 31st Jan 2014	0
2014	Spring	1st Feb 2014 to 30th Apr 2014	61
	Summer	1st May 2014 to 31st Jul 2014	304
	Autumn	1st Aug 2014 to 31st Oct 2014	208
	Winter	1st Nov 2014 to 31st Jan 2015	790
2015	Spring	1st Feb 2015 to 30th Apr 2015	816
	Summer	1st May 2015 to 31st Jul 2015	701
	Autumn	1st Aug 2015 to 31st Oct 2015	0
	Winter	1st Nov 2015 to 31st Jan 2016	0
2016	Spring	1st Feb 2016 to 30th Apr 2016	832
	Summer	1st May 2016 to 31st Jul 2016	524
	Autumn	1st Aug 2016 to 31st Oct 2016	329
	Winter	1st Nov 2016 to 31st Jan 2017	0

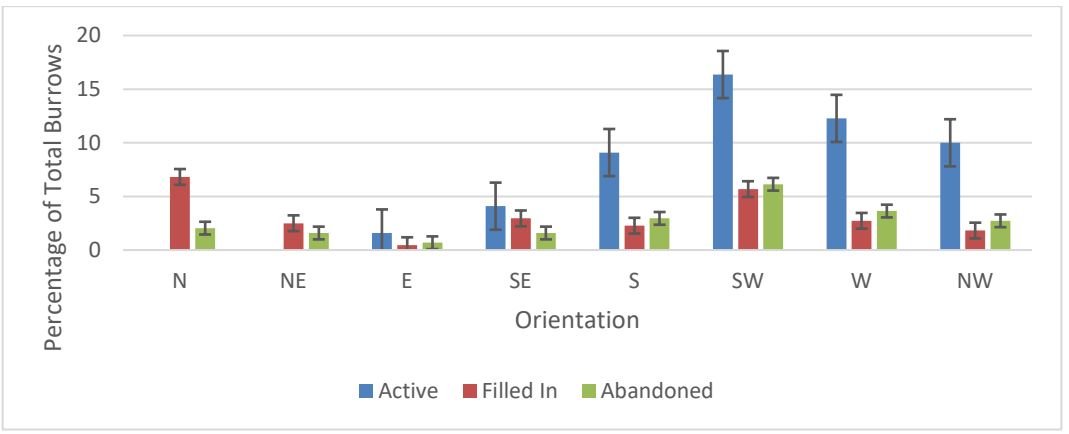
However, looking to see if there was any significant difference between orientation and season for active burrows for either site showed that there was a significant difference for WAS χ^2 (21, N=292)=33.47, p<0.0412 (Figure 3-33), while there was no difference determined for the orientation and season in MUG χ^2 (21, N=275)=13.38, p<0.895 (Figure 3-34). These findings are investigated in the discussion.



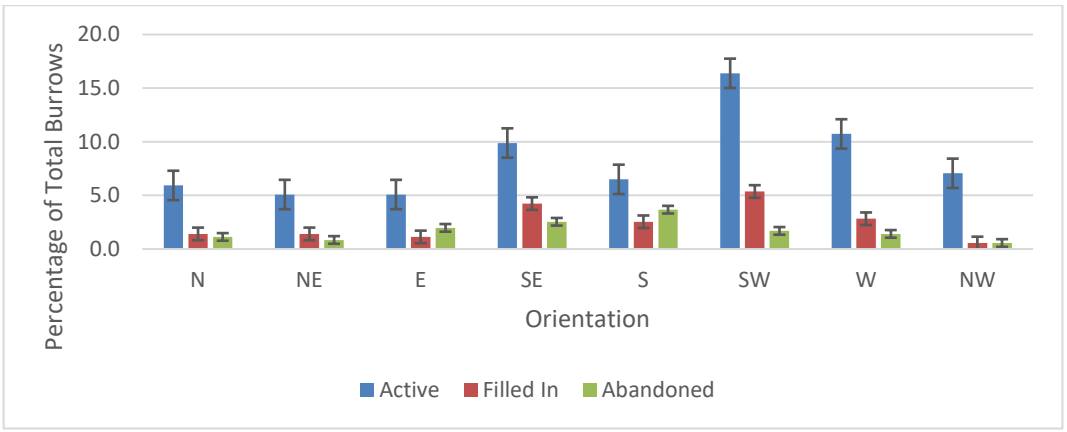
a



b



c



d

Figure 3-32. Mean percentage of burrow orientation where the orientation was noted (SEM error bars) for both sites combined during spring *n=842* (a), summer *n=960* (b), autumn *n=440* (c) and winter *n=354* (d) for the survey years

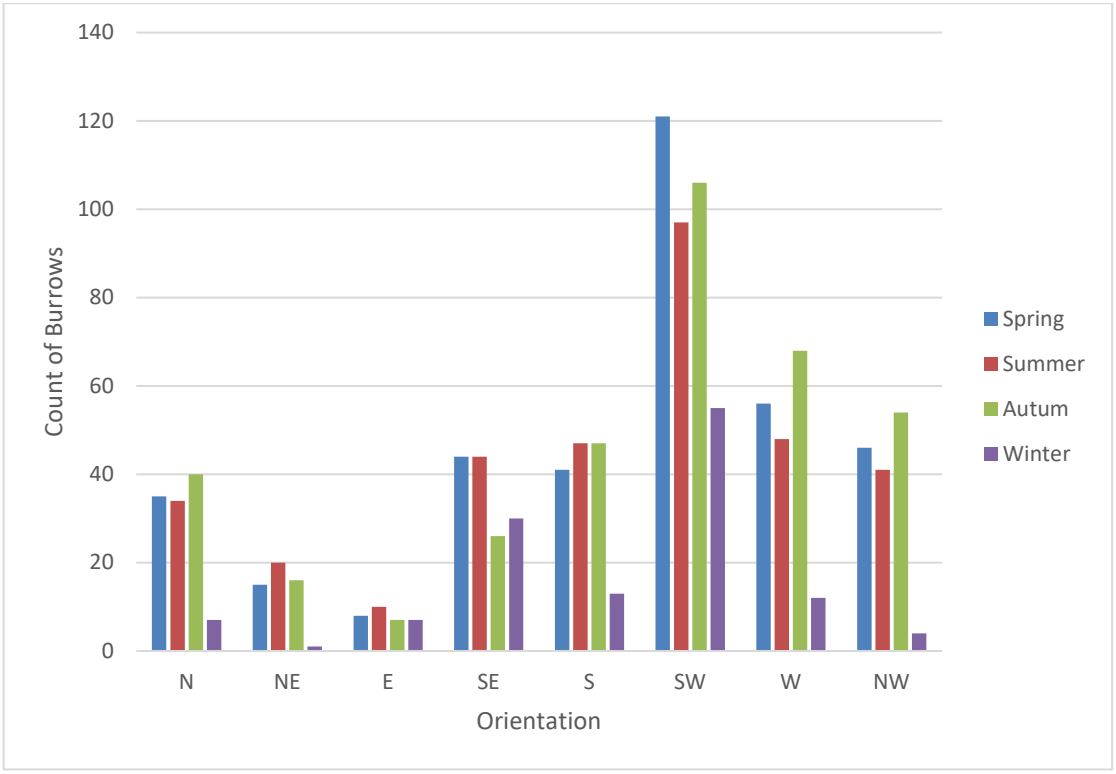


Figure 3-33. Burrow orientation by season for WAS (*N*=1200).

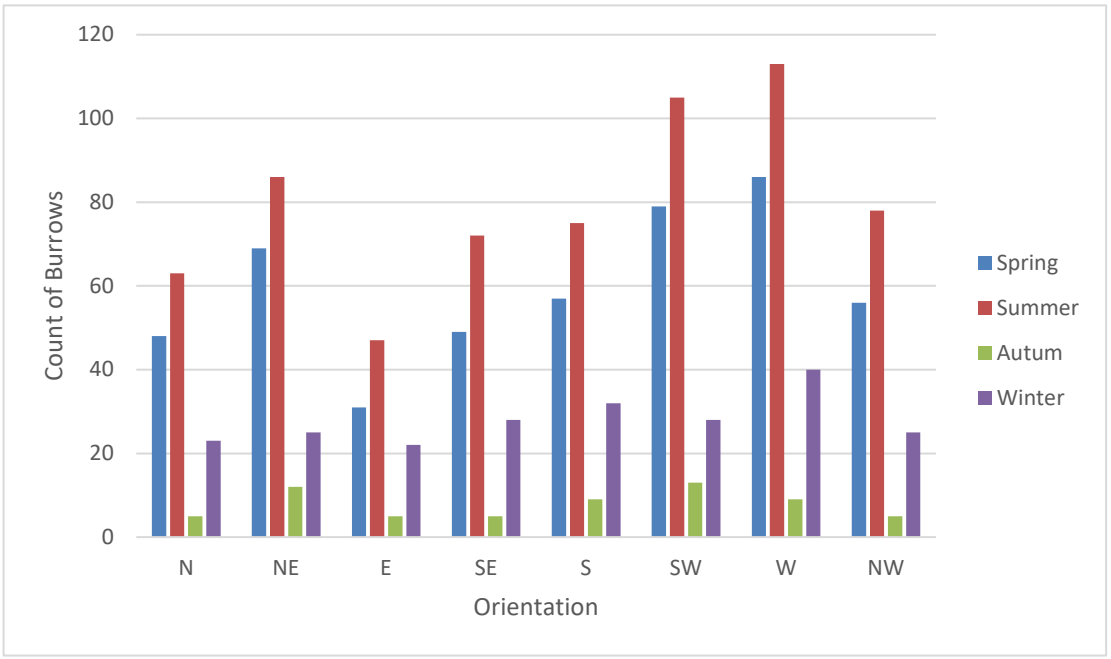


Figure 3-34. Burrow orientation by season for MUG (*N*=1400).

Examining these further to see if there was any significant difference between the burrow orientation for MUG (as season did not affect the orientation), and whether the burrow was Active, Abandoned, Inactive or Filled In for each season showed again that there was no significant difference $\chi^2(21, N = 1396) = 29.45$, $p = .104$ recorded (Figure 3-35). However, again for WAS (Figure 3-36), there was a significant difference $\chi^2(21, N = 1198) = 45.81$, $p < .001$.

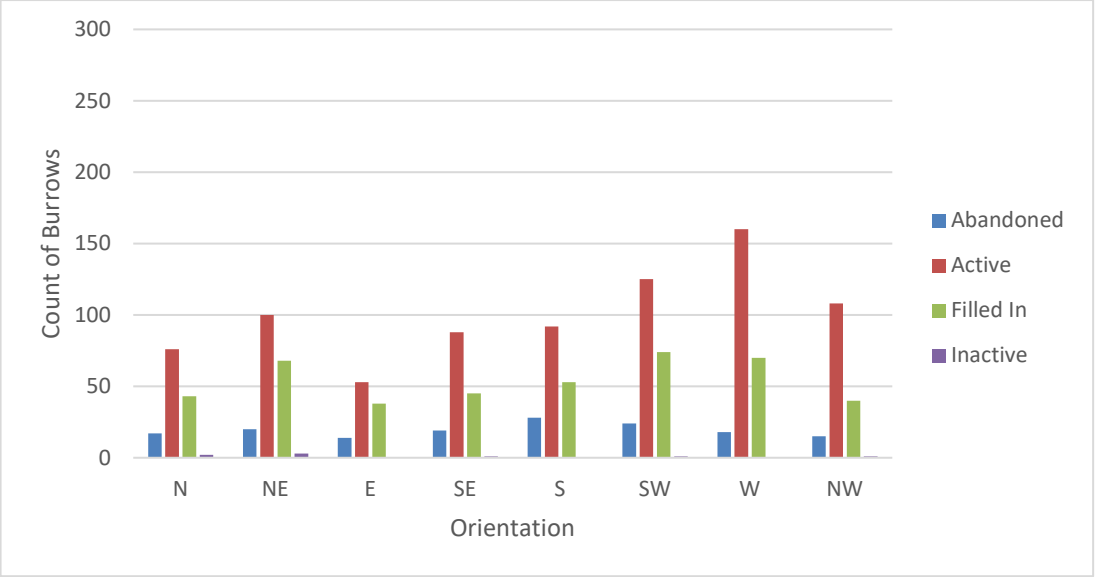


Figure 3-35. Count of burrow orientation recorded by status over the study period for MUG (*N*=1400).

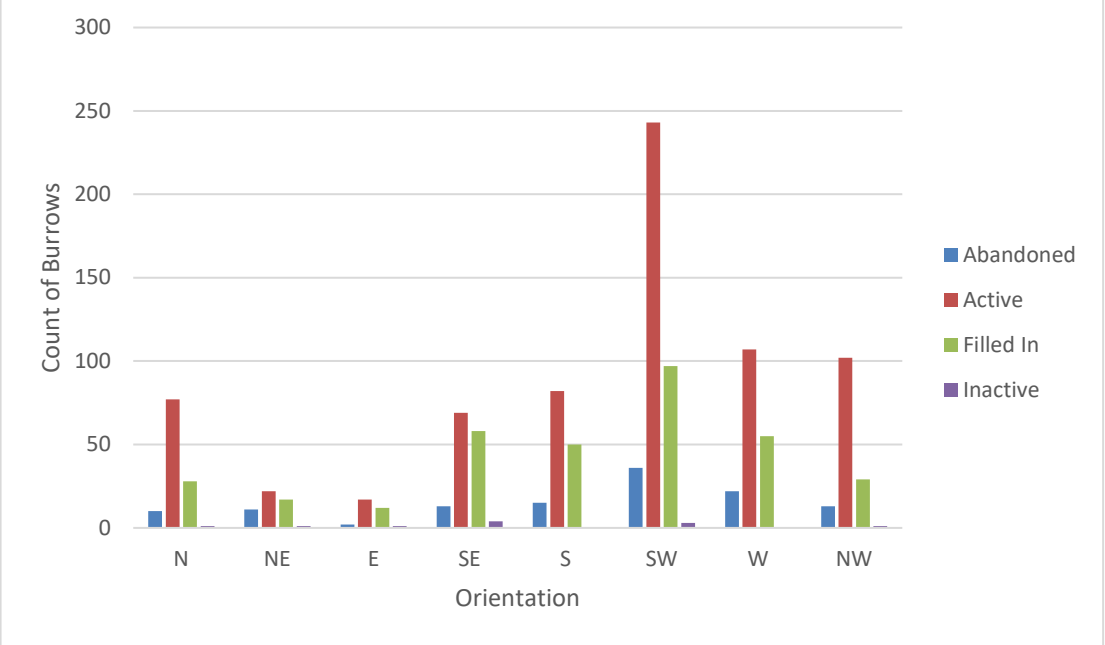


Figure 3-36. Count of burrow orientation recorded by status over the study period for WAS (*N*=1200).

When the orientation against season for the reduced number of burrows (i.e., resampled burrows were not included) was looked at for MUG and WAS pooled there was no statistical difference χ^2 (21, N=803)=29.975, p<0.0925. However, there was a significant difference between MUG and WAS in relation to burrow status and site, there was again a significant difference χ^2 (3, N=803)=8.501, p<0.0367.

Predominantly, when WAS was looked at on its own, the data suggested that burrow orientation was affected by season (χ^2 (21, N=391)=42.198, p<0.0040) and burrow status (χ^2 (21, N=391)=36.043, p<0.0216) while those burrows sampled in MUG did not show the same differences.

3.3.8 Burrow Opening

As mentioned above, of the 4,869 burrow records, there were 1,611 unique burrows surveyed, (610 of these were from WAS and 841 from MUG (Table 3-14)). The remaining burrows were those from other sites. Of the total unique burrows and when filled in and inactive burrows were removed (it was not possible to accurately measure these burrows), there were 534 remaining from all of the remaining sites where burrow measurements (width x height) were recorded. Overall, for all orientations combined, there was a large variation in burrow height, from a minimum of 1.2 cm to a maximum of 12.0 cm, while the minimum width was 6.5 cm to a maximum of 40.0 cm. Table 3-16 and Table 3-17 describe some of the basic statistics for the height and width of the burrows sampled by orientation for all sites.

Table 3-16. Basic statistics for the burrow height for each compass point for all measured active, inactive or abandoned burrows (*N*=503) throughout the study period from spring 2013 to winter 2016.

Orientation	N[a]	Min[b]	Max[c]	M[d]	95% CI[e]	Med[f]	Vari[g]	SD[h]	SEM[i]
N	56	1.2	12	6.08	5.6 to 6.5	5.7	2.9638	1.7216	0.2301
NE	41	3.5	17	6.507	5.8 to 7.2	6.5	5.5092	2.3472	0.3666
E	17	4	12	6.876	5.6 to 8.1	7	5.7557	2.3991	0.5819
SE	58	3.5	14	6.46	6.0 to 7.0	6.1	3.6842	1.9194	0.252
S	67	3	13	6.407	5.9 to 6.9	6.1	4.2907	2.0714	0.2531
SW	111	2.6	10.6	6.182	5.9 to 6.5	6	2.2862	1.512	0.1435
W	92	2.4	10	6.083	5.8 to 6.4	6	2.3863	1.5448	0.1611
NW	61	3.5	10.3	6.177	5. 8 to 6.6	6.2	2.3221	1.5239	0.1951

[a] Number; [b] Minimum; [c] Maximum; [d] Mean; [e] Confidence interval; [f] Median; [g] Variance; [h] standard deviation; [i] standard error. *11 Records were not recorded as they had no orientation attached.*

Some of the variation was recorded in sites outside of WAS and MUG and have led to wide variation in the results with burrow entrance max heights of 17 cm (Table 3-16) and max widths of 65 cm (Table 3-17). When one looks at the WAS (*N=201*) and MUG (*N=272*) data alone, the mean height 6.251 cm, SEM 0.111 and 6.245 cm, SEM 0.112 respectively for the height and 21.085 cm, SEM 0.402 and 21.345 cm, SEM 0.3414 for the width is very similar across both sites.

To determine whether there is any statistical significance, a one way ANOVA (p<0.05) looking at burrow orientation and height in WAS F(7,160)=1.929, P = 0.068 and MUG F(7,114)= 0.459, P = 0.862 and burrow orientation and width for WAS F(7,160)=1.376, P = 0.265 and MUG F(7,114)= 0.854, P =

0.545, suggest no statistical difference between these and the orientation.

Table 3-17. Descriptive statistics for the burrow width for each compass point for all measured active, inactive or abandoned (*N*=503) burrows throughout the study period from spring 2013 to winter 2016.

Orientation	N[a]	Min[b]	Max[c]	M[d]	95% CI[e]	Med[f]	Vari[g]	SD[h]	SEM[i]
N	56	7.5	40	19.91	18.8 to 21.3	18.75	28.48	5.34	0.71
NE	41	11	45	19.43	17.5 to 21.4	18.2	37.99	6.16	0.96
E	17	10.1	25.2	20.34	18.5 to 22.2	20	12.72	3.57	0.87
SE	58	6.5	65	20.66	18.5 to 22.8	21	68.63	8.28	1.09
S	67	7	35	21.51	19.9 to 23.1	20.5	42.71	6.54	0.80
SW	111	9	33	20.74	19.8 to 21.7	19.6	27.25	5.22	0.50
W	92	8	35	21.76	20.6 to 23.0	22	33.53	5.79	0.60
NW	61	7	33	22.84	21.4 to 24.3	23.1	33.75	5.81	0.74

[a] Number; [b] Minimum; [c] Maximum; [d] Mean; [e] Confidence interval; [f] Median; [g] Variance; [h] standard deviation; [i] standard error. *11 Records were not recorded as they had no orientation attached.*

A further ANOVA (p<0.05) looking at season and burrow width in WAS $F(3,742)=0.232$, p= 0.874 or for MUG $F(3,647)=1.044$, p= 0.372 and season and burrow height in WAS $F(3,164)=2.087$, P = 0.104 and MUG $F(3,118)= 0.489$, P = 0.690 suggested there was again, no significant difference between the width or height of burrows and the seasons they were recorded.

Finally, a one way ANOVA (p<0.05) looking at difference in relation to burrow height (Figure 3-37a) $F(1,299)=0.646$, P = 0.422 and burrow width (Figure 3-37b) $F(1,299)=1.229$, P = 0.268 between WAS and MUG showed no statistical difference between either site.

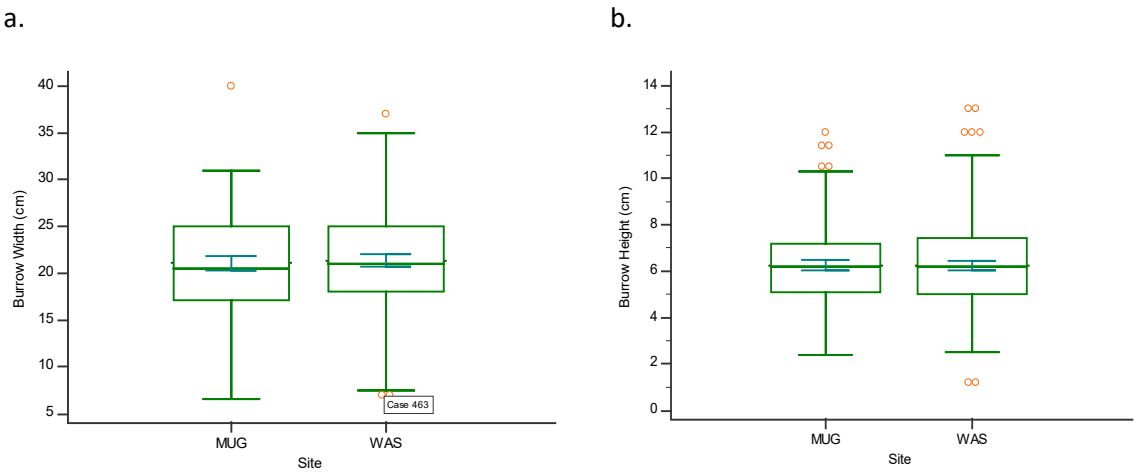


Figure 3-37 a. Comparison of the mean burrow width and Figure 3-37b mean burrow height of MUG and WAS for all unique burrows over the study period.

3.3.9 Burrow Fidelity

There was a total of 156 individual animals captured between WAS and MUG during the study. All of these were implanted with a microchip for identification at later times. Of these, 36 microchipped animals (Table 3-26, APPENDIX 3-2 and Figure 3-40) were recorded over 18 different locations (Table 3-18 and Figure 3-41) from 7th March 2015 through to 15th Jan 2019 using the RFID trap (Figure 3-11) giving a dataset of 349,360 records (APPENDIX 3-8). This was broken into two further datasets, firstly (*n=244,893 records; 70%*) animals which were recorded visiting burrows which were not considered to be their home burrow (where they were initially caught) (Figure 3-38) and secondly (*n=104,015 records; 30%*) animals recorded at what was considered to be their home burrow (the burrow the animal was initially captured in) (Figure 3-39). There were 452 records from dhub which didn't have a sex assigned to them which are not included below.

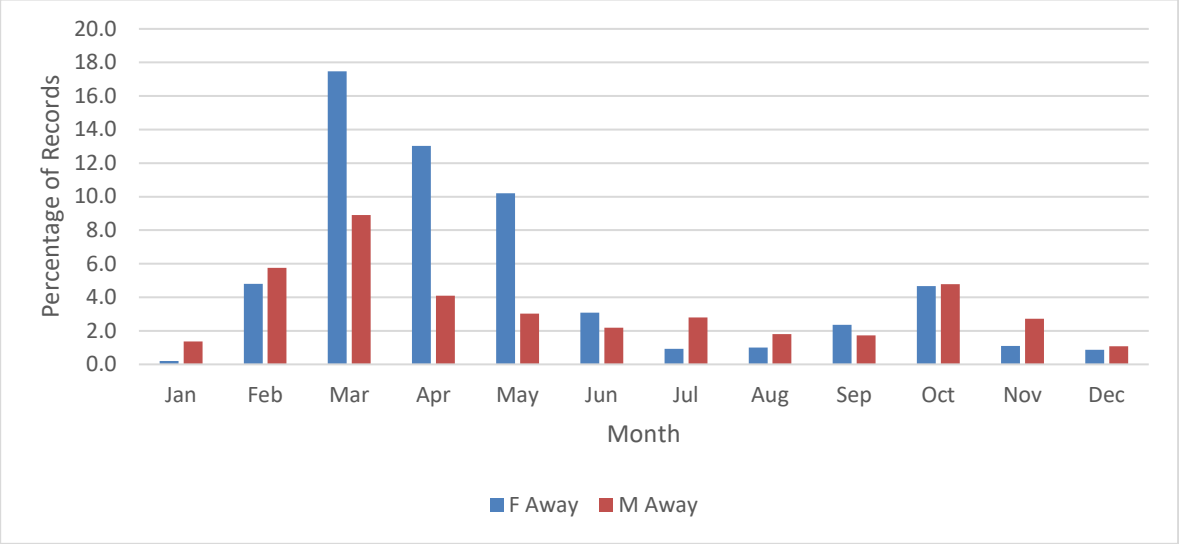


Figure 3-38. The percentage of records where females (F Away, *N*=146,254) and males (M Away, *N*=98,639) were recorded away from their home burrow for each month. There were 382 records from a single dhub whose sex was not determined.

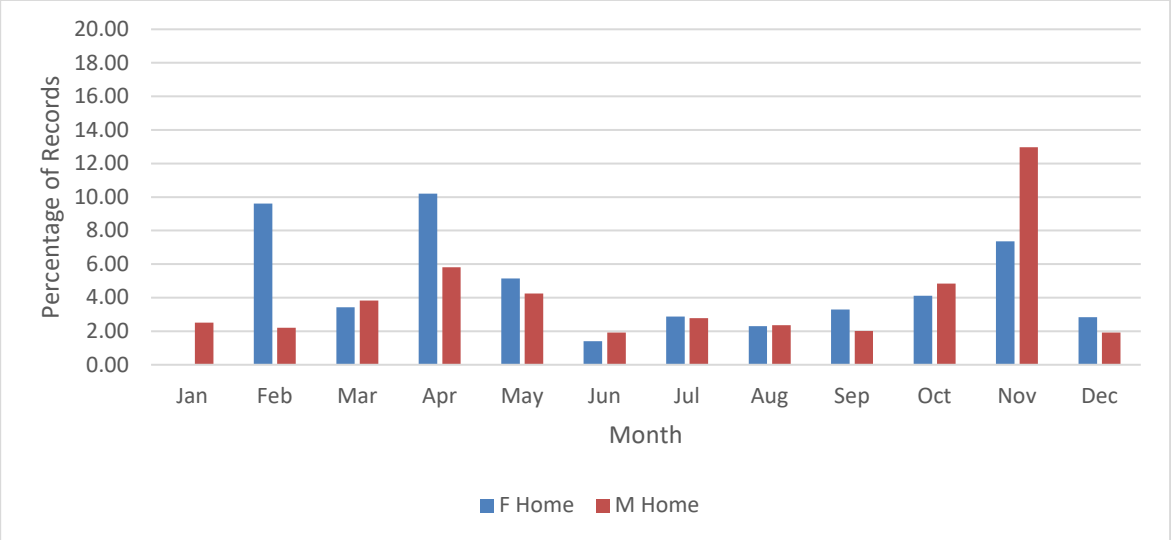


Figure 3-39. The percentage of records where females (F Home, *N*=54,707) and males (M Home, *N*=49,308) were recorded at their home burrow for each month.

Only 30% of recorded animals were recorded at their home burrow, while 70% of were recorded at a burrow which was not described as their home burrow. The peak for females investigating other burrows was March, April and May, while males had two apparent periods of investigating other burrows, February and March and again in October. Females were recorded primarily at their home burrow in February and April and again in November while males were primarily recorded at their home burrow in November (13% of records).

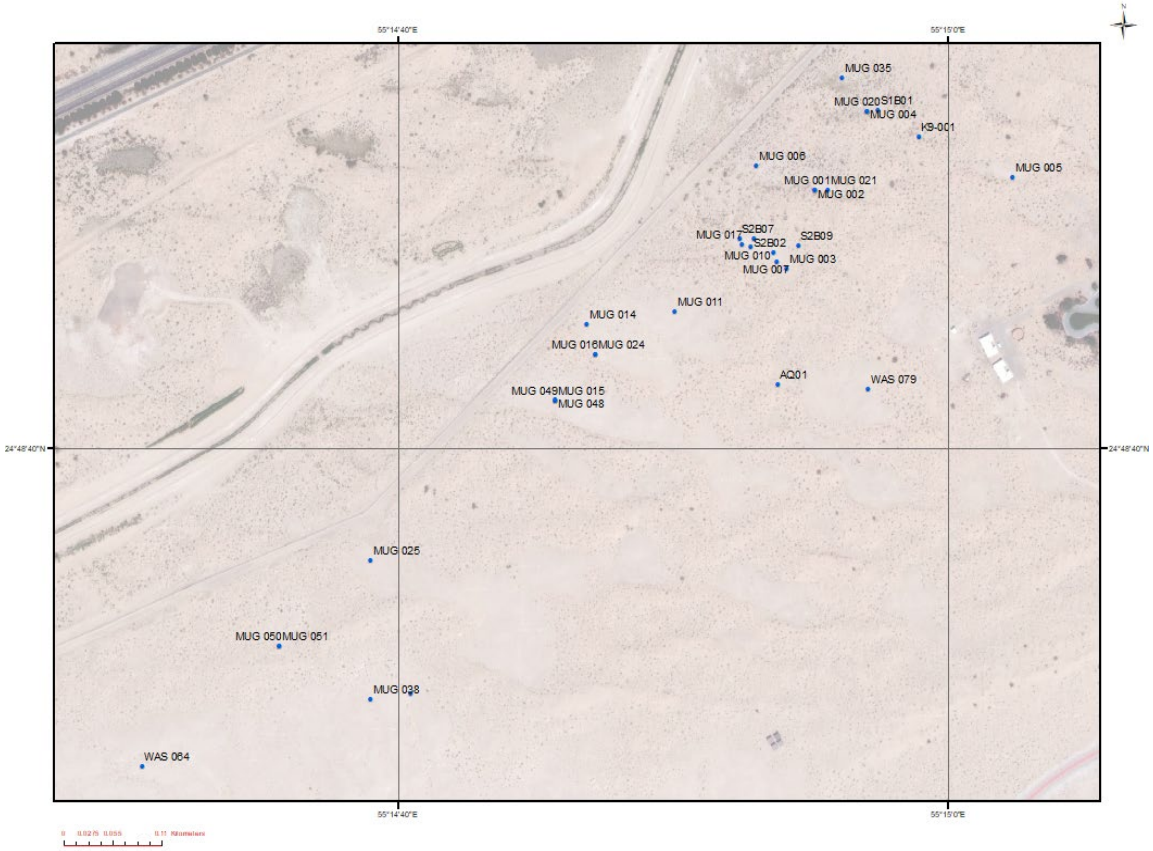


Figure 3-40. Home burrow locations of all animals captured in the RFID traps.

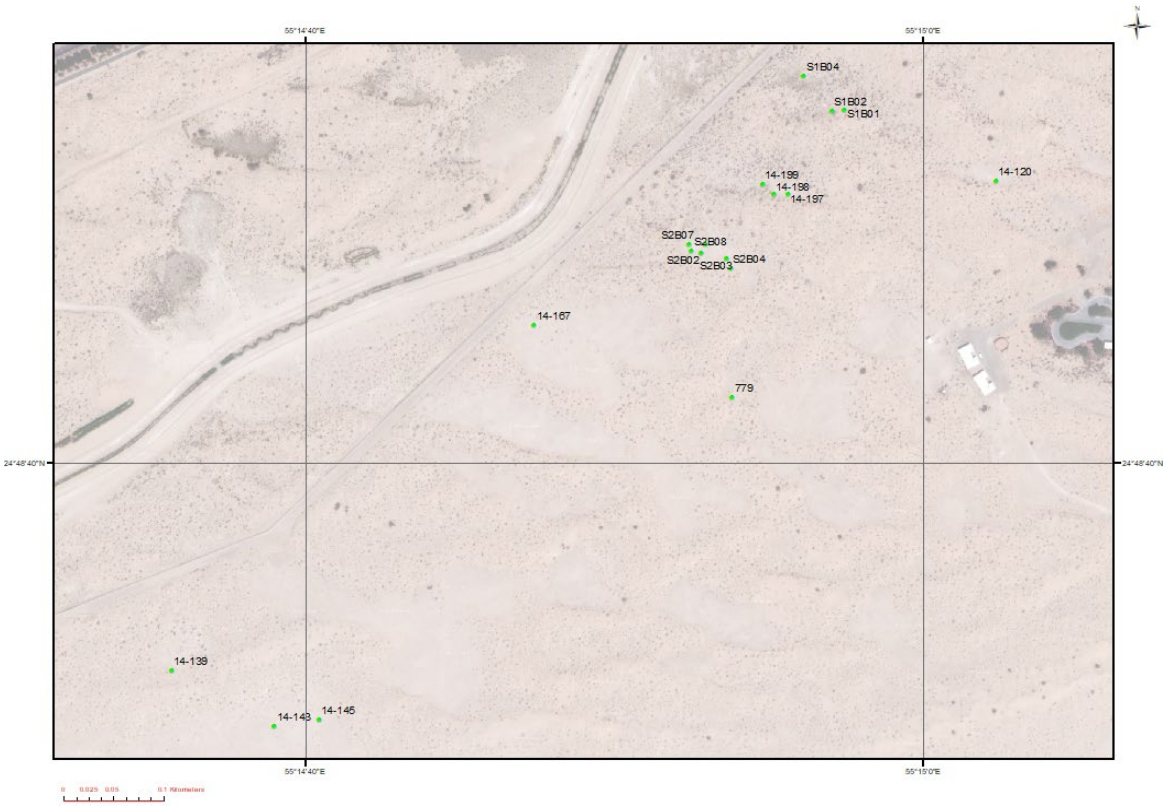


Figure 3-41. RFID trap locations in MUG

Table 3-18. Location of the seven RFID Traps from 7th March 2015 through to 15th Jan 2019 with the duration they were in place, the earliest and latest time an animal was recorded together with the total number of records.

Burrow	First Record	Last Record	Earliest Record	Latest Record	Months	Days	# of Records
14-120	11-Mar-15	24-Apr-15	07:12	18:13	1	44	803
14-139	22-Jan-16	28-Dec-18	05:25	19:11	35	1,071	9,188
14-143	15-Nov-17	13-Oct-18	06:09	19:25	11	332	103,748
14-145	29-Nov-17	15-Jan-19	06:17	18:44	14	412	3,768
14-167	10-Feb-16	25-Apr-16	07:30	17:38	2	75	977
14-197	14-Jul-17	11-Sep-18	06:10	19:25	14	424	37,960
14-198	29-May-16	23-May-18	06:42	19:09	24	724	35,954
14-199	14-Jul-17	07-Dec-18	06:52	17:48	17	511	5,713
779	04-May-17	15-Jan-19	06:20	18:53	20	621	7,122
S1B01	10-Apr-15	06-Dec-15	06:25	19:13	8	240	2,630
S1B02	13-Apr-15	11-May-16	06:32	19:04	13	394	8,960
S1B04	20-Jul-15	20-Jul-15	09:36	09:37	0	0	3
S2B01	18-Apr-15	02-May-17	06:09	19:22	25	745	24,693
S2B02	18-Apr-15	04-May-17	05:45	19:29	25	747	10,432
S2B03	08-May-15	18-Jul-17	06:05	19:29	26	802	32,992
S2B04	31-Jul-15	11-May-17	05:55	18:30	22	650	26,450
S2B07	07-Mar-15	20-Jun-15	06:42	19:13	3	105	2,862
S2B08	28-Apr-15	04-May-17	06:01	19:09	25	737	35,105

There was a total of 18 females and 15 males with 3 unidentified animals' movement captured in the RFID traps. The mean distance travelled by males (162 m SEM=26 m) and females (164 m SEM 22 m)

very similar and there was no statistical difference between the distance travelled for males or females ($t(140)=0.84$, $p=0.4047$) (Figure 3-42). Females were recorded more frequently than males with some females travelling further (maximum 370 m) from their capture burrow than males (maximum 333.7 m) (Table 3-19).

Table 3-19. Breakdown for males and females in relation to the first and last records

Observation	Female ID	Record	Male ID	Record
Earliest Recorded (Time)	MUG 015	05:55	WAS 064	05:25
Latest Recorded (Time)	S2B02	19:29	MUG 003	19:29
Furthest Distance From Capture Burrow (m)	MUG 016	370.7	MUG 004	333.7
Mean Distance Travelled (m)		162		164
Longest Monitored (Days)	MUG 015	1121	MUG 017	1118

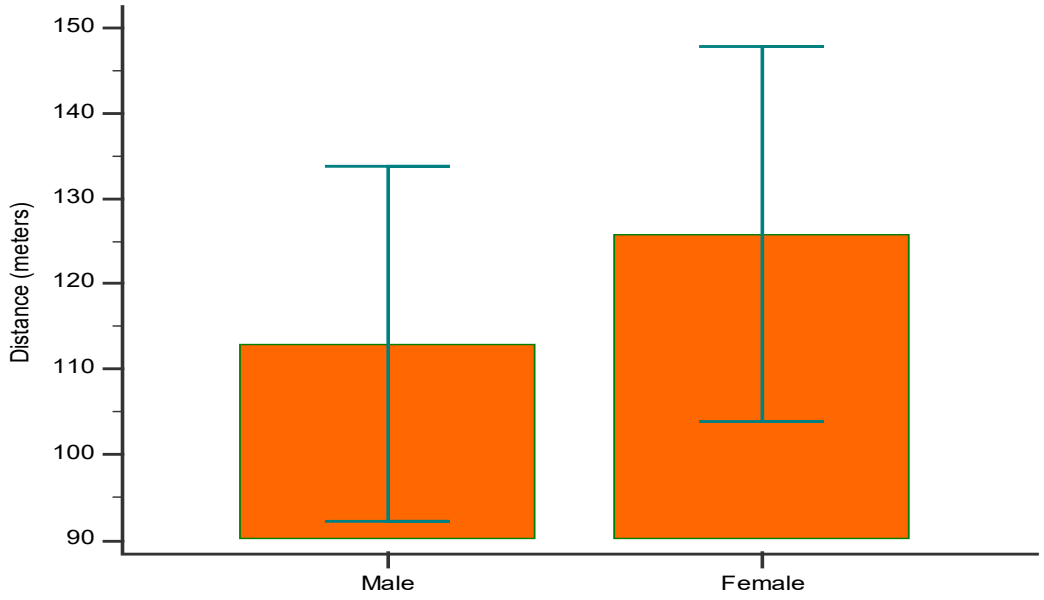


Figure 3-42**.** Mean with 95% CI for the distance travelled (meters) for males and females.

In relation to the active times, there were no great differences between males and females when one looks at the earliest and latest recordings for the animals.

The RFID trap data recorded in MUG captured a total of 167 recorded unique burrow visits (*n=349,360*) from 35 of the recorded 36 animals. MUG 50 was only ever recorded at his capture burrow. The 17 animals which had RFID traps placed on their burrows were recorded there 104,015 times in total. Female MUG 003 was never recorded in her capture burrow S2B05.

3.3.10 Active Periods

When one looks at the RFID data from a seasonal perspective, Table 3-43 suggests that the most active period is spring and in particular March and April. There is a unimodal activity pattern with most activity between 10:00 to 15:00 with a peak in the middle of the day between 12:00 to 14:00 in March, followed by April. With the onset of summer, May demonstrates the beginning of a bimodal activity period which is maintained until September. June, July and August are the least active months with large gaps (approximately 3 hours) between the time when the dhub return to their burrows in the morning and emerge again in the afternoon. From October activity increases, while the majority of activity starts from 10:00 and continues throughout the day, it does peak about mid-day. December shows a reduced activity profile, while the least activity is found in January with most activity restricted to between 09:00 and 14:00.

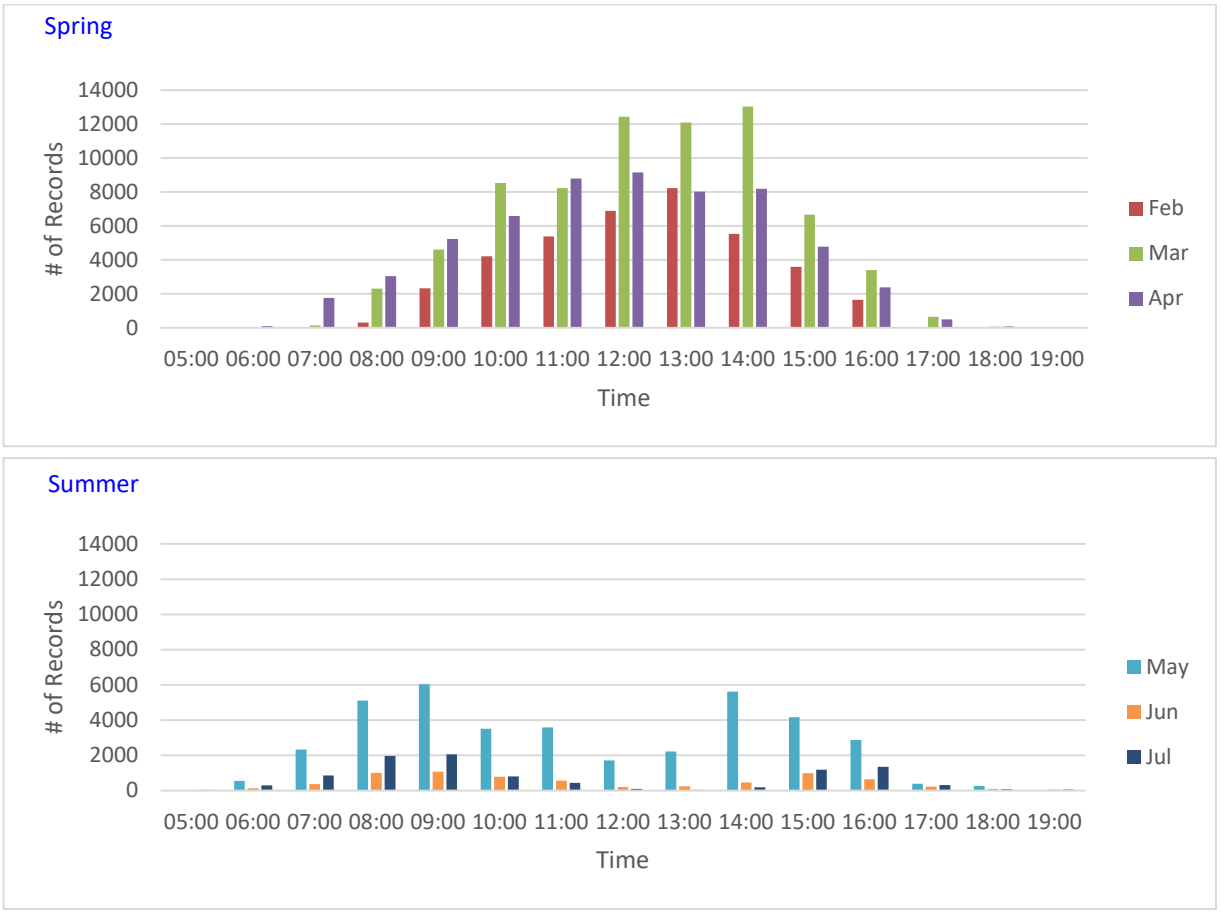


Figure 3-43 Seasonal activity profile for all RFID records

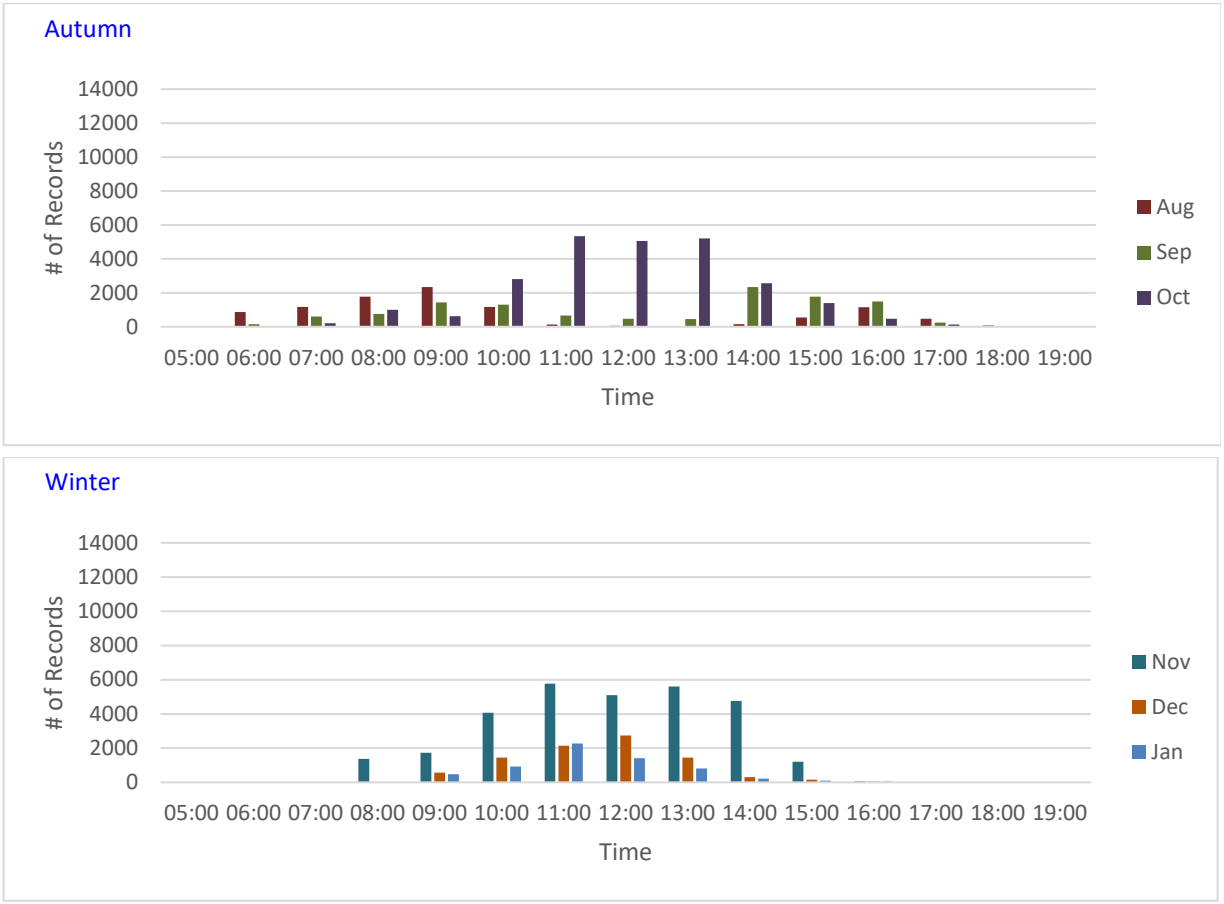


Figure 3-43 (*cont.*). Seasonal activity profile for all RFID records

Movement of dhubs captured for either Vitamin D portion of the study or translocation studies

During the Vitamin D portion of the study (Chapter 5) and as part of the translocation aspects, a total of 317 capture events of dhub were undertaken. For each event, the animal identification, burrow location plus other morphometric data were recorded. From these data 50% of the animals were caught only once (APPENDIX 3-9). 14 animals (9%) were caught more than 5 times during the study. Males were repeatedly caught slightly more often at 3.1% compared to females at 2.7%. The dhub which were recaught would generally be caught in a different burrow as captures were completed in a systematic way to reduce the likelihood of recaptures, suggesting that males were slightly more mobile than females.

3.3.11 Distance Travelled

843 m travelling between burrows was the furthest recorded for a female. This was from a translocated female (AQ01). MUG 005, who was not translocated, was the furthest a male was found from its burrow at more than 1.1 Km. Mean travel distance (excluding these two high values) was recorded as being the distance the animal moved from its first capture burrow (Figure 3-44) to the furthest of the RFID traps, was similar 128.79 m (*SEM* 11.04) for females and 112.96 m (*SEM* 10.40) for males.

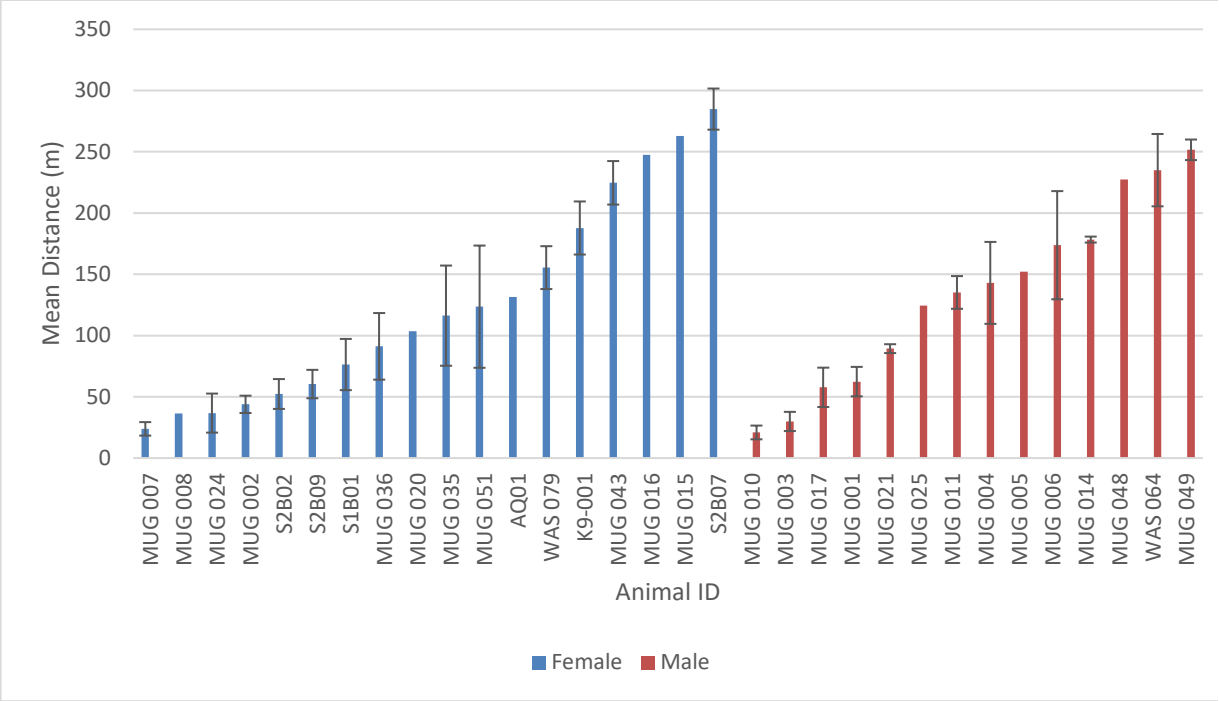


Figure 3-44. Mean distance with SEM for each animal was recorded using the RFID trap from its home burrow, where the home burrow was the burrow it was captured at originally for female and males.

Two animals MUG 050 and MUG 038 were not recorded as moving away from their initial capture burrow. Both were recorded as sub adult animals.

3.3.12 SPECIES, OTHER THAN DHUBS, ASSOCIATED WITH DHUB BURROWS.

During different aspects of this study and while recording footage for a Dubai Government sponsored Animal Planet wildlife series, numerous recording methods were used to identify dhub, to observe their behaviour or observe burrow philopatry. Several different species were observed either emerging from the burrow such as the desert monitor, or different gecko species (Figure 3-45 and Figure 3-46). There was no quantitative data recorded on burrow usage for other species.



Figure 3-45. Gecko species, most probably *Hemidactylus robustus* (Heyden's gecko) in dhub burrow.



Figure 3-46. *Cyrtopodion scabrum* (rough tailed bow foot gecko) red arrow sharing burrow of *Uromastyx* yellow arrow.



Figure 3-47. Red fox (*Vulpes vulpes arabica*) caught on camera trap looking into dhub burrow (arrow) and desert monitor (*Varanus griseus*) after emerging from the same burrow. While a young Arabian hare (*Lepus capensis*) and gerbil species explore the burrow.

3.4 DISCUSSION

3.4.1 MAXIMUM EFFECTIVE TEMPERATURES (TE) FOR DHUB

Since Cowles & Bogert (1944) first suggested the significance of thermoregulation in reptiles, there have been many attempts at quantifying the different components of thermoregulation, such as operative temperature (T_e), body temperature (T_b), target or set temperature (T_{Set}), the difference between body temperature and air temperature (T_d), selected temperature (T_{Sel}), critical thermal maximum temperature (CT_{Max}), critical thermal minimum temperature (CT_{Min}), to name a few. All of these factors relate to how the species manages its thermoregulatory behaviour. Bakken & Gates (1975) introduced the concept of T_e through successive approximations to the real situation.

Qu *et al* (2011) suggest that thermal preference and thermal tolerance differ amongst lizards that have different distributions, temporal activity pattern and habitat use, arguing that lizards in thermally more variable regions are better able to tolerate low and high temperatures. For most ectothermic terrestrial species found in areas of extreme temperature, the primary concern is not attaining high body temperature but how to avoid reaching a CT_{Max}. As such, many organisms have adapted specific thermal preferences within their fundamental niche. By comparing the physiological limits to operative body temperatures, Sunday *et al* (2014) determined that most ectotherms are incapable of surviving in open habitats through physiological thermal tolerance alone and thus must have access to thermal refugia to survive.

Brewster & Beaupre (2019) recognized that postural adjustments are an important part of behavioural thermoregulation while Stevenson (1985b) suggested that the change from a perpendicular to a parallel orientation in an ectotherm can change T_d by as much as 57%. Obviously there are many variations and subtle modifications of positional change which could control T_d more precisely. Plasman & Torres (2019) argued that even short-term variation of environmental temperature affects the performance and humoral immunity in Dickerson's collared lizard (*Crotaphytus dickersonae*) with the potential that high temperatures compromise some components of the male's immunity. Refsnider *et al* (2021) argued that both prolonged temperature increases and acute heat stress on greater short-horned lizards (*Phrynosoma hernandesi*), each of which are predicted to occur with climate change, had different cellular and/or whole organismal-level effects on lizards. Predicting the biological impacts of climate change is an ever-increasing priority for ecological research.

Generally the climate of the UAE is described as hyperarid with different bioclimatic zones (Boer, 1997). As such, understanding how the dhub responds to different temperatures is key to also understanding the means that the species uses for thermoregulation, the requirement for refugia in

translocation events as well as the potential effects of climate change. Within the current study, several different sources of data were utilised whilst determining temperatures. The primary method being iButtons which were used to record temperature and humidity data. While a number of authors have demonstrated the value of the iButtons in research projects (Roznik & Alford, 2012; Vallone *et al*, 2015; Dallmann *et al*, 2016; Fawcett *et al*, 2019), it was important to determine how reliable and relevant these sources were at delivering an accurate account of the prevailing conditions on the ground for the current study.

Temperature data recorded at the study burrows suggest that while there is a difference in the mean temperatures across the three burrow locations, it does not differ significantly from the temperatures recorded by the professional weather station. To put this in context, the mean standard error of the mean for the different locations (± 0.143 °C) differed less than the results obtained by Roznik & Alford (2012) where they found that a difference of 1.3 °C, between waterproofed and non-treated iButtons, was an acceptable value in their study. Berg *et al* (2015) reported that skin temperature (T_{sk}) was highly correlated to T_b for the *Oplurus saxicola* (marked Madagascar swift) and *O. quadrimaculatus* (Madagascar spotted spiny-tailed iguana), and *Zonosaurus laticaudatus* (western girdled lizard), which they studied. While they believed that the accuracy of their data loggers could be increased by colouring them according to the animals' backs, to mimic solar reflection and absorption, they did not find notable differences between painted and unpainted devices. As such, it is believed that the suspended iButton data from this study accurately indicates the local microclimatic conditions faced by the dhub.

While a number of studies have determined various operating temperatures for dhub, those were area- specific, Saudi Arabia (Wilms *et al*, 2011), Kuwait, etc. (Stevenson, 1985; Wilms *et al*, 2011; Sinclair *et al*, 2016; Rubalcaba *et al*, 2019), so this is the first study for the United Arab Emirates. Below will be a discussion of how the operating temperatures for dhub in the UAE and the means to achieve it, compare with these aforementioned locations/studies.

Many authors suggest that lizards exhibit temperature-dependent colour change tending to be darker in the morning to facilitate rapid warming and lighter in the heat of the day to prevent overheating (Stevenson, 1985b; Sinclair *et al*, 2016; Stephenson *et al*, 2017) and this was observed in the present research.

3.4.2 TEMPERATURES AT DIFFERENT HEIGHTS ABOVE THE GROUND

Various authors have described methods by which reptiles control their body temperature (Huey & Kingsolver, 1989; Sunday *et al*, 2014; Cox *et al*, 2018; Huey & Pianka, 2018; Michelangeli *et al*, 2018).

Stevenson (1985b) suggests that the choice of being aboveground or belowground has the greatest impact on T_b, but its effect is less than that of regulating the time of activity. This effect has been shown in the present study for the data collected for the animal burrows. Among various postural adjustments, positioning the body so as to vary heat transfer with the substrate by conduction had the greatest impact on T_b. Another mechanism utilised an elevated position such as a bush or similar elevated area to raise itself off the ground, thereby increasing the potential cooling surface area available (Figure 3-17). When the copper analogue was raised off the ground, however, there was no statistically significant difference between the temperatures versus pipe positions (RA v PG).

It was therefore concluded that while using an animal analogue, it did not matter if the analogue was on the ground or above the ground when determining the potential lumen temperature of the dhub. It is not believed that the resultant data from the analogues was faulty, rather that the thermal conduction capacity of the ground was similar to the cooling capacity of raising the body off the ground.

3.4.3 TEMPERATURES OF COPPER ANALOGUES

Hertz *et al* (1993) suggest that hollow metal or plastic pipes offer a realistic model of T_e. In the present study, the copper pipe animal analogue offered an insight into the potential body temperature if a dhub remained outside for the whole day. These temperatures could exceed 60 °C for many months of the year. As found by other researchers previously (Dzialowski, 2005; Wilms *et al*, 2011), these analogues were useful in calculating the effective temperature of their study animals. The current results demonstrated that the operative temperature T_e range was ± 19 °C (a low of 19 °C in winter to a high of 38 °C in summer). The standard error of the mean across all the study locations was extremely small at 0.1 to 0.2 °C. Similarly, there appeared to be little difference between the standard deviation, minimum or maximum values of any of the locations where the dhub analogues were placed. As there was no difference in temperatures at any of the locations recorded in MUG, it is suggested therefore that the heating and cooling behaviours observed in these locations should be the same across the study and that the animal analogue suggests that the determined T_e can be used for any of the survey animals within the Mugatrah site. Taking that there was no statistical difference between mean daily, mean maximum or mean minimum temperatures between MUG and WAS (Appendix 1) it is therefore likely that the T_e for both MUG and WAS are the same.

Not all reptile thermoregulation, however, is undertaken to heat up. As with many other species, reptiles will need to engage in some form of thermotaxis to cool down. Stevenson (1985a) suggested that animals larger than 1 kg (such as dhub) cannot heat and cool quickly enough to follow the daily cycling of the thermal environment. The current study suggested that T_e at the point of return to the

burrow was similar across all the months when thermoregulation to cool would be the primary goal. The activity patterns of animals S2B07, AQ01, S1B02 and MUG005 did not appear to be influenced by solar radiation (W/m^2) as they emerged from their burrow when the solar radiation had actually increased. Consequently, the data suggest that it is the temperature (T_e) which determines when the dhub returns to its burrow, rather than solar radiation or other environmental factors.

The bimodal emergence behaviour demonstrated by S2B07, AQ01, S1B02 and MUG005 for May 2015 when two periods, a short morning period followed by a longer afternoon period, were spent outside the burrows, suggests that the return of the animal to the burrow after the morning emergence appears to come when T_e is approached. Similarly, they emerged again between 13.00 and 14.00 staying outside until the T_{sad} temperature reached close to the T_e temperature at 17.00, when again they returned to their burrows.

Temperature and humidity data from animal tracking and monitoring phase of the study
This is the first long term study to examine the temperatures of dhub within their burrows, using the bespoke saddle (T_{sad}) to study animals in situ. The data collected confirmed the bimodal daily activities which were observed by the author in the field, which had been suggested previously by a number of authors (Cunningham, 2000b; Wilms *et al*, 2011). As demonstrated above for S2B07, AQ01, S1B02 and MUG005, the bimodal daily activities were in fact determined by seasonal factors, such as temperature. Humidity was very consistent in all the burrows where it was recorded, apart from April which would most likely be due to increased activity in the burrows (as this is the breeding season) and the possible different depths that the animals might have achieved within the burrows.

It is interesting that the humidity within the burrows remained stable with no significant difference between months, apart from April. Bulova (2002) suggested that greater tortoise burrow length and smaller entrances were correlated with greater burrow humidity. Unfortunately, there was no way of testing this in the current study as there was no depth data and the actual burrow that the animal occupied was not known either, but this could be examined in future research. Temperatures were also constant with no significant differences between sex or sex*month, but there was a significant difference in the internal temperatures for the months of March, April and May. Similar to the change in humidity, this is most likely due to the advent of the breeding season and the increased activities of the animals during this time period. It could be argued that burrows were occupied by more than one animal and that perhaps they did not retreat as far into the burrow as they could potentially do, thereby increasing their exposure to differing temperatures closer to the surface. The results from the lost data recorder (Figure 3-27) demonstrated the static nature of the burrow temperatures at 100 cm depth when not moved. It has been reported that the buffering effect of soil increases with increasing

depth and below a certain depth (20–120 cm), little variation in air temperature occurs (Whittington-Jones *et al*, 2011). This was shown in the burrow temperature data in the current study also, which showed a stable environment within the burrow. The constant temperatures allowed the animal to maintain a significant temperature within the T_{set} for the species with mean temperature in the burrow at midnight in January at 24 °C compared to 16.4 °C outside (APPENDIX 3-4).

3.4.4 BURROW ORIENTATION, SHAPE AND SIZE

White (2005) has suggested that the length and shape of a burrow for fossorial species will have an impact on the energy yield of a species. The less energy that an animal has to expend on burrow maintenance the greater the energy benefits for that species. The width and height will have a definite impact on the security of the burrow (see tight fit Figure 3-28) while the orientation could be argued to have an energetic saving in the form of burrow maintenance.

The study sites showed a number of statistical differences when the burrows were examined in detail. While there appeared to be no statistical difference between orientation at either site, there did appear to be an obvious difference between orientation and the season as well as orientation and status for WAS. The reason for this is not fully understood, but it might be related to the grazing pressure of that site which has resulted in bare sand (stabilising vegetation removed) and as a result there was far more particulate material in the air and subsequently entering the burrows. MUG showed a more generalised orientation across all the compass points. In comparison for *Uromastyx aegyptia microlepis,* Cunningham (2001a) reported in his study, 80% burrow orientation to the south and east while Wilms *et al* (2009) suggested a preference for south west and south east opening. Bouskila (1986) and Al-Ogily & Hussain (1983) did not describe any particular pattern to burrow orientation.

Although in the present study the majority of burrows recorded were oriented in a westerly direction, neither study site showed a definitive orientation when it came to burrow placement. This suggests that burrow orientation may be primarily influenced by the unique characteristics of each site and the surrounding landscape, rather than a need for a specific direction, indicating a more opportunistic approach to orientation. Indeed, dune pattern and alignment within the UAE are reported to vary considerable from area to area (Anon, 2001) and Abed & Hellyer (2001) suggest that due to soil or micro-climatic considerations, the structure and function of even adjoining areas may differ appreciably from each other. When the orientation in relation to season is examined, one finds a greater number of active burrows in the same westerly direction during the autumn period when temperatures would be highest. These orientations would primarily be due to the prevailing Shamal (El-Ghonemy, 1985) winds which are from the north west (Wilderson, 1991; Anon, 2013; NCM, 2019;

Paparella *et al*, 2019). These Shamal winds commonly occur following a cold front and are generally weaker during the summer months, but can be seasonal with gusts of up to 100 km hr^{-1} being recorded. As such, most active dunes are aligned north east to south west (Vine, 1996) with burrows predominantly facing in a west-south west direction, it would help cool burrows during the summer, while keeping them slightly warmer in the winter.

As seen, MUG showed no significant seasonal difference in recorded burrow orientation and had a more generalised orientation with burrows being recorded in many directions, which might be in part due to the density of burrows with 0.82 Ha^{-1}, which is a similar number as recorded in an Israeli study (Bouskila, 1983) compared to only 0.31 Ha^{-1} in WAS.

3.4.5 Burrow Opening

Wilms *et al* (2010) has looked at the height and width of dhub burrows, but not many other authors have investigated these parameters. In the present study, in general there did not appear to be any statistical difference in relation to the opening height or width between the sites on their own or when examined in relation to orientation, season or status, when these parameters could be recorded accurately.

As a general observation when conducting the surveys, wider burrows tended to be those where there were a number of animals in close proximity. This might have been due to a number of animals utilising the same burrow or perhaps the age of the burrow. Burrow security would be another important consideration when the height and width were being considered by the animal. As mentioned in the results, the “tight fit” seen in burrows inhabited by live dhubs may aid in defence of the burrow, as well as providing a thermal bridge enabling the dhub to maintain the constant temperatures recorded within the burrow.

Aguilar & Cruz (2010) found that the Patagonian nocturnal lizard (*Homonota darwini*) used refugia on the warmer side of slopes while Maia-Carneiro & Rocha (2013) found that Lutz's tree iguana (*Liolaemus lutzae*) built their burrows in sand dunes adjacent to the waterline, perhaps as the sand was less compact or closer to their food source rather than other environmental factors. Similarly, it is believed that dhub utilise burrows which are convenient and secure for them, close to forage sites rather than having a specific environmental requirement (Bouskila, 1985; Cunningham, 2000a, 2001a; Al-Sayegh, 2017; Al-Sayegh *et al*, 2020).

3.4.6 Burrow Fidelity

Philopatry has been described, for example in pine snakes *Pituophis melanoleucus* (Burger &

Zappalorti, 1992), amphibians (Heemeyer & Lannoo, 2012), reintroduced bearded vultures (*Gypaetus barbatus*) (Jenny *et al*, 2018) and various reptiles, but it has not been described in *Uromastyx* species. Within this study it was not possible to tell with any precision whether a burrow where an animal was captured was in fact their home burrow. However, two animals were always recorded on the RFID traps at the same burrow, while many others visited other burrows but returned to what was considered their home burrow. While site fidelity was considered to be a more important aspect for the conservation of this species, it is suggested that burrow philopatry is present, but it can also be fluid.

Tuberville *et al* (2005) suggest that the lack of adequate monitoring of translocated amphibians and reptiles meant that many people discarded translocation of these species as a viable option. The current study is the first time that RFID traps have been used to determine burrow usage and fidelity in this species.

This relied on two assumptions, the reader would pick up the visiting animal and that the animal recorded was at its home burrow when first caught and identified. Similar to the PIT tag surveys done on salmon (Gargan *et al*, 2022) the current study utilised a bespoke RFID tag reader. As an animal passed under the antennae, the identification of that animal was recorded. 13% of the animals were considered to be visiting animals with the remaining 87% of animals were recorded at their home burrow which would suggest a certain degree of burrow fidelity. While there was little difference in the mean distance travelled by males and females, the furthest distance of 370 m was that of a female. Wilms *et al* (2009) suggest that 73% of activity observed occurred in spring and early summer, while the current study puts that figure at only 60% of the records being captured during February to May which would suggest that this activity was breeding related. Of the 50% of animals which were captured more than once, only six females were recaptured in the same burrow and 20 males suggesting that females were far more mobile than males.

As there is a lack of work completed on burrow selection in *Uromastyx* in relation to the breeding season, it is suggested that this peak movement of females in April might be an effort on behalf of the females to source a better burrow or search for potential mates but would suggest that there is large movement prior to the main breeding month of May. Males on the other hand have been seen to actively enter burrows and drag females out for mating purposes, suggesting that their investigation of alternative burrows would primarily be linked with ensuring that females are within the burrow and available for breeding, with December and January being the least active months (Chapter 2).

While a number of authors suggest that one sex tends to be more philopatric than the other, thereby

reducing the possibility of inbreeding (Greenwood, 1980; Burger & Zappalorti, 1992; Tuberville *et al*, 2005; Heemeyer & Lannoo, 2012) this was not immediately obvious in this study with adult dhub. This might be the case with juvenile dhub, which were not captured due to the net size. As such, the data from the present study, while indicating inter-burrow animal movement, did not reveal any significant long-range movements.

3.4.7 SPECIES, OTHER THAN DHUBS, ASSOCIATED WITH DHUB BURROWS.

While no effort was made to specifically capture data on species utilising the burrows, at different points in the study, as information became available it was noted. On numerous occasions different gecko species were seen entering and leaving the burrows. The Arabian red fox was observed on a number of occasions visiting the burrows. While the video did not show the animal investigating the burrow in detail, the burrow would potentially provide refuge for small reptiles if needed. Throughout the study, there was never any snake tracks outside the burrow indicating that of the burrows investigated, snakes did not use the burrows. There have been no other reports in the literature looking specifically at the association of other species with dhub burrows.

3.4.8 CONCLUSION

The operative temperatures T_e is the predicted equilibrium temperatures of non-regulating ectotherms i.e. body temperatures that non-regulating animals would achieve. This was estimated to have a range of ± 19 °C (19 °C to 38 °C). As the determination of T_{set} was considered to be a welfare issue, those already determined (Zari, 1991; Al-Johany, 2003) were used during the study.

The bimodal summer behaviours as reported by a number of authors was also demonstrated and it was determined that it was when the outside temperature approached the T_e value that the animal returned to its burrow. The level of UV-B did not appear to affect any of its behaviours and the thermotactic requirement for shelter, as the animal reached T_{max}, was the driving force.

While a number of studies have looked at the orientation of burrow openings, this study had by far the most data available and the predominant orientation differed from other research. The opening width and height did not differ significantly across the study sites, and it is believed that the shape and size is directly related to the animal's defence and cooling during the summer. It could be argued that temperatures and humidity were constant when the animal was in the burrow and certainly protected it from extremes above ground. It is suggested that the high levels of humidity recorded reduced the evaporative effects of the heat on the animal and assisted as a means of water conservation, but would require further investigation to prove conclusively.

Only one dhub, a juvenile male, did not venture away from its original home burrow while the RFID trap was present. All others were found to travel in the region of 120 to 130 m from their burrow. This was corroborated with the data from the repeat captures where only a few animals were caught in the same burrow repeatedly. While philopatry has been suggested in a number of species, the current study showed a large degree of burrow fidelity, which taken in context of the mean distance dhub travelled between burrows would suggest that *Uromastyx aegyptia leptieni* were also philopatric. Proximity to forage sites and low disturbance would be a primary driver for burrow selection.

3.4.9 FUTURE STUDIES

This study was limited in the number of RFID traps at its disposal. As they were bespoke and designed specifically for this project, they have proved to be very successful in what they were designed to do. They ensured an accurate identification of dhub, they ensured that disturbance in relation to observer bias was removed or dramatically reduced. While this study was an initial effort to establish a baseline in relation to burrow choice and fidelity it would be important to perhaps establish more RFID traps in several colonies within close proximity to get a better understanding of potential gene flow. Evidence collected from different facets of the study indicate that dhub for whatever reason simply vacate a burrow. For translocation projects to succeed it would be important to understand why this is happening.

A further area of interest would be the exact reasons why burrow orientation was season dependent in WAS. Again, these are extremely important considerations to consider when designing future conservation projects for the species.

3.5 REFERENCE

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3.6 APPENDIX

APPENDIX 3-1 – ANIMAL CAPTURE DETAILS

Table 3-20. The animal id, burrow, date, and time an animal was first and last recorded, number of days between the first and last time the animal was recorded with the total number of records and the maximum distance the animal travelled from their home burrow when captured in the RFID trap.

Dhub	Sex	Burrow	First Date	Last Date	First Time	Last Time	Days	Total Records	Distance (m)
AQ01	F	779	18/06/2015	09/01/2018	07:43	18:30	936	2,953	141.8
K9-001	F	15-028	21/06/2016	21/06/2016	09:43	09:54	0	15	187.8
MUG 001	M	14-198	09/05/2015	07/12/2018	06:10	19:25	1,308	43,990	100.0
MUG 002	F	14-198	02/06/2016	07/12/2018	06:42	19:09	918	32,669	85.0
MUG 003	M	S2B05	11/06/2015	01/08/2016	09:02	19:29	417	276	43.9
MUG 004	M	S1B02	10/04/2015	04/06/2016	06:30	19:13	421	11,104	333.7
MUG 005	M	14-120	14/03/2015	09/06/2015	07:12	18:13	87	577	152.1
MUG 006	M	Dhub215	18/03/2015	14/08/2015	08:09	17:37	149	131	261.8
MUG 007	F	S2B04	06/09/2015	16/09/2015	09:30	16:32	10	54	31.7
MUG 008	F	S2B01	19/04/2015	23/11/2018	06:09	19:22	1,314	22,691	88.1
MUG 010	M	S2B03	26/04/2015	14/11/2016	06:05	19:25	568	32,394	36.5
MUG 011	M	Dhub225	15/08/2015	31/05/2018	06:10	19:08	1,020	32,663	194.0
MUG 014	M	14-168	14/05/2015	21/10/2015	08:49	16:34	160	19	183.2
MUG 015	F	14-169	23/04/2015	18/05/2018	05:55	18:22	1,121	17,918	329.8
MUG 016	F	14-166	11/06/2015	24/06/2018	06:20	18:53	1,109	2,784	370.7
MUG 017	M	S2B08	19/04/2015	01/12/2018	05:45	19:16	1,322	13,462	139.0
MUG 020	F	S1B02	20/07/2015	16/04/2017	07:41	18:29	636	11,937	180.1
MUG 021	M	14-197	07/10/2015	11/05/2016	07:08	17:19	217	1,335	92.9
MUG 024	F	14-166	18/04/2016	25/04/2016	09:47	13:28	7	18	36.7
MUG 025	M	14-149	01/05/2016	14/05/2016	10:11	11:00	13	20	124.4
MUG 035	F	S1B04	07/10/2015	21/06/2016	10:39	16:36	258	6	189.5
MUG 036	F	14-145	14/05/2018	10/06/2018	10:53	17:28	27	40	141.1
MUG 038	U	14-143	14/08/2016	20/06/2018	06:58	18:06	675	396	106.1
MUG 043	F	14-160	12/09/2018	15/01/2019	06:30	18:40	125	1,667	224.7
MUG 048	M	14-170	20/05/2018	20/05/2018	15:16	15:16	0	2	227.3

Table 3-20. *continued*. The animal id, burrow, date and time animal was first and last recorded, number of days the trap was in place with the total number of records and the maximum distance the animal travelled when captured in the RFID trap.

Dhub	Sex	Burrow	First Date	Last Date	First Time	Last Time	Days	Total Records	Distance (m)
MUG 049	M	14-169	06/04/2017	22/04/2018	10:04	13:20	381	36	263.2
MUG 050	M	14-139	23/10/2016	12/05/2017	06:39	18:33	201	4,510	0
MUG 051	F	14-139	14/07/2017	28/12/2018	06:09	19:25	532	104,310	141.1
NoID01	NR		18/04/2015	17/05/2015	06:25	19:18	29	33	
NoID02	NR		18/04/2015	18/07/2017	06:31	15:47	822	23	
S1B01	F	S1B01	06/06/2015	08/05/2018	10:16	17:05	1,067	146	100.8
S2B02	F	S2B02	19/04/2015	06/05/2018	06:12	19:29	1,113	3,005	175.2
S2B07	F	S2B07	07/03/2015	12/03/2015	09:47	17:14	5	167	284.9
S2B09	F	S2B09	19/04/2015	20/04/2015	09:36	15:30	1	435	60.4
WAS 064	M	14-135	22/01/2016	15/01/2019	05:25	19:11	1,089	7,428	282.6
WAS 079	F	14-123	24/05/2016	30/10/2018	06:54	17:51	889	146	185.4

*Both animals were recorded but no information regarding the dates they had microchips implanted, or where they were caught from were found. *M=Male, F=Female, NR=Not Recorded and U=Unsure*.

†MUG 050 has a recorded max distance travelled of 0 as this was his capture burrow and has only been recorded there.

APPENDIX 3-2 - COPPER ANALOGUE DETAILS

Copper Analogue ANOVA

Table 3-21. One way ANOVA of mean monthly temperatures recorded at three different locations. These included records from three iButtons (14-155, D21 and H07) held within a copper tube as an animal analogue.

Month	DF	Adj SS	Adj MS	F-Value	P-Value
Jan	2	14.80	7.402	0.07	0.935
Feb	2	12.86	6.431	0.05	0.948
Mar	2	16.54	8.271	0.06	0.938
Apr	2	20.1	10.03	0.07	0.934
May	2	11.7	5.863	0.04	0.963
Jun	2	17.7	8.851	0.06	0.944
Jul	2	7.59	3.797	0.03	0.972
Aug	2	16.38	8.189	0.06	0.944
Sep	2	12.9	6.445	0.04	0.957
Oct	2	19.90	9.952	0.07	0.929
Nov	2	12.30	6.148	0.05	0.948
Dec	2	14.34	7.169	0.07	0.936

Table 3-22.One way ANOVA of maximum temperatures recorded at four different locations. These included unshaded records from three iButtons (14-155, D21 and H07) as well as temperatures from a fan aspirated professional grade Davis weather station.

Month	DF	Adj SS	Adj MS	F-Value	P-Value
Jan	3	114.0	38.00	0.72	0.540
Feb	3	190.9	63.62	1.37	0.258
Mar	3	254.4	84.79	0.78	0.509
Apr	3	154.4	51.47	0.58	0.630
May	3	170.4	56.79	0.67	0.572
Jun	3	88.73	29.58	0.40	0.756
Jul	3	139.1	46.37	0.66	0.580
Aug	3	168.3	56.11	0.80	0.496
Sep	3	265.0	88.34	0.98	0.406
Oct	3	183.9	61.31	0.91	0.440
Nov	3	73.18	24.39	0.46	0.710
Dec	3	0.63	0.2100	0.00	1.000

Table 3-23. One way ANOVA of minimum temperatures recorded at four different locations. These included unshaded records from three iButtons (14-155, D21 and H07) as well as temperatures from a fan aspirated professional grade Davis weather station.

Month	DF	Adj SS	Adj MS	F-Value	P-Value
Jan	3	41.87	13.96	1.21	0.312
Feb	3	31.64	10.55	0.44	0.726
Mar	3	53.02	17.67	0.76	0.518
Apr	3	0.85	0.2838	0.01	0.999
May	3	20.90	6.966	0.12	0.947
Jun	3	53.94	17.98	0.36	0.781
Jul	3	41.01	13.67	0.29	0.830
Aug	3	12.45	4.150	0.10	0.961
Sep	3	13.57	4.522	0.08	0.971
Oct	3	9.29	3.096	0.07	0.977
Nov	3	32.02	10.67	0.51	0.676
Dec	3	14.82	4.940	0.22	0.882

Table 3-24. One way ANOVA of maximum monthly temperatures for the animal analogue from three burrows 14-155, D21 and H07 held within a copper tube as an animal analogue.

Month	DF	Adj SS	Adj MS	F-Value	P-Value
Jan	2	27.42	13.71	0.10	0.904
Feb	2	15.08	7.540	0.06	0.942
Mar	2	35.5	17.73	0.10	0.907
Apr	2	19.9	9.941	0.05	0.951
May	2	30.9	15.44	0.08	0.922
Jun	2	25.0	12.52	0.07	0.932
Jul	2	13.1	6.550	0.04	0.961
Aug	2	9.1	4.552	0.03	0.973
Sep	2	24.3	12.15	0.07	0.934
Oct	2	59.2	29.59	0.18	0.832
Nov	2	39.7	19.87	0.14	0.873
Dec	2	46.1	23.07	0.16	0.856

Table 3-25. One way ANOVA of minimum monthly temperatures for the animal analogue from three burrows 14-155, D21 and H07 held within a copper tube as an animal analogue.

Month	DF	Adj SS	Adj MS	F-Value	P-Value
Jan	2	0.20	0.1025	0.01	0.995
Feb	2	4.69	2.343	0.06	0.946
Mar	2	1.94	0.9682	0.03	0.969
Apr	2	10.87	5.435	0.10	0.907
May	2	12.01	6.006	0.06	0.945
Jun	2	17.33	8.664	0.08	0.925
Jul	2	1.74	0.8699	0.01	0.991
Aug	2	15.19	7.593	0.07	0.929
Sep	2	0.70	0.349	0.00	0.997
Oct	2	3.27	1.636	0.02	0.984
Nov	2	0.29	0.1449	0.00	0.995
Dec	2	9.29	4.647	0.12	0.891

APPENDIX 3-3 – BURROW VISIT DETAILS

Table 3-26. Number of times animals visited different burrows which were not considered their home burrows.

Dhub	14-120	14-139	14-143	14-145	14-167	14-197	14-198	14-199	779	S1B01	S1B02	S1B04	S2B01	S2B02	S2B03	S2B04	S2B07	S2B08
AQ01									66				5		3	7		1
K9-001																1		
MUG 001						214	52	42		1	1		12	3	10	15		4
MUG 002						16	246	90						1	1	1		
MUG 003													8	5	9	17		
MUG 004	2				50		2			43	128		3	5	1			4
MUG 005	35									2								
MUG 006	3									2	5							
MUG 007													3	1	4	3		
MUG 008						12		114					424	31	5	6	2	11
MUG 010													22	18	453	18	4	14
MUG 011						1	5	2	1				14	43	11	8		429
MUG 014														1			1	3
MUG 015								1					3	1	31	213	4	3
MUG 016						1	2	3	94	2	2		6	1	8	9		3
MUG 017						1	3	4	3				22	295	18	14	20	170
MUG 020							188			1	8	1	1		2	11		1
MUG 021										9	9							
MUG 024					2													
MUG 025		3																
MUG 035							1			1								1
MUG 036		2	3	1														
MUG 038		6	6	1														
MUG 043									106									

Table 3-2627. (*continued*) Number of times animals visited different burrows which were not considered their home burrows.

Dhub	14-120	14-139	14-143	14-145	14-167	14-197	14-198	14-199	779	S1B01	S1B02	S1B04	S2B01	S2B02	S2B03	S2B04	S2B07	S2B08
MUG 048									1									
MUG 049									1				1		1	2		
MUG 050		84																
MUG 051		22	169	50														
NoID01										1	1		2	3	1		1	
NoID02											1		2	1	1		1	1
S1B01						1	2	2		16	9							
S2B02						1	2	2			1		29	86	3	5	2	14
S2B07	2																2	
S2B09																	2	
WAS 064		201	19	124														
WAS 079									12				1	1	2	1		

3.6.1 Distance From Burrows

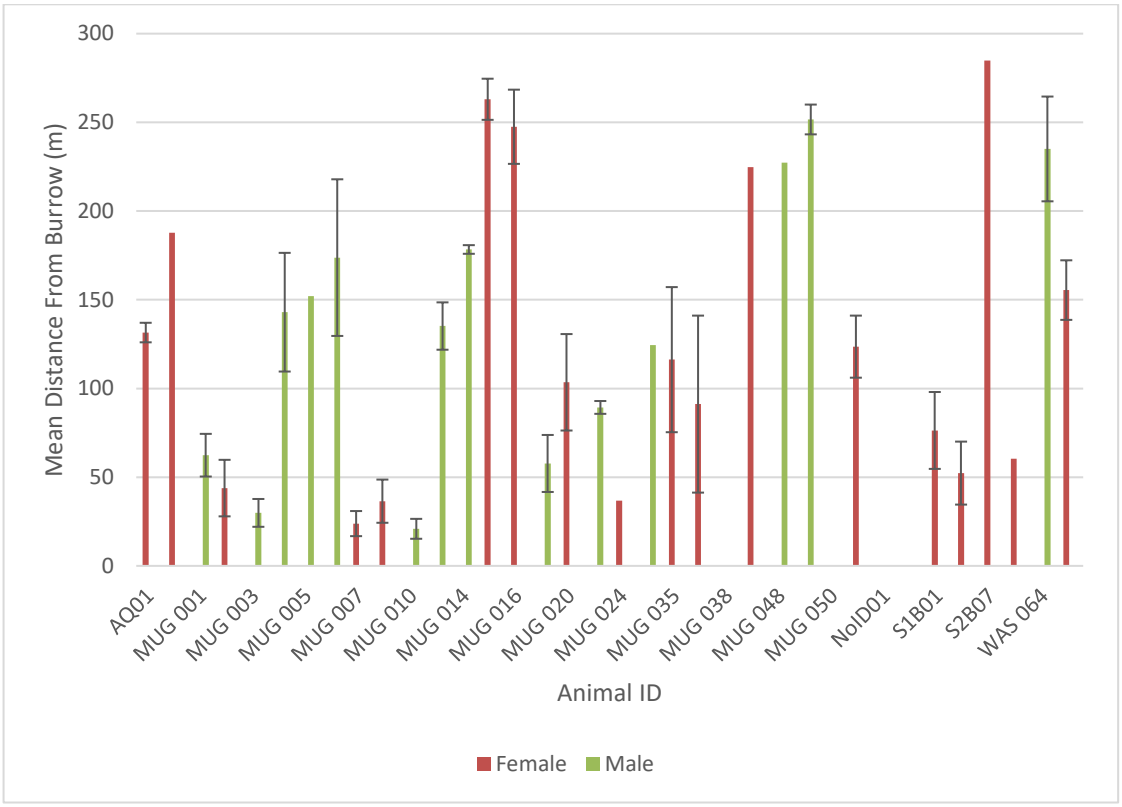


Figure 3-48. The mean distance an animal was recorded from its home burrow

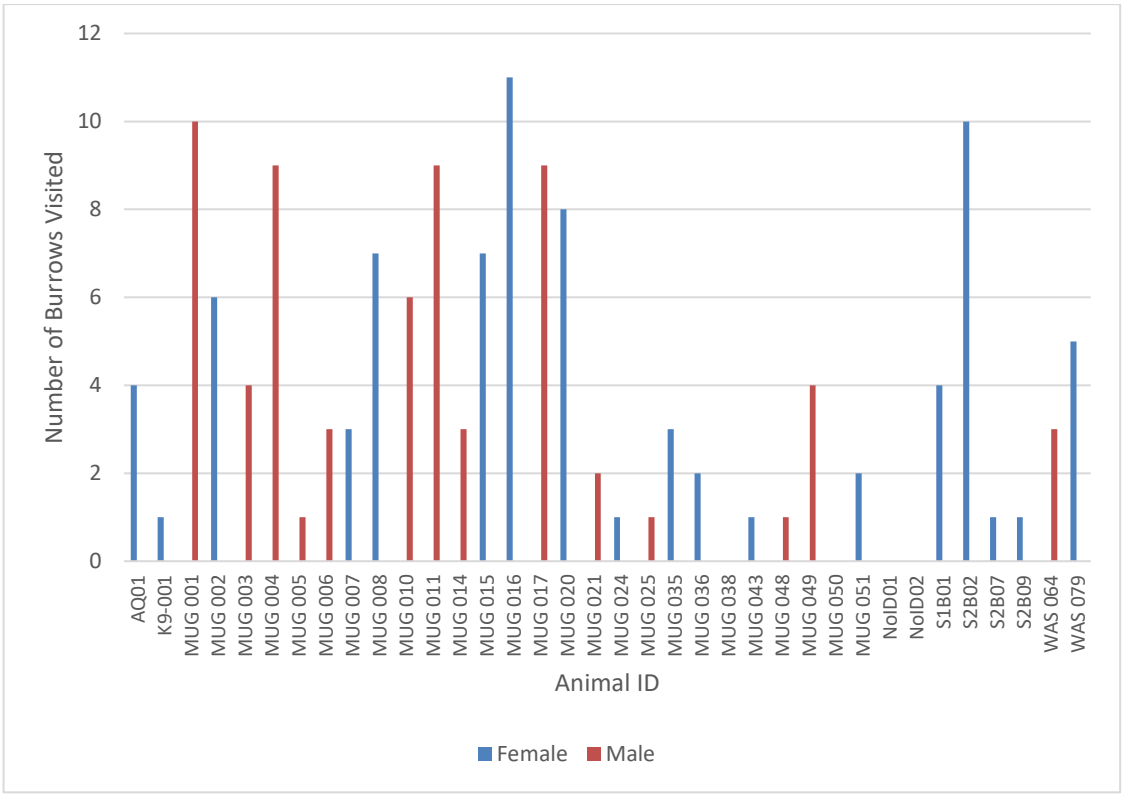


Figure 3-49. The number of burrows an animal was recorded visiting on the RFID trap.

3.6.2 Mean, maximum and minimum Mugatrah and Wadi Al Safa Temperatures 2006 to 2019

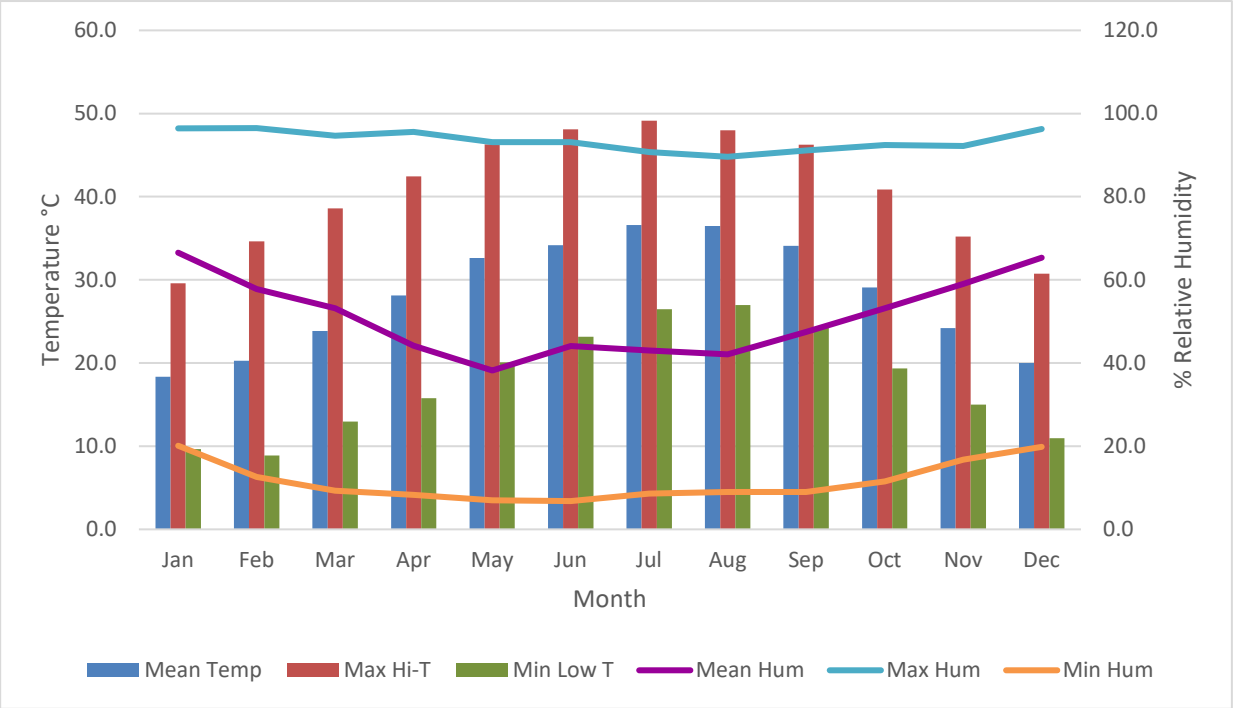


Figure 3-50. Mean, maximum (Max) and minimum (Min) temperatures (Temp) and humidity (Hum) for Mugatrah from 2006 through to 2019, taken from the on-site Davis Weather Station.

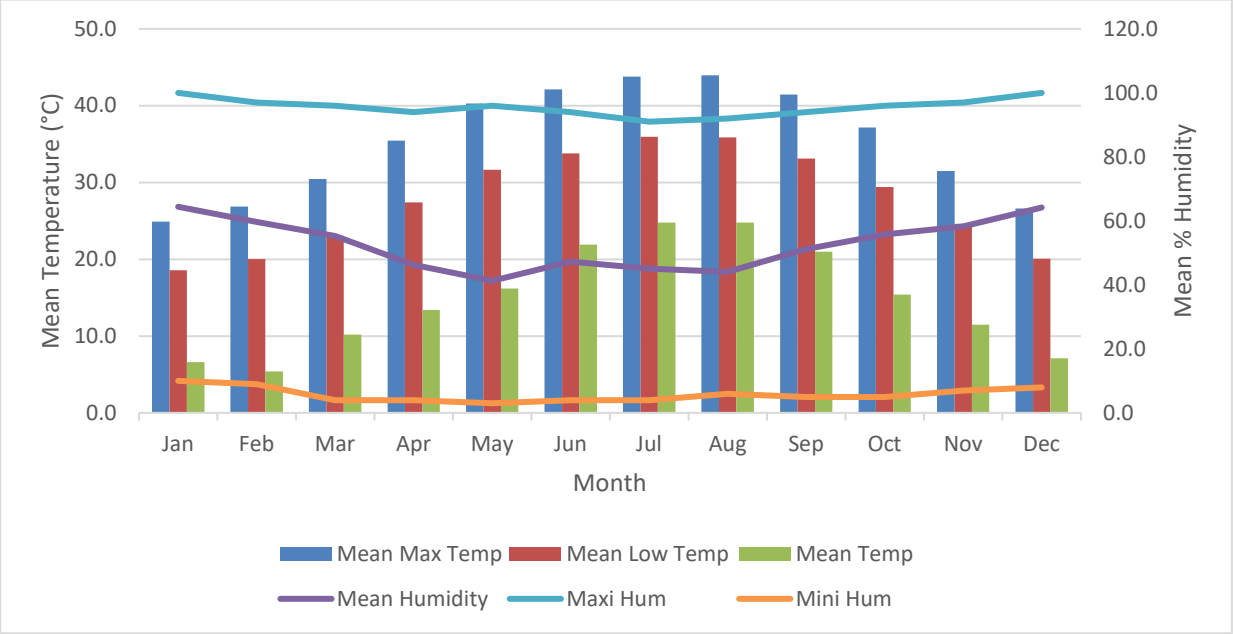


Figure 3-51. Mean, maximum (Max) and minimum (Min) temperatures (Temp) and humidity (Hum) for Wadi Al Safa from 2006 through to 2019, taken from the on-site Davis Weather Station.

3.6.3 Basic Statistics for Temperatures

Table 3-28. Results from the 2-sample t-test mean WAS and Mug temperatures.

	Sample 1	Sample 2
Sample size	366	366
Arithmetic mean	27.7814	28.1281
95% CI for the mean	27.1399 to 28.4229	27.4616 to 28.7947
Variance	38.9452	42.0472
Standard deviation	6.2406	6.4844
Standard error of the mean	0.3262	0.3389

F-test for equal variances	P = 0.464

T-test (assuming equal variances)

Difference	0.3467
Pooled Standard Deviation	6.3637
Standard Error	0.4704
95% CI of difference	-0.5768 to 1.2703
Test statistic t	0.737
Degrees of Freedom (DF)	730
Two-tailed probability	P = 0.4613

Table 3-29. Results from the 2-sample t-test maximum WAS and Mug temperatures.

	Sample 1	Sample 2
Sample size	366	366
Arithmetic mean	28.1077	28.6869
95% CI for the mean	27.4636 to 28.7517	28.0121 to 29.3617
Variance	39.2590	43.0989
Standard deviation	6.2657	6.5650
Standard error of the mean	0.3275	0.3432

F-test for equal variances	P = 0.373

T-test (assuming equal variances)

Difference	0.5792
Pooled Standard Deviation	6.4171
Standard Error	0.4744
95% CI of difference	-0.3520 to 1.5105
Test statistic t	1.221
Degrees of Freedom (DF)	730
Two-tailed probability	P = 0.2225

Table 3-30. Results from the 2-sample t-test minimum WAS and Mug temperatures.

	Sample 1	Sample 2
Sample size	366	366
Arithmetic mean	27.4557	27.5593
95% CI for the mean	26.8168 to 28.0947	26.9019 to 28.2167
Variance	38.6373	40.9053
Standard deviation	6.2159	6.3957
Standard error of the mean	0.3249	0.3343
F-test for equal variances	P = 0.586	

T-test (assuming equal variances)

Difference	0.1036
Pooled Standard Deviation	6.3064
Standard Error	0.4662
95% CI of difference	-0.8117 to 1.0188
Test statistic t	0.222
Degrees of Freedom (DF)	730
Two-tailed probability	P = 0.8243

A 2-sample t-test was conducted to compare the mean daily temperature of WAS to MUG from 2007 through to June 2019 t(730)=0.737, *p*=0.461. Similarly, mean max temperature t(730)=1.221, *p*=0.223, mean minimum temperatures t(730)=0.222, *p*=0.824 and

Table 3-31. Results from the 2-sample t-test mean WAS and Mug humidity.

	Sample 1	Sample 2
Sample size	366	366
Arithmetic mean	52.9891	51.8298
95% CI for the mean	52.1304 to 53.8477	50.7452 to 52.9144
Variance	69.7810	111.3362
Standard deviation	8.3535	10.5516
Standard error of the mean	0.4366	0.5515
F-test for equal variances	P < 0.001	

T-test (assuming equal variances)

Difference	-1.1593
Pooled Standard Deviation	9.5162
Standard Error	0.7035
95% CI of difference	-2.5403 to 0.2218
Test statistic t	-1.648
Degrees of Freedom (DF)	730
Two-tailed probability	P = 0.0998

3.6.4 UV AND IRRADIANCE READINGS FOR WADI AL SAFA

Data relating to ultra violet radiation was recorded in the form of a UV Index (Figure 3-52) (Solarmeter 6.5 UV Index Meter on a scale of 0 to 10) and UV irradiance Figure 3-53 (Solarmeter 6.2 Sensitive UVB Meter in μWcm^2, Solartech, Inc., Harrison Township, MI). These data were collected every hour from 05:30 through to 19:30 on a daily basis from September 2015 through to November 2016 with extra data collected in February and March 2017.

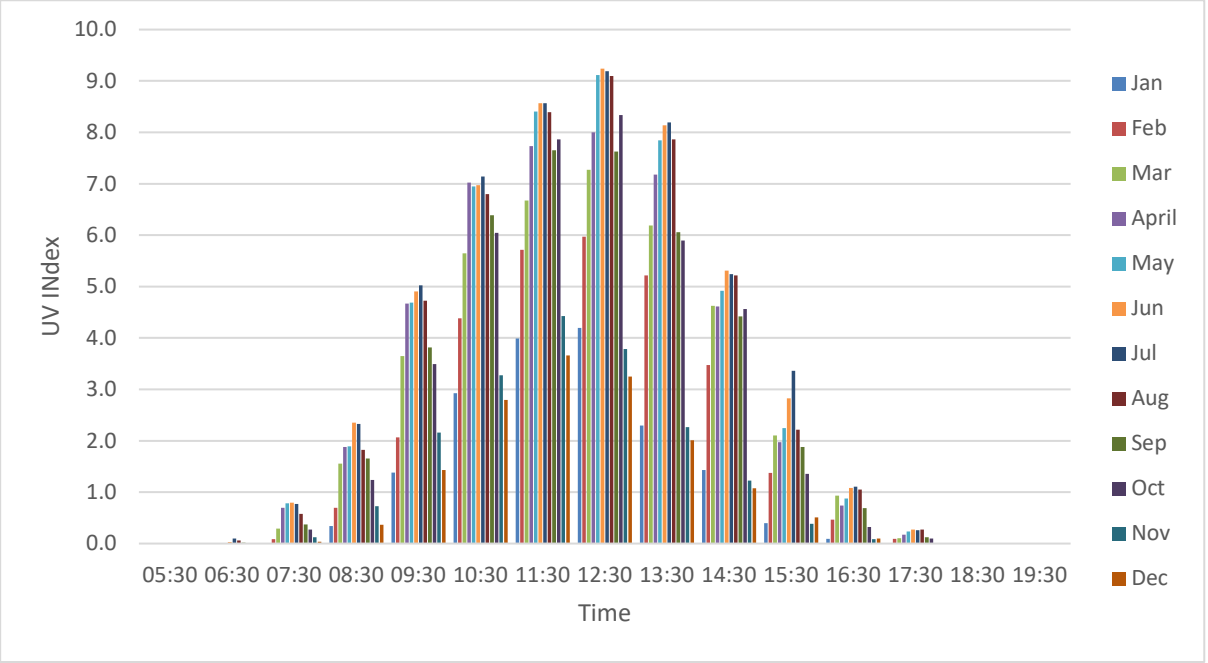


Figure 3-52. Mean hourly UV Index from 05:30 through to 19:30 for 2015/2016

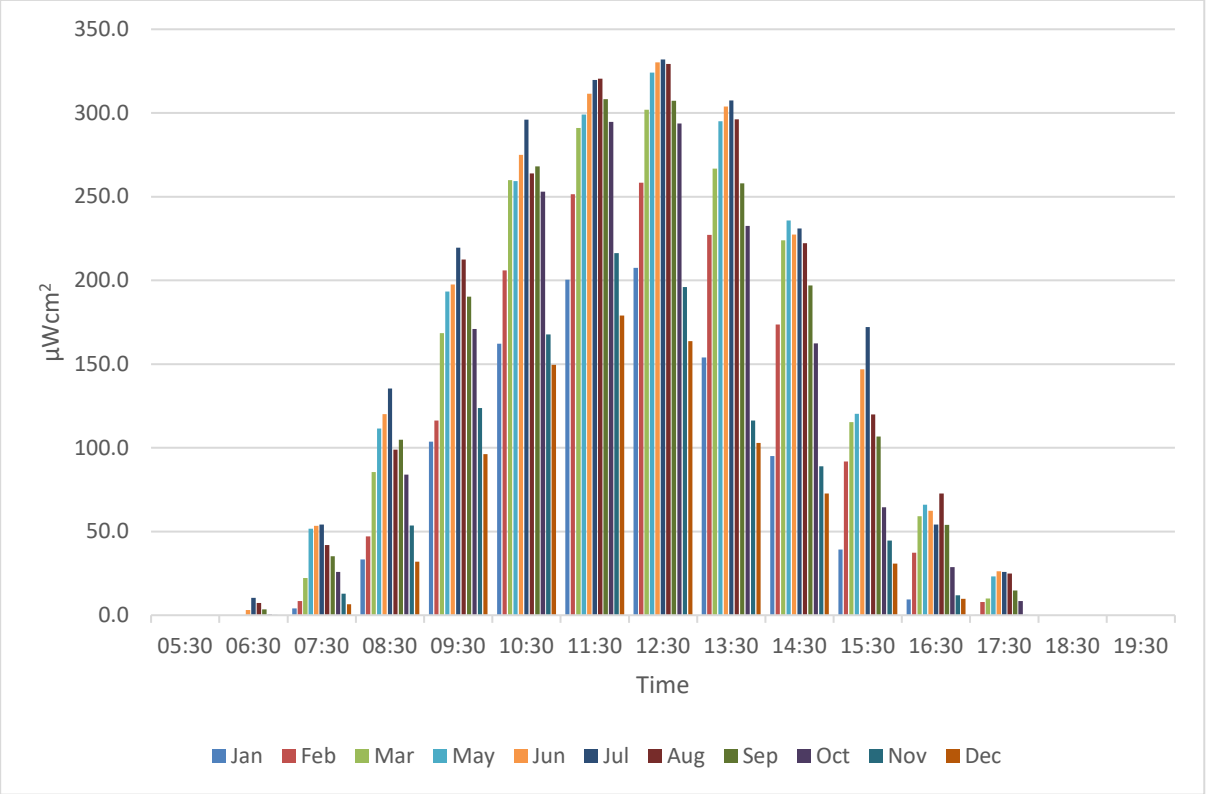


Figure 3-53. Mean hourly UV irradiance from 05:30 through to 19:30 for 2015/2016. Data for April has been omitted from this presentation due to the possibility of error.

APPENDIX 3-4 – WIND DETAILS

3.6.5 WIND DIRECTION FOR WAI AL SAFA AND MUGATRAH 2006 TO 2019

Table 3-32. Number of times the particular wind direction was recorded for each of the 8 compass points* between 08 Oct 2006 and 18 Dec 2019 in WAS.

	NW	S	W	N	E	SE	SW	NE
Jan	3130	1611	2215	1404	1246	1221	1032	1079
Feb	2642	1837	2270	1405	1282	1351	851	1240
Mar	3395	2021	2542	1588	1357	1622	1131	1396
Apr	3681	1933	2340	1585	1158	1297	1378	1161
May	3975	2357	2662	1470	796	1226	1728	782
Jun	3989	2523	2615	1608	964	822	1956	739
Jul	4218	2606	2119	2043	1570	1327	1731	965
Aug	4019	2315	948	2481	2220	1858	1270	1658
Sep	3516	1884	1024	2060	1696	1607	1216	1061
Oct	3782	1766	1028	1938	1847	1657	994	1253
Nov	3304	1635	1439	1612	1989	1584	812	1740
Dec	3251	2046	1991	1652	1398	1367	1143	1431
Total	42902	24534	23193	20846	17523	16939	15242	14505
% Time	24.4	14.0	13.2	11.9	10.0	9.6	8.7	8.3

Table 3-33. Number of times the particular wind direction was recorded for each of the 8 compass points* between 11 Nov 2006 and 11 Sep 2019 in MUG.

	NW	S	SE	SW	E	NE	N	W
Jan	1688	1168	1108	555	482	370	190	245
Feb	1547	964	943	398	410	398	329	227
Mar	1862	954	979	390	494	547	479	168
Apr	2119	934	807	519	329	252	138	256
May	2119	1252	603	575	245	170	93	207
Jun	2422	1313	650	766	256	244	157	272
Jul	2667	1648	1006	937	561	416	269	301
Aug	2653	1560	1310	621	875	623	340	182
Sep	1932	1093	1163	454	757	473	360	113
Oct	1471	734	985	248	520	312	225	127
Nov	1485	952	1120	327	669	500	241	240
Dec	1905	1357	1124	564	621	560	173	291
Total	23870	13929	11798	6354	6219	4865	2994	2629
% Time	32.9	19.2	16.2	8.7	8.6	6.7	4.1	3.6

Compass points recorded by Davis Weather Stations were recorded at 22.5° intervals. For the purposes of this study and to standardise the data presentation, these points were amalgamated into 45° intervals as per the Trimble Geo 7 GPS:

NE (= 22.5-67.5°), E (= 67.5-112.5°), SE (= 112.5-157.5°), S (= 157.5- 202.5°), SW (= 202.5-247.5°), W (= 247.5-292.5°), NW (= 292.5-337.5°), and N (= 337.5-22.5°).

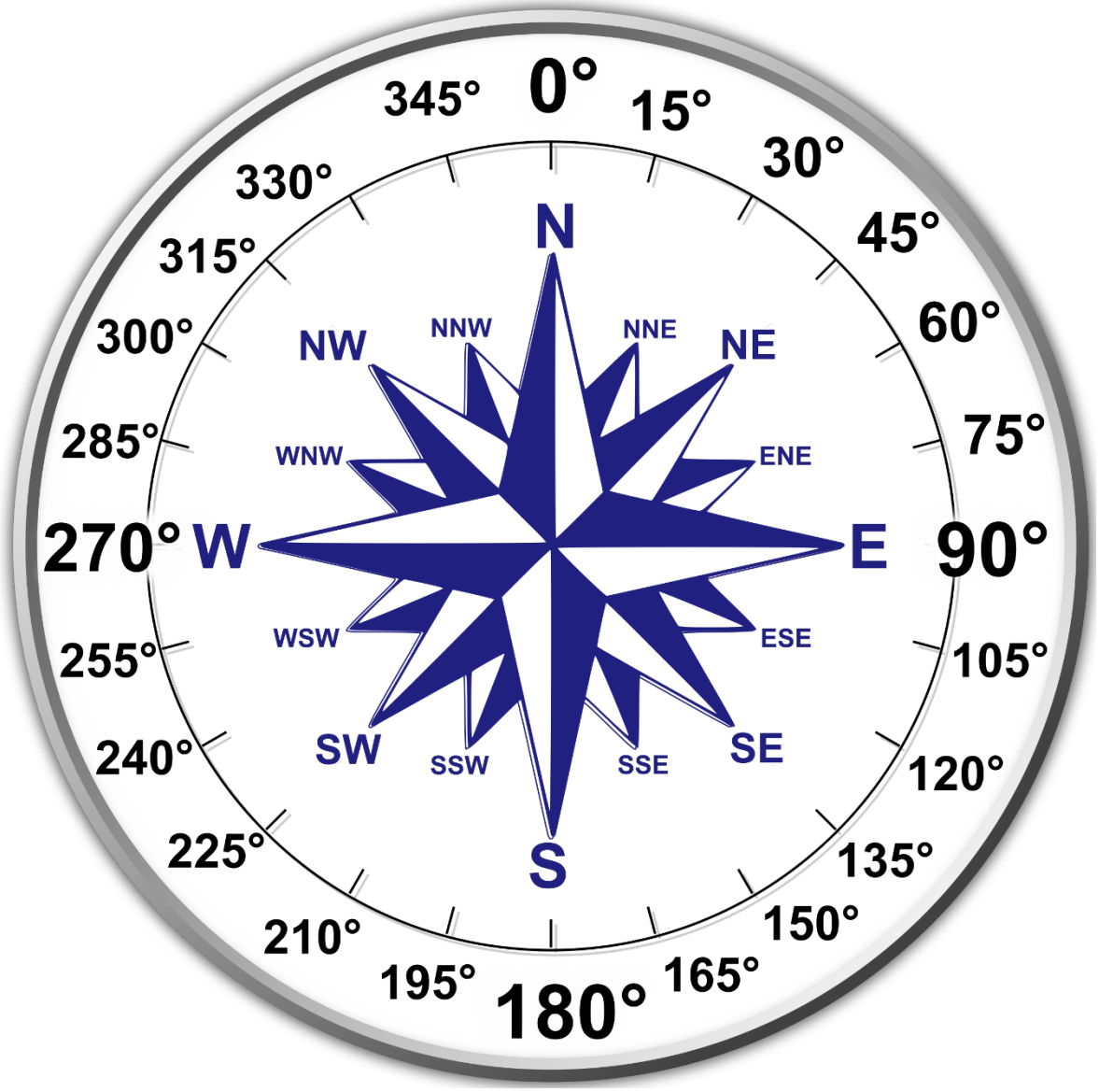


Figure 3-54. 16-point compass rose with degrees.

(https://www.pngfind.com/mpng/TomRTb_16-point-compass-rose-with-degrees-clipart-compass/).

APPENDIX 3-5 - SADDLE TEMPERATURES

3.6.6 SADDLE TEMPERATURE DATA FROM ALL STUDY ANIMALS

Table 3-34. Mean hourly temperatures (°C), pooled for the study years 2014 to 2019 taken from T_{sad} for each of the tracked animals for January.

	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AQ01	24.1	24.1	24.0	24.0	24.0	23.9	23.9	23.8	23.8	23.9	24.1	25.7	28.0	29.8	29.4	28.2	27.1	25.5	24.7	24.4	24.3	24.2	24.1	24.0
MUG001	25.5	25.5	25.4	25.3	25.3	25.3	25.3	25.2	25.2	25.2	27.5	31.1	33.9	35.6	35.0	33.4	31.2	28.8	27.6	26.9	26.4	26.1	25.9	25.6
MUG004	24.2	24.2	24.2	24.1	24.1	24.1	24.0	24.0	23.9	23.9	24.5	25.4	26.0	26.4	26.5	26.1	25.4	24.8	24.5	24.4	24.3	24.2	24.2	24.2
S2B07	25.0	24.9	24.9	24.8	24.8	24.8	24.8	24.8	24.8	24.8	25.5	27.7	28.3	29.1	29.3	28.2	27.3	26.1	25.7	25.4	25.2	25.1	25.0	25.0
WAS056	24.6	24.6	24.4	24.4	24.3	24.3	24.2	24.1	24.2	25.4	26.7	27.6	28.3	26.8	27.5	27.3	26.8	25.5	25.3	25.2	25.0	24.9	24.6	24.4
WAS058	24.2	24.2	23.9	23.9	23.7	23.6	23.4	23.3	23.3	23.9	26.1	32.0	30.4	30.1	30.0	29.2	27.8	26.3	25.7	25.2	24.9	24.5	24.3	24.1
WAS059	21.5	21.3	21.1	20.9	20.7	20.6	20.4	20.2	20.1	20.1	20.0	20.9	22.8	23.2	23.3	23.2	22.8	22.5	22.2	22.1	22.0	22.0	21.8	21.6
WAS060	25.2	25.2	25.0	24.9	24.9	24.8	24.7	24.7	24.6	24.6	25.4	29.7	33.2	34.2	32.6	30.8	28.7	27.0	26.2	25.8	25.6	25.5	25.3	25.2
WAS064	23.7	23.6	23.5	23.4	23.3	23.2	23.2	23.1	23.1	23.4	26.3	31.6	32.4	33.0	32.1	31.0	28.9	26.4	25.2	24.6	24.3	24.1	23.9	23.7
WAS065	23.3	23.0	22.9	22.8	22.7	22.6	22.5	22.3	22.4	23.2	27.0	32.3	33.6	34.2	33.7	32.4	29.7	26.8	25.4	24.7	24.2	23.9	23.7	23.4
Mean	24.1	24.1	23.9	23.8	23.8	23.7	23.6	23.6	23.5	23.8	25.3	28.4	29.7	30.2	29.9	29.0	27.6	26.0	25.2	24.9	24.6	24.5	24.3	24.1
Max	25.5	25.5	25.4	25.3	25.3	25.3	25.3	25.2	25.2	25.4	27.5	32.3	33.9	35.6	35.0	33.4	31.2	28.8	27.6	26.9	26.4	26.1	25.9	25.6
Min	21.5	21.3	21.1	20.9	20.7	20.6	20.4	20.2	20.1	20.1	20.0	20.9	22.8	23.2	23.3	23.2	22.8	22.5	22.2	22.1	22.0	22.0	21.8	21.6
SEM	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.7	1.2	1.2	1.3	1.1	1.0	0.7	0.5	0.4	0.4	0.4	0.4	0.4	0.4

Table 3-35. Mean hourly temperatures (°C), pooled for the study years 2014 to 2019 taken from T_{sad} for each of the tracked animals for February.

	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AQ01	22.6	22.4	22.2	22.0	21.9	21.8	21.7	21.7	22.4	23.4	25.4	28.5	30.9	32.1	31.7	30.6	28.9	26.9	25.3	24.3	23.7	23.2	22.8	22.6
MUG001	24.5	24.4	24.2	24.2	24.1	24.0	24.0	23.9	23.9	24.8	31.4	37.5	39.1	39.7	38.4	35.8	33.6	30.3	28.0	26.8	26.0	25.4	24.9	24.7
MUG004	24.8	24.6	24.6	24.5	24.4	24.4	24.3	24.3	24.2	24.3	25.8	30.3	33.3	34.3	34.7	32.9	31.6	29.0	27.3	26.5	25.9	25.5	25.3	25.1
S2B07	24.8	24.7	24.7	24.6	24.5	24.4	24.4	24.4	24.4	24.5	27.3	33.2	34.2	35.7	35.2	33.9	31.2	28.6	27.0	26.1	25.6	25.4	25.2	25.1
WAS027	24.3	24.1	24.0	23.9	23.9	23.8	23.6	23.6	23.9	26.6	30.3	31.4	32.4	31.2	32.0	31.3	30.8	28.5	26.6	26.1	25.7	25.2	24.9	24.6
WAS056	26.1	26.1	25.9	25.8	25.7	25.7	25.7	25.6	25.7	28.3	32.6	31.3	33.8	36.2	35.1	33.4	32.8	30.4	28.7	27.9	27.4	27.0	26.6	26.4
WAS059	22.8	22.6	22.3	22.1	21.8	21.6	21.3	21.1	21.0	21.9	24.4	25.9	29.8	31.2	30.9	30.3	28.6	26.2	25.0	24.6	24.3	23.9	23.6	23.4
WAS060	24.6	24.6	24.5	24.4	24.4	24.3	24.2	24.2	24.2	24.4	27.1	33.5	36.2	36.6	34.5	32.7	30.0	27.9	26.7	26.1	25.7	25.3	25.1	24.9
WAS064	23.9	23.7	23.5	23.4	23.3	23.1	23.1	23.0	23.2	24.1	28.9	35.1	36.5	37.2	35.0	34.4	31.8	28.6	26.6	25.6	25.1	24.7	24.3	24.1
WAS065	22.4	22.1	22.0	21.7	21.6	21.5	21.2	21.2	22.0	25.1	33.1	37.0	37.2	36.5	35.2	34.2	32.6	28.9	26.2	24.8	24.1	23.6	23.2	22.9
MUG021	26.3	26.2	26.0	25.9	25.8	25.8	25.8	25.8	26.2	28.1	28.4	32.8	34.8	34.5	34.7	32.9	32.0	30.1	28.9	28.1	27.6	27.1	26.7	26.6
Mean	24.3	24.1	24.0	23.9	23.8	23.7	23.6	23.5	23.7	25.1	28.6	32.4	34.4	35.0	34.3	33.0	31.3	28.7	26.9	26.1	25.5	25.1	24.8	24.6
Max	26.3	26.2	26.0	25.9	25.8	25.8	25.8	25.8	26.2	28.3	33.1	37.5	39.1	39.7	38.4	35.8	33.6	30.4	28.9	28.1	27.6	27.1	26.7	26.6
Min	22.4	22.1	22.0	21.7	21.6	21.5	21.2	21.1	21.0	21.9	24.4	25.9	29.8	31.2	30.9	30.3	28.6	26.2	25.0	24.3	23.7	23.2	22.8	22.6
SEM	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.9	1.0	0.8	0.8	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4

Table 3-36. Mean hourly temperatures (°C), pooled for the study years 2014 to 2019 taken from T_{sad} for each of the tracked animals for March.

	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
MUG004	27.2	27.1	26.9	26.8	26.8	26.7	26.6	26.5	26.7	29.0	33.0	36.9	37.5	37.4	37.7	36.5	34.8	32.4	30.5	29.2	28.5	28.1	27.7	27.5
S2B07	25.8	25.8	25.7	25.7	25.6	25.6	25.5	25.5	25.4	26.4	29.5	32.1	34.2	33.9	35.3	33.7	32.8	30.6	28.3	27.3	26.8	26.4	26.3	26.1
WAS001	27.9	27.8	27.6	27.5	27.4	27.1	26.9	26.7	26.8	30.0	35.3	36.2	37.6	37.3	37.2	37.3	33.3	30.5	29.1	28.5	28.2	28.0	27.9	28.0
WAS003	26.1	25.9	25.8	25.7	25.6	25.6	25.5	25.9	26.5	28.7	34.0	36.5	37.0	36.3	36.0	34.6	32.2	30.4	28.7	27.8	27.3	26.9	26.6	26.3
WAS006	27.0	26.9	26.7	26.6	26.4	26.3	26.2	26.1	26.2	28.7	35.4	39.0	38.0	37.6	36.7	35.8	33.1	30.5	29.2	28.4	28.0	27.7	27.4	27.3
WAS027	25.3	24.9	24.6	24.4	24.1	23.9	23.7	23.6	24.4	29.9	34.2	36.3	35.0	34.4	35.2	35.1	34.3	31.2	28.7	27.7	27.0	26.4	26.0	25.7
WAS056	27.2	26.9	26.8	26.7	26.7	26.6	26.5	26.4	26.7	30.1	34.0	36.1	37.4	37.8	37.2	35.6	33.8	31.3	29.8	28.8	28.3	27.8	27.6	27.4
WAS059	24.7	24.3	23.9	23.7	23.3	23.1	22.8	22.8	24.4	29.6	33.9	35.6	35.2	35.5	35.6	35.1	33.3	30.5	28.5	27.2	26.6	26.0	25.5	25.1
WAS060	27.0	26.8	26.7	26.6	26.5	26.3	26.3	26.2	26.1	27.2	32.3	35.7	37.0	37.2	36.9	36.2	34.1	31.8	29.9	28.8	28.2	27.8	27.6	27.3
WAS064	25.4	25.2	25.1	25.0	24.9	24.9	24.8	24.7	24.9	27.5	31.2	33.7	35.4	34.9	35.1	35.0	33.1	29.9	28.1	27.0	26.3	25.9	25.6	25.3
WAS065	26.1	25.8	25.5	25.2	24.8	24.6	24.7	24.9	25.6	29.3	33.4	32.1	32.4	33.0	32.7	32.8	33.7	31.8	30.3	29.1	28.3	27.6	27.1	26.6
MUG021	26.3	26.1	26.0	25.9	25.8	25.6	25.5	25.5	26.9	31.9	33.4	34.5	35.2	35.0	34.9	34.1	32.6	30.5	29.0	28.0	27.3	26.9	26.6	26.3
Mean	26.3	26.1	26.0	25.8	25.6	25.5	25.4	25.4	25.9	29.0	33.3	35.4	36.0	35.9	35.9	35.1	33.4	30.9	29.2	28.2	27.6	27.1	26.8	26.6
Max	27.9	27.8	27.6	27.5	27.4	27.1	26.9	26.7	26.9	31.9	35.4	39.0	38.0	37.8	37.7	37.3	34.8	32.4	30.5	29.2	28.5	28.1	27.9	28.0
Min	24.7	24.3	23.9	23.7	23.3	23.1	22.8	22.8	24.4	26.4	29.5	32.1	32.4	33.0	32.7	32.8	32.2	29.9	28.1	27.0	26.3	25.9	25.5	25.1
SEM	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.3	0.3	0.4	0.5	0.6	0.5	0.5	0.4	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3

Table 3-37. Mean hourly temperatures (°C), pooled for the study years 2014 to 2019 taken from T_{sad} for each of the tracked animals for April.

	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AQ01	31.3	31.0	30.8	30.6	30.4	30.3	30.1	30.1	30.7	34.1	38.3	38.6	36.8	35.3	36.3	38.2	39.3	36.9	34.7	33.7	32.9	32.3	31.9	31.6
MUG001	31.0	30.8	30.5	30.3	30.1	30.0	29.9	30.0	32.8	36.8	40.1	39.6	38.1	36.9	37.1	39.2	38.5	35.3	33.6	33.4	32.8	32.2	31.7	31.3
MUG004	30.7	30.4	30.2	30.0	29.8	29.6	29.5	29.5	30.6	36.0	38.7	38.0	37.2	37.5	37.9	38.8	37.4	35.6	34.3	33.2	32.5	31.9	31.5	31.1
S2B07	30.6	30.3	30.0	29.8	29.6	29.4	29.3	29.4	30.5	35.2	38.3	37.8	36.0	35.0	34.8	37.3	39.2	36.7	34.3	33.1	32.2	31.7	31.3	30.9
WAS001	30.8	30.7	30.6	30.3	30.1	29.8	29.5	29.3	32.0	36.4	38.0	38.6	37.3	35.5	37.3	38.4	37.9	35.4	33.0	32.1	31.5	31.2	31.0	31.0
WAS006	30.2	29.9	29.7	29.5	29.3	29.0	28.9	28.9	31.7	36.1	38.6	37.5	36.2	36.3	37.3	37.8	37.8	35.0	33.1	32.3	31.8	31.4	31.0	30.7
WAS027	28.4	28.0	27.6	27.3	27.0	26.7	26.5	26.4	29.8	35.9	37.2	34.6	34.6	35.4	36.0	35.8	36.6	34.8	32.1	31.1	30.4	29.9	29.5	29.0
WAS056	29.5	29.2	29.0	28.9	28.7	28.5	28.4	28.5	32.9	37.1	38.5	38.8	37.9	37.5	38.3	38.1	36.8	34.5	32.8	31.9	31.3	30.7	30.3	30.0
WAS059	27.9	27.5	27.4	27.0	26.8	26.6	26.3	26.7	31.0	35.6	36.3	35.9	36.7	37.4	37.1	36.3	35.8	34.1	32.2	30.9	30.3	29.8	29.2	28.7
WAS060	29.6	29.5	29.4	29.3	29.1	28.9	28.7	28.4	30.3	34.5	37.7	37.6	37.8	39.3	38.8	37.6	36.6	34.4	32.4	31.4	30.8	30.3	30.0	29.9
WAS065	28.0	27.6	27.2	26.9	26.7	26.5	26.4	26.8	28.5	32.8	36.0	34.8	35.1	35.4	36.8	35.8	35.4	34.2	33.1	31.8	30.8	29.9	29.1	28.5
MUG021	29.4	29.0	28.7	28.3	28.2	28.0	27.8	29.0	35.2	37.2	37.0	37.4	37.3	36.5	38.6	38.1	37.2	35.6	34.2	32.9	31.7	31.0	30.6	30.1
Mean	29.8	29.5	29.2	29.0	28.8	28.6	28.4	28.6	31.3	35.7	37.9	37.4	36.8	36.5	37.2	37.6	37.4	35.2	33.3	32.3	31.6	31.0	30.6	30.2
Max	31.3	31.0	30.8	30.6	30.4	30.3	30.1	30.1	35.2	37.2	40.1	39.6	38.1	39.3	38.8	39.2	39.3	36.9	34.7	33.7	32.9	32.3	31.9	31.6
Min	27.9	27.5	27.2	26.9	26.7	26.5	26.3	26.4	28.5	32.8	36.0	34.6	34.6	35.0	34.8	35.8	35.4	34.1	32.1	30.9	30.3	29.8	29.1	28.5
SEM	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.4	0.3	0.5	0.3	0.4	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3

Table 3-38. Mean hourly temperatures (°C), pooled for the study years 2014 to 2019 taken from T_{sad} for each of the tracked animals for May.

	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AQ01	34.1	33.9	33.6	33.4	33.3	33.0	32.9	32.8	33.9	37.8	38.9	36.8	35.6	35.1	34.8	36.2	40.7	41.1	37.4	36.5	35.8	35.2	34.7	34.4
MUG001	34.0	33.9	33.8	33.6	33.5	33.4	33.2	33.3	35.3	37.7	38.9	37.8	36.4	35.8	37.0	39.9	41.5	39.6	36.6	35.8	35.6	35.0	34.6	34.3
MUG004	34.8	34.6	34.4	34.2	34.1	33.9	33.5	33.6	36.1	38.5	38.7	38.1	37.0	36.5	36.7	38.3	40.6	40.1	38.1	37.1	36.4	35.8	35.5	35.2
MUG005	34.6	34.3	34.3	34.1	34.0	33.8	33.5	32.8	34.2	37.0	38.2	36.7	35.9	35.5	35.5	36.4	39.0	39.0	36.6	35.4	35.4	35.1	34.9	34.7
S2B07	33.9	33.6	33.3	33.2	33.0	32.8	32.6	32.5	33.7	38.3	39.5	37.2	35.5	35.1	35.0	36.1	39.5	39.8	37.4	36.2	35.5	34.8	34.4	34.2
WAS001	34.1	34.0	33.9	33.8	33.6	33.4	33.1	33.3	37.6	40.7	40.0	36.2	35.1	34.5	35.1	36.8	39.5	39.8	36.9	35.5	34.7	34.5	34.4	34.3
WAS006	33.7	33.6	33.5	33.3	33.2	33.1	32.9	33.0	33.1	34.2	37.0	37.2	37.3	37.8	37.7	39.5	39.1	37.7	36.0	35.3	34.8	34.4	34.1	34.0
WAS027	33.8	33.4	33.0	32.7	32.2	32.0	31.8	32.2	37.9	39.8	39.4	38.3	36.5	36.3	36.5	36.6	37.8	39.5	37.1	36.2	35.7	35.1	34.7	34.4
WAS056	34.7	34.3	34.0	33.8	33.3	33.2	32.2	33.1	36.6	40.5	40.6	38.4	37.4	37.1	38.9	41.0	41.3	39.5	36.8	36.1	35.9	35.5	35.2	34.9
WAS059	34.7	34.3	34.0	33.7	33.4	33.2	32.8	32.2	36.1	38.1	39.8	39.3	38.1	37.4	37.6	39.5	41.4	39.7	36.8	35.8	35.6	35.2	35.0	34.9
WAS060	35.1	34.9	34.6	34.4	34.1	33.9	33.8	33.5	36.1	38.7	40.6	39.1	38.0	37.4	38.9	40.9	41.9	39.9	38.0	37.1	36.2	35.8	35.6	35.4
WAS065	33.0	32.8	32.5	32.3	32.1	32.0	31.8	31.8	37.7	41.2	41.7	38.9	37.0	36.4	36.3	36.8	39.8	40.3	37.5	36.7	35.7	34.6	34.0	33.5
MUG021	32.1	31.9	31.6	31.2	31.1	30.8	31.0	32.9	36.9	38.8	38.4	36.4	35.8	35.2	36.5	39.8	40.6	37.9	35.8	34.8	34.1	33.6	33.1	32.5
Mean	34.1	33.8	33.6	33.4	33.1	33.0	32.7	32.9	35.8	38.6	39.4	37.7	36.6	36.2	36.6	38.3	40.2	39.5	37.0	36.0	35.5	35.0	34.6	34.4
Max	35.1	34.9	34.6	34.4	34.1	33.9	33.8	33.6	37.9	41.2	41.7	39.3	38.1	37.8	38.9	41.0	41.9	41.1	38.1	37.1	36.4	35.8	35.6	35.4
Min	32.1	31.9	31.6	31.2	31.1	30.8	31.0	31.8	33.1	34.2	37.0	36.2	35.1	34.5	34.8	36.1	37.8	37.7	35.8	34.8	34.1	33.6	33.1	32.5
SEM	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.5	0.5	0.3	0.3	0.3	0.3	0.4	0.5	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Table 3-39. Mean hourly temperatures (°C), pooled for the study years 2014 to 2019 taken from T_{sad} for each of the tracked animals for June.

	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AQ01	36.9	36.7	36.5	36.3	36.2	36.1	35.9	35.5	36.1	38.0	38.4	37.2	36.9	36.8	36.8	36.9	39.1	41.9	39.2	37.1	37.6	37.4	37.3	37.1
J018	34.8	34.7	34.7	34.7	34.7	34.8	34.8	34.8	34.8	34.8	34.8	34.8	34.8	34.8	34.8	34.9	34.8	34.8	34.9	34.9	34.8	34.8	34.9	34.8
MUG001	35.9	35.9	35.9	35.9	35.8	35.5	33.7	34.7	36.5	38.7	38.3	38.1	37.2	36.7	36.6	38.7	42.1	41.0	38.1	36.1	36.9	36.6	36.3	36.1
MUG004	37.0	36.9	36.8	36.8	36.8	36.8	36.8	36.8	36.8	37.2	37.8	37.6	37.2	37.0	37.0	37.2	40.3	42.2	40.2	38.8	38.0	37.6	37.3	37.2
MUG005	36.0	36.0	35.9	35.9	35.9	35.8	34.9	35.1	36.4	37.5	36.9	36.5	36.3	36.2	36.1	36.4	38.2	40.1	37.8	36.7	36.7	36.5	36.3	36.2
S2B07	34.6	34.5	34.4	34.4	34.4	34.3	34.2	34.2	34.2	34.9	35.3	35.1	35.1	35.2	35.2	35.4	38.0	40.5	38.2	36.6	35.7	35.3	35.0	34.8
WAS001	35.4	35.7	35.9	35.9	35.9	35.8	35.3	34.8	38.2	40.1	40.0	37.3	36.6	36.4	36.3	36.7	38.2	40.7	38.5	36.2	35.7	35.2	35.1	35.2
WAS006	30.7	29.9	29.5	29.0	28.7	28.3	28.9	32.7	38.5	45.1	51.0	55.5	58.1	58.1	56.1	53.0	49.2	44.8	40.6	37.0	34.7	33.3	32.3	31.4
WAS027	35.9	35.6	35.3	35.0	34.7	34.3	33.9	33.8	37.2	41.8	40.3	38.1	37.8	37.6	37.8	37.9	38.4	38.9	38.5	37.7	37.3	36.8	36.5	36.3
WAS056	35.9	35.8	35.6	35.5	35.4	35.2	34.4	35.0	36.3	39.3	40.3	38.7	37.6	37.1	37.2	39.0	41.2	40.2	38.2	36.8	37.0	36.7	36.3	36.1
WAS059	36.3	36.3	36.2	36.0	35.7	35.5	35.0	33.7	35.3	38.0	40.9	39.9	39.0	38.1	38.1	39.1	41.4	40.5	38.3	37.0	37.2	36.9	36.7	36.6
WAS060	37.0	37.0	36.8	36.8	36.7	36.5	36.4	35.7	35.9	39.6	41.1	39.0	38.1	37.7	39.0	40.5	42.3	41.0	39.0	38.2	37.9	37.6	37.3	37.2
WAS064	36.9	36.7	36.7	36.4	36.4	36.5	34.4	33.3	37.4	41.1	39.1	37.9	37.3	37.1	37.1	37.6	41.9	40.1	40.0	37.7	38.2	37.7	37.4	37.3
Mean	35.6	35.5	35.4	35.3	35.2	35.0	34.5	34.6	36.4	38.9	39.5	38.9	38.6	38.4	38.3	38.7	40.4	40.5	38.6	37.0	36.8	36.3	36.0	35.9
Max	37.0	37.0	36.8	36.8	36.8	36.8	36.8	36.8	38.5	45.1	51.0	55.5	58.1	58.1	56.1	53.0	49.2	44.8	40.6	38.8	38.2	37.7	37.4	37.3
Min	30.7	29.9	29.5	29.0	28.7	28.3	28.9	32.7	34.2	34.8	34.8	34.8	34.8	34.8	34.8	34.9	34.8	34.8	34.9	34.9	34.7	33.3	32.3	31.4
SEM	0.5	0.5	0.5	0.6	0.6	0.6	0.5	0.3	0.3	0.8	1.1	1.4	1.7	1.7	1.5	1.3	0.9	0.6	0.4	0.3	0.3	0.4	0.4	0.4

Table 3-40. Mean hourly temperatures (°C), pooled for the study years 2014 to 2019 taken from T_{sad} for each of the tracked animals for July.

	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AQ01	37.5	37.4	37.5	37.4	37.4	37.3	37.1	36.2	37.4	40.2	41.2	39.6	38.7	38.3	38.1	38.0	38.2	39.2	39.1	38.3	38.1	37.9	37.8	37.7
J018	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5
MUG001	36.7	36.6	36.5	36.4	36.3	36.2	35.2	35.3	36.9	38.1	38.3	38.0	37.4	37.0	36.8	38.2	41.5	42.2	39.7	37.7	37.7	37.2	36.9	36.8
MUG004	37.9	37.8	37.7	37.7	37.6	37.6	37.5	37.5	37.6	38.8	39.4	38.9	38.5	38.2	38.1	38.1	39.3	41.3	40.4	39.4	38.8	38.4	38.2	38.0
MUG005	37.2	37.1	37.0	37.0	37.0	36.9	35.6	35.6	37.5	40.9	40.9	39.3	38.5	38.1	37.8	37.7	37.9	38.8	38.3	37.5	37.6	37.4	37.4	37.3
S2B07	35.6	35.5	35.5	35.4	35.4	35.3	35.3	35.3	35.4	37.0	37.2	36.5	36.0	35.8	35.7	35.8	36.2	37.6	37.8	36.7	36.2	35.9	35.8	35.7
WAS001	34.3	34.3	34.1	34.0	33.9	33.6	33.2	33.8	36.6	40.1	41.2	41.0	41.2	41.1	41.6	41.6	41.9	41.8	39.6	37.0	35.7	35.0	34.7	34.5
WAS006	31.7	31.0	30.6	30.2	29.8	29.6	29.9	32.6	37.1	43.3	48.8	54.1	57.2	58.0	57.4	54.9	51.7	47.6	43.2	38.9	36.2	34.6	33.4	32.6
WAS027	37.6	37.6	37.5	37.5	37.3	37.4	35.8	34.5	36.4	41.3	41.3	39.3	38.5	38.4	38.2	38.0	37.9	38.2	38.5	37.2	38.0	37.8	37.7	37.7
WAS056	37.6	37.7	37.6	37.5	37.4	37.2	35.0	36.2	38.9	40.7	39.5	38.7	38.4	38.2	38.1	38.3	40.2	41.4	39.1	38.5	38.6	38.1	37.8	37.7
WAS059	33.9	33.7	33.4	33.3	32.9	32.8	32.6	33.5	35.2	37.2	39.2	40.6	41.4	41.8	41.1	40.1	39.9	39.2	37.6	36.1	35.4	34.9	34.4	34.1
WAS060	38.2	38.1	38.0	38.0	37.9	37.8	37.4	35.2	37.3	40.2	41.5	39.7	38.8	38.5	38.4	38.4	40.3	41.7	40.0	38.3	38.9	38.7	38.4	38.3
WAS064	37.6	37.6	37.5	37.5	37.5	37.6	33.1	33.3	37.1	40.9	41.9	40.1	39.0	38.6	38.2	38.1	39.3	42.1	40.0	38.1	39.4	38.5	37.8	37.7
Mean	36.3	36.2	36.1	36.0	35.9	35.8	34.9	35.0	36.9	39.6	40.5	40.2	40.0	39.9	39.7	39.5	40.1	40.6	39.2	37.7	37.5	37.0	36.7	36.5
Max	38.2	38.1	38.0	38.0	37.9	37.8	37.5	37.5	38.9	43.3	48.8	54.1	57.2	58.0	57.4	54.9	51.7	47.6	43.2	39.4	39.4	38.7	38.4	38.3
Min	31.7	31.0	30.6	30.2	29.8	29.6	29.9	32.6	35.2	36.5	36.5	36.5	36.0	35.8	35.7	35.8	36.2	36.5	36.5	36.1	35.4	34.6	33.4	32.6
SEM	0.5	0.6	0.6	0.6	0.7	0.7	0.6	0.4	0.3	0.5	0.8	1.2	1.5	1.6	1.5	1.3	1.1	0.8	0.5	0.3	0.4	0.4	0.4	0.5

Table 3-41. Mean hourly temperatures (°C), pooled for the study years 2014 to 2019 taken from T_{sad} for each of the tracked animals for August.

	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AQ01	38.5	38.4	38.4	38.3	38.2	38.2	38.1	36.8	37.8	39.7	40.1	39.2	39.0	38.8	38.6	38.5	38.9	40.9	40.5	39.5	39.2	38.9	38.7	38.5
J018	37.4	37.4	37.4	37.3	37.3	37.4	37.3	37.4	37.4	37.4	37.4	37.4	37.4	37.4	37.4	37.4	37.4	37.4	37.4	37.4	37.4	37.4	37.4	37.4
MUG001	37.3	37.2	37.2	37.1	37.1	37.1	36.7	35.2	36.3	40.3	41.0	39.7	38.7	38.1	37.7	37.5	39.5	41.6	39.9	38.9	38.3	37.8	37.5	37.4
MUG004	38.5	38.4	38.3	38.3	38.2	38.2	38.2	38.0	38.0	39.4	40.6	40.0	39.4	39.1	38.9	38.8	39.3	41.7	40.9	39.9	39.3	39.0	38.7	38.5
MUG005	37.8	37.7	37.6	37.6	37.5	37.5	35.6	35.0	37.1	40.2	40.7	39.9	39.2	38.7	38.4	38.2	38.9	40.4	39.4	38.7	38.4	38.2	38.0	37.9
S2B07	36.3	36.2	36.1	36.1	36.0	36.0	35.9	35.9	35.9	35.9	36.4	36.5	36.4	36.3	36.2	36.2	36.4	38.4	39.3	38.0	37.2	36.8	36.5	36.4
WAS001	37.2	36.9	36.9	36.8	36.7	36.6	35.5	33.9	36.3	40.0	40.1	39.1	38.9	38.3	37.8	38.0	38.3	39.0	39.1	38.7	38.2	37.8	37.6	37.5
WAS027	38.1	38.0	37.9	37.7	37.6	37.4	35.4	33.6	35.6	40.1	40.7	39.7	39.1	38.9	38.8	38.7	38.7	39.4	39.0	38.0	39.0	38.6	38.4	38.3
WAS056	38.4	38.3	38.3	38.2	38.1	37.8	32.0	34.8	38.8	39.9	39.4	39.1	38.9	38.8	38.8	38.9	40.6	41.1	39.2	40.1	39.5	39.0	38.7	38.5
WAS064	37.6	37.7	37.6	37.6	37.6	37.6	33.8	32.3	37.6	42.0	42.7	41.2	39.8	39.0	38.6	38.4	38.3	41.2	40.1	39.0	39.5	38.7	38.1	37.8
Mean	37.7	37.6	37.6	37.5	37.4	37.4	35.9	35.3	37.1	39.5	39.9	39.2	38.7	38.3	38.1	38.1	38.6	40.1	39.5	38.8	38.6	38.2	38.0	37.8
Max	38.5	38.4	38.4	38.3	38.2	38.2	38.2	38.0	38.8	42.0	42.7	41.2	39.8	39.1	38.9	38.9	40.6	41.7	40.9	40.1	39.5	39.0	38.7	38.5
Min	36.3	36.2	36.1	36.1	36.0	36.0	32.0	32.3	35.6	35.9	36.4	36.5	36.4	36.3	36.2	36.2	36.4	37.4	37.4	37.4	37.2	36.8	36.5	36.4
SEM	0.2	0.2	0.2	0.2	0.2	0.2	0.6	0.6	0.3	0.5	0.6	0.4	0.3	0.3	0.3	0.3	0.4	0.5	0.3	0.3	0.3	0.2	0.2	0.2

Table 3-42. Mean hourly temperatures (°C), pooled for the study years 2014 to 2019 taken from T_{sad} for each of the tracked animals for September.

	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AQ01	37.3	37.2	37.2	37.1	37.0	37.0	36.9	35.7	35.5	37.5	41.5	41.3	39.8	38.6	38.3	38.9	40.4	39.9	38.3	37.8	37.6	37.4	37.3	37.2
J018	36.8	36.8	36.8	36.8	36.8	36.8	36.8	36.8	36.8	36.8	36.8	36.9	36.8	36.9	36.9	36.9	36.8	36.9	36.8	36.8	36.8	36.8	36.9	36.9
MUG001	36.1	35.9	35.9	35.8	35.9	35.8	35.4	34.3	35.6	36.8	38.3	37.9	37.1	36.8	37.1	39.5	40.0	38.9	37.7	37.2	36.8	36.5	36.4	36.3
MUG004	38.4	38.2	38.2	38.0	37.9	37.9	38.0	38.1	38.1	37.8	38.2	38.1	38.2	38.4	38.5	39.8	41.8	40.8	40.0	39.6	39.2	39.1	39.0	38.6
MUG005	38.2	38.0	38.1	38.0	37.9	37.7	34.9	34.0	36.8	38.2	40.6	39.6	38.7	38.3	38.1	39.5	40.3	39.7	38.1	38.0	38.0	37.9	37.7	37.9
S2B07	36.4	36.3	36.2	36.2	36.2	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.2	36.9	38.7	37.9	37.6	37.1	36.8	36.5	36.5
WAS001	36.2	36.1	36.0	35.9	35.8	35.7	35.3	34.5	34.6	35.3	38.5	38.9	38.6	38.3	38.1	38.8	39.4	38.4	37.4	36.9	36.5	36.2	36.0	36.0
WAS027	38.9	38.6	38.4	38.2	38.0	37.9	36.7	34.1	34.9	37.1	38.0	37.7	37.9	38.2	38.8	39.2	40.4	39.7	37.0	37.8	38.7	38.7	38.8	38.7
WAS064	37.0	37.0	37.2	37.3	37.4	37.3	34.8	31.8	35.5	38.5	42.1	40.8	39.3	38.5	38.2	38.0	38.9	40.2	39.0	39.1	38.4	37.7	37.4	37.1
Mean	37.3	37.1	37.1	37.0	37.0	36.9	36.1	35.0	36.0	37.1	38.9	38.6	38.0	37.8	37.8	38.5	39.4	39.2	38.0	37.9	37.7	37.5	37.3	37.2
Max	38.9	38.6	38.4	38.2	38.0	37.9	38.0	38.1	38.1	38.5	42.1	41.3	39.8	38.6	38.8	39.8	41.8	40.8	40.0	39.6	39.2	39.1	39.0	38.7
Min	36.1	35.9	35.9	35.8	35.8	35.7	34.8	31.8	34.6	35.3	36.0	36.0	36.0	36.0	36.0	36.2	36.8	36.9	36.8	36.8	36.5	36.2	36.0	36.0
SEM	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.6	0.4	0.3	0.7	0.6	0.4	0.3	0.3	0.4	0.6	0.4	0.3	0.3	0.3	0.3	0.3	0.3

Table 3-43. Mean hourly temperatures (°C), pooled for the study years 2014 to 2019 taken from T_{sad} for each of the tracked animals for October.

	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AQ01	35.2	35.2	35.1	35.0	35.0	35.0	35.0	33.2	33.7	38.1	40.8	39.6	37.3	36.9	36.6	36.6	36.1	35.7	35.7	35.6	35.4	35.3	35.3	35.2
S2B07	33.1	33.1	33.1	33.1	33.1	33.1	33.1	33.1	31.1	30.0	32.5	40.4	40.3	34.7	34.0	33.9	33.6	33.6	33.5	33.4	33.4	33.4	33.4	33.4
WAS001	26.7	25.9	25.4	25.1	25.2	24.5	24.2	26.1	30.1	37.5	44.6	49.0	50.7	46.9	42.0	39.0	36.8	34.4	32.4	31.1	29.8	28.5	27.5	26.9
WAS002	34.0	33.9	34.0	34.0	34.0	33.9	33.8	33.8	33.8	34.4	35.2	35.5	35.5	35.1	35.1	34.9	34.6	34.5	34.5	34.4	34.2	34.0	34.0	34.0
WAS004	25.9	25.7	25.6	25.3	25.1	24.7	24.6	25.6	28.1	32.4	34.7	36.2	36.0	36.0	35.6	33.5	31.7	29.5	28.2	27.6	27.1	26.9	26.4	26.1
WAS056	34.7	34.7	34.6	34.3	34.3	34.0	34.2	33.6	34.9	37.3	39.0	39.1	38.2	38.5	37.2	36.6	35.8	35.1	35.2	35.2	35.1	35.0	34.9	34.8
WAS058	34.8	34.6	34.5	34.3	34.1	33.8	33.6	33.0	33.8	36.4	37.8	37.0	36.7	36.6	37.2	38.7	37.0	35.6	35.5	35.3	35.1	35.1	34.9	34.7
WAS061	25.5	24.8	24.1	23.7	23.2	22.8	22.5	25.2	31.2	37.0	39.9	42.6	44.2	44.5	43.7	42.0	38.2	34.2	31.6	30.3	29.0	27.9	27.1	26.2
WAS063	30.9	30.6	30.3	30.0	29.8	29.6	29.5	30.1	31.5	34.7	38.5	40.3	40.3	40.6	39.7	39.0	36.9	34.6	33.3	32.8	32.3	31.9	31.7	31.3
WAS065	33.0	32.9	32.7	32.4	32.2	32.1	32.0	32.1	32.9	35.8	39.4	41.0	40.6	39.7	39.7	39.9	38.5	36.0	34.9	34.2	33.6	33.3	32.9	32.6
Mean	31.4	31.1	30.9	30.7	30.6	30.4	30.2	30.6	32.1	35.3	38.2	40.1	40.0	39.0	38.1	37.4	35.9	34.3	33.5	33.0	32.5	32.1	31.8	31.5
Max	35.2	35.2	35.1	35.0	35.0	35.0	35.0	33.8	34.9	38.1	44.6	49.0	50.7	46.9	43.7	42.0	38.5	36.0	35.7	35.6	35.4	35.3	35.3	35.2
Min	25.5	24.8	24.1	23.7	23.2	22.8	22.5	25.2	28.1	30.0	32.5	35.5	35.5	34.7	34.0	33.5	31.7	29.5	28.2	27.6	27.1	26.9	26.4	26.1
SEM	1.2	1.3	1.4	1.4	1.4	1.5	1.5	1.1	0.7	0.8	1.1	1.2	1.5	1.3	1.0	0.9	0.7	0.6	0.7	0.8	0.9	1.0	1.1	1.2

Table 3-44. Mean hourly temperatures (°C), pooled for the study years 2014 to 2019 taken from T_{sad} for each of the tracked animals for November.

	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
MUG001	30.7	30.7	30.6	30.6	30.6	30.5	30.5	30.5	30.6	31.1	32.0	33.9	35.8	37.1	35.8	33.9	32.4	31.6	31.7	31.4	31.2	31.0	30.9	30.8
S2B07	30.3	30.2	30.1	30.1	30.0	29.9	29.9	29.9	29.9	29.9	32.8	35.6	35.4	34.9	33.4	32.6	31.3	30.8	30.6	30.5	30.4	30.3	30.2	30.2
WAS002	32.8	32.6	32.4	32.3	33.2	33.8	33.8	33.8	33.8	34.0	34.5	34.4									33.0	32.9	32.9	32.8
WAS056	30.6	30.4	30.3	30.3	30.9	32.6	35.3	37.4	37.7	36.7	36.0	35.0	33.4	32.8	32.6	32.2	32.0	31.7	31.5	31.3	31.2	31.0	30.9	30.8
WAS058	31.1	30.8	30.6	30.6	30.7	32.9	36.9	37.0	37.2	36.0	36.7	36.6	34.8	33.9	33.3	33.0	32.7	32.4	32.2	32.0	31.9	31.7	31.5	31.3
WAS061	20.3	19.9	19.8	22.2	27.2	31.2	35.2	36.6	37.2	38.0	37.9	36.4	34.0	30.6	28.2	27.3	26.2	25.1	24.3	23.6	22.7	21.8	21.1	20.7
WAS063	24.3	24.0	23.8	24.1	26.2	29.4	33.5	36.7	39.6	39.4	38.7	37.5	34.5	31.6	29.5	28.5	27.5	26.7	26.2	25.6	25.7	25.4	24.9	24.6
WAS065	27.1	26.9	26.8	27.0	27.9	31.6	35.8	38.3	40.0	39.3	38.2	36.1	33.7	31.8	30.7	30.0	29.5	29.2	28.9	28.5	28.1	27.8	27.6	27.3
Mean	28.4	28.2	28.0	28.4	29.6	31.5	33.9	35.0	35.7	35.6	35.9	35.7	34.5	33.2	31.9	31.1	30.2	29.7	29.4	29.0	29.3	29.0	28.8	28.6
Max	32.8	32.6	32.4	32.3	33.2	33.8	36.9	38.3	40.0	39.4	38.7	37.5	35.8	37.1	35.8	33.9	32.7	32.4	32.2	32.0	33.0	32.9	32.9	32.8
Min	20.3	19.9	19.8	22.2	26.2	29.4	29.9	29.9	29.9	29.9	32.0	33.9	33.4	30.6	28.2	27.3	26.2	25.1	24.3	23.6	22.7	21.8	21.1	20.7
SEM	1.5	1.5	1.5	1.3	0.8	0.5	0.9	1.1	1.4	1.3	0.9	0.4	0.3	0.8	1.0	0.9	1.0	1.1	1.2	1.2	1.3	1.3	1.4	1.5

Table 3-45. Mean hourly temperatures (°C), pooled for the study years 2014 to 2019 taken from T_{sad} for each of the tracked animals for December.

	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AQ01	25.3	25.3	25.3	25.3	25.3	25.3	25.3	25.3	25.2	25.2	24.8	24.8	25.3	25.3	25.3	25.3	25.3	25.3	25.3	25.3	25.3	25.3	25.4	25.4
MUG001	26.8	26.7	26.7	26.7	26.6	26.6	26.7	26.6	26.6	26.6	27.4	30.4	34.3	35.4	35.6	32.3	30.8	29.0	28.1	27.6	27.2	27.0	26.8	26.8
MUG004	26.6	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	32.5	32.5	29.2	28.0	27.4	27.0	26.9	26.7	26.6	26.3
S2B07	26.0	26.0	25.9	25.9	25.9	25.8	25.9	26.0	25.9	25.8	26.3	27.1	27.9	27.9	27.9	26.9	26.5	26.2	26.2	26.2	26.1	26.0	25.9	25.9
WAS056	27.3	27.1	27.0	26.9	26.8	26.7	26.7	26.7	26.7	27.2	29.9	32.6	33.9	34.7	34.0	32.6	30.1	29.2	28.6	28.2	27.8	27.6	27.4	27.2
WAS058	28.5	28.4	28.2	28.0	27.9	27.9	27.7	27.6	27.7	28.5	33.7	35.8	35.2	35.3	34.7	34.3	32.0	30.5	29.7	29.1	28.7	28.6	28.4	28.4
WAS059	23.6	23.5	23.2	23.0	22.7	22.5	22.3	22.3	22.3	22.5	22.8	23.6	26.4	28.7	29.4	28.3	26.5	25.6	25.1	24.8	24.5	24.3	24.1	23.8
WAS060	27.2	27.1	27.1	27.1	27.1	27.0	27.0	27.0	27.0	27.1	28.4	32.3	34.3	34.6	33.9	31.8	29.7	28.7	28.1	27.8	27.6	27.5	27.3	27.3
WAS064	25.5	25.5	25.4	25.3	25.3	25.2	25.1	25.0	25.1	25.7	28.7	32.4	33.2	33.9	33.1	31.9	29.6	27.6	26.9	26.6	26.2	26.0	25.8	25.7
WAS065	23.5	23.3	23.1	22.9	22.7	22.6	22.5	22.4	23.3	25.3	31.3	35.2	36.2	35.2	34.7	32.7	29.8	27.1	25.8	25.1	24.6	24.2	23.9	23.6
Mean	26.1	25.9	25.8	25.7	25.6	25.6	25.5	25.5	25.6	26.0	27.9	30.0	31.3	31.7	32.1	30.9	29.0	27.7	27.1	26.8	26.5	26.3	26.2	26.0
Max	28.5	28.4	28.2	28.0	27.9	27.9	27.7	27.6	27.7	28.5	33.7	35.8	36.2	35.4	35.6	34.3	32.0	30.5	29.7	29.1	28.7	28.6	28.4	28.4
Min	23.5	23.3	23.1	22.9	22.7	22.5	22.3	22.3	22.3	22.5	22.8	23.6	25.3	25.3	25.3	25.3	25.3	25.3	25.1	24.8	24.5	24.2	23.9	23.6
SEM	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.5	0.5	1.0	1.4	1.4	1.3	1.1	0.9	0.7	0.5	0.5	0.5	0.4	0.5	0.5	0.5

APPENDIX 3-6 – MUGATRAH MEAN HOURLY TEMPERATURE 2004 TO 2019

Table 3-46. Mean hourly temperatures (°C) from the Davis Weather station in Mugatrah from 2004 through to 2019.

	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Jan	16.4	15.6	15.2	14.8	14.5	14.2	14.0	13.7	14.3	16.5	19.7	21.9	23.3	24.2	24.7	24.8	24.3	23.0	21.3	19.8	18.8	18.0	17.4	16.7
Feb	17.8	17.0	16.6	16.2	15.9	15.7	15.3	15.0	15.9	18.5	21.4	23.4	24.9	26.0	26.5	26.3	25.7	24.5	22.7	21.2	20.1	19.2	18.6	18.0
Mar	20.8	20.2	19.6	19.2	18.9	18.5	18.4	18.3	19.9	22.9	25.6	27.6	29.0	30.0	30.6	30.5	29.6	28.3	26.6	24.8	23.6	22.7	22.0	21.4
Apr	24.0	23.6	23.1	22.7	22.4	22.1	21.8	22.5	25.1	28.9	31.5	33.4	35.0	35.8	35.8	35.3	34.2	32.6	30.9	28.9	27.5	26.5	25.6	24.8
May	28.1	27.1	26.5	26.0	25.6	25.3	25.1	26.4	30.0	33.7	36.4	38.3	39.7	40.6	40.7	40.0	38.9	37.4	35.6	33.5	31.8	30.6	29.6	28.7
Jun	30.4	29.4	28.8	28.3	27.8	27.6	27.4	28.7	32.1	35.5	38.2	40.3	41.9	42.8	43.0	42.2	41.0	39.4	37.7	35.7	34.1	32.9	32.0	31.1
Jul	33.4	32.4	31.9	31.4	31.0	30.7	30.4	31.3	34.0	37.0	39.5	41.5	43.0	44.0	44.2	43.9	42.7	41.3	39.7	38.0	36.5	35.5	34.6	33.9
Aug	33.4	32.5	31.9	31.4	30.9	30.6	30.4	30.9	33.6	36.7	39.4	41.5	43.0	44.1	44.3	43.6	42.4	40.8	39.3	37.6	36.4	35.4	34.6	33.8
Sep	30.6	29.7	29.1	28.6	28.1	27.8	27.6	28.1	30.6	33.9	36.7	38.9	40.5	41.6	42.0	41.4	39.9	38.0	36.1	34.5	33.5	32.6	31.8	31.0
Oct	27.1	26.4	25.8	25.3	24.8	24.5	24.2	24.3	26.3	29.9	32.7	34.8	36.3	37.3	37.5	37.1	35.8	33.9	32.1	30.8	29.8	29.0	28.3	27.6
Nov	21.4	20.7	20.2	20.0	20.2	20.5	20.7	20.8	22.1	25.0	27.5	28.8	29.5	29.8	29.8	29.5	28.6	27.2	25.7	24.5	23.6	23.0	22.4	21.7
Dec	18.2	18.1	17.9	17.7	17.5	17.2	16.9	16.6	17.0	19.0	21.9	23.7	24.7	25.3	25.6	25.5	24.8	23.5	21.9	20.7	19.8	19.1	18.5	18.1

APPENDIX 3-7

3.6.7 BASIC FREQUENCY RESULTS FOR BURROW DATA

All data which had NR (Not Recorded) for orientation or burrow status was excluded.

The data suggests that there was a significant difference between the burrow status and site χ^2 (3, N=803)=8.501, p<0.0367

There was a significant difference with burrow status against season (MUG and WAS pooled) χ^2 (9, N=803)=61.984, p<0.0001. All data where the burrow status was recorded as NR have been excluded n= 6.

Burrow orientation against site χ^2 (7, N=809)=35.579, p<0.0001 suggesting a significant difference between the orientations that were recorded and the site of the recording.

Burrow orientation against season (MUG and WAS pooled) χ^2 (21, N=809)=28.753, p<0.1201 suggesting that there was no significant difference between the seasons and orientation of the burrows when the data was pooled.

Similarly, burrow orientation against season (MUG) showed there was no significant difference between the season and orientation of the burrows χ^2 (21, N=416)=19.021, p<0.5838

However, burrow orientation against season (WAS) showed there was a significant difference between the season and orientation of the burrows there χ^2 (21, N=393)=42.287, p<0.0039

When the orientation by season for "*active"* burrows was tabulated, there was no significant difference between the season and direction χ^2 (21, N=567)=20.018, p<0.5201

Similarly, when the orientation x season for "*abandoned"* burrows (MUG and WAS pooled) no difference χ^2 (21, N=123)=25.544, p<0.2244.

When orientation v season and active burrows for WAS were looked at, there was a significant difference χ^2 (21, N=292)=34.472, p<0.0412 as was the case for orientation v season and

"*abandoned"* burrows χ^2 (14, N=62)=33.236, p<0.0027.

When Orientation v Season for "*active"* burrows in MUG was examined, there was no statistical difference χ^2 (21, N=275)=13.380, p<0.8947

When Orientation v Season for "*abandoned"* burrows in MUG was examined, there was no statistical difference χ^2 (21, N=78)=23.062, p<0.3407

APPENDIX 3-8 - RFID DATA FOR EACH STUDY ANIMAL

Table 3-47. Recorded data for each animal captured in the RFID traps showing their ID, the original coordinates for their home burrow, sex, the coordinates of the burrow they were recorded at, the burrow id, distance they were (m) from their home burrow, the number of times they visited that burrow, the first and last date they visited the burrow.

Animal ID/Sex/Original Burrow		Home Lat/Lon/Ele (24.811652152, 55.248279583, 78.385 m)					
AQ01 (Female) 779							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.81286	55.24792	75.548	S2B08	139	23	10-Sep-15	10-Sep-15
24.81271	55.24827	75.913	S2B04	118	73	13-Aug-15	24-Jul-16
24.81280	55.24823	76.894	S2B03	127	34	09-Sep-15	24-Jul-16
24.81291	55.24804	75.969	S2B01	141	121	18-Jun-15	10-Sep-15
24.81165	55.24828	78.385	779		2702	19-Oct-17	09-Jan-18

Animal ID/Sex/Original Burrow		Home Lat/Lon/Ele (24.813790214, 55.249703119, 75.573 m)					
K9-001 (Female) 15-028							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.81271	55.24827	75.913	S2B04	187	15	21-Jun-16	21-Jun-16

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.813329311, 55.248656775, 75.008 m)				
MUG 001 (Male) 14-198							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.81341	55.24856	73.981	14-199	13	4079	05-Oct-17	07-Dec-18
24.81333	55.24866	75.008	14-198	0	213	30-May-16	23-May-18
24.81402	55.24929	75.273	S1B01	100	9	09-May-15	09-May-15
24.81401	55.24918	74.057	S1B02	91	4	11-May-16	11-May-16
24.81291	55.24804	75.969	S2B01	77	1803	19-Apr-16	01-May-17
24.81284	55.24801	76.215	S2B02	85	9	16-Apr-16	24-May-16
24.81280	55.24823	76.894	S2B03	73	200	07-Jun-15	04-May-17
24.81271	55.24827	75.913	S2B04	78	84	16-Apr-16	11-May-17
24.81286	55.24792	75.548	S2B08	91	7	19-Apr-16	25-May-16
24.81332	55.24878	76.713	14-197	12	37582	14-Jul-17	11-Sep-18

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.813329311, 55.248656775, 75.008 m)				
MUG 002 (Female) 14-198							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.81341	55.24856	73.981	14-199	13	406	14-Jul-17	07-Dec-18
24.81284	55.24801	76.215	S2B02	85	1	04-May-17	04-May-17
24.81332	55.24878	76.713	14-197	12	58	02-Oct-17	23-Jul-18
24.81280	55.24823	76.894	S2B03	73	13	30-Apr-17	30-Apr-17
24.81271	55.24827	75.913	S2B04	78	1	28-Oct-16	28-Oct-16
24.81333	55.24866	75.008	14-198	0	32190	02-Jun-16	23-May-18

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.812652603, 55.248367759, 76.466 m)				
MUG 003 (Male) S2B05							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.81291	55.24804	75.969	S2B01	43	16	11-Jun-15	01-Aug-16
24.81284	55.24801	76.215	S2B02	42	18	22-Oct-15	01-Aug-16
24.81280	55.24823	76.894	S2B03	21	29	11-Jun-15	30-Jul-16
24.81271	55.24827	75.913	S2B04	12	213	17-Sep-15	30-Jul-16

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.813435296, 55.250654446, 77.635 m)				
MUG 005 (Male) 14-120							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.81344	55.25065	77.635	14-120		571	14-Mar-15	24-Apr-15
24.81402	55.24929	75.273	S1B01	152	6	07-Jun-15	09-Jun-15

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.809644703, 55.248545905, 85.35 m)				
MUG 043 (Female) 14-160							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.81165	55.24828	78.385	779	224	1667	12-Sep-18	15-Jan-19

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.814006825, 55.249177571, 74.057 m)				
MUG 004 (Male) S1B02							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.81401	55.24918	74.057	S1B02	0	8402	13-Apr-15	08-May-16
24.81224	55.24650	74.944	14-167	333	959	10-Feb-16	20-Apr-16
24.81402	55.24929	75.273	S1B01	11	1469	10-Apr-15	06-Dec-15
24.81344	55.25065	77.635	14-120	161	23	19-Apr-15	20-Apr-15
24.81291	55.24804	75.969	S2B01	167	14	14-May-16	19-May-16
24.81284	55.24801	76.215	S2B02	175	187	28-Dec-15	19-May-16
24.81280	55.24823	76.894	S2B03	165	34	11-May-16	11-May-16
24.81286	55.24792	75.548	S2B08	180	11	28-Dec-15	18-May-16
24.81333	55.24866	75.008	14-198	91	5	01-Jun-16	04-Jun-16

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.8135360330343, 55.2480609901249,				
MUG 006 (Male) Dhub215							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.81344	55.25065	77.635	14-120	261	89	18-Mar-15	21-Mar-15
24.81401	55.24918	74.057	S1B02	124	34	17-Jul-15	14-Aug-15
24.81402	55.24929	75.273	S1B01	135	8	25-Apr-15	14-Aug-15

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.812714445, 55.248267029, 75.913 m)				
MUG 007 (Female) S2B04							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.81291	55.24804	75.969	S2B01	31	5	06-Sep-15	08-Sep-15
24.81284	55.24801	76.215	S2B02	30	1	08-Sep-15	08-Sep-15
24.81271	55.24827	75.913	S2B04	13	07-Sep-15	16-Sep-15	
24.81280	55.24823	76.894	S2B03	9	35	06-Sep-15	13-Sep-15

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.812909831, 55.248037577, 75.969 m)				
MUG 008 (Female) S2B01							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.81291	55.24789	75.192	S2B07	14	4	09-May-15	07-Jun-15
24.81286	55.24792	75.548	S2B08	13	64	27-Jul-15	29-Jul-16
24.81280	55.24823	76.894	S2B03	23	76	12-May-16	04-May-17
24.81284	55.24801	76.215	S2B02	8	71	10-May-15	07-Sep-16
24.81332	55.24878	76.713	14-197	88	302	23-Jun-18	11-Aug-18
24.81291	55.24804	75.969	S2B01	0	20963	19-Apr-15	02-May-17
24.81341	55.24856	73.981	14-199	75	1156	23-Jun-18	23-Nov-18
24.81271	55.24827	75.913	S2B04	31	55	29-Mar-16	19-Apr-17

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.812795516, 55.24823081, 76.894 m)				
MUG 010 (Male) S2B03							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.81284	55.24801	76.215	S2B02	23	100	29-Apr-15	06-Jun-16
24.81286	55.24792	75.548	S2B08	32	23	09-May-15	06-Jun-16
24.81291	55.24789	75.192	S2B07	36	5	27-Apr-15	14-May-15
24.81280	55.24823	76.894	S2B03	0	31991	08-May-15	14-Nov-16
24.81291	55.24804	75.969	S2B01	23	195	26-Apr-15	12-Jun-16
24.81271	55.24827	75.913	S2B04	9.	80	17-Oct-15	07-Aug-16

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.812176918, 55.246343465, 75.133 m)				
MUG 014 (Male) 14-168							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.81286	55.24792	75.548	S2B08	175	17	14-May-15	21-Oct-15
24.81291	55.24789	75.192	S2B07	175	1	17-May-15	17-May-15
24.81284	55.24801	76.215	S2B02	183	1	05-Jul-15	05-Jul-15

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.8122850339859, 55.2472359593957,				
MUG 011 (Male) Dhub225							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.81271	55.24827	75.913	S2B04	114	44	16-Aug-15	30-Apr-17
24.81333	55.24866	75.008	14-198	184	127	23-Apr-17	13-May-18
24.81332	55.24878	76.713	14-197	194	4	31-May-18	31-May-18
24.81341	55.24856	73.981	14-199	182	8	13-May-18	31-May-18
24.81165	55.24828	78.385	779	126	2	04-May-17	04-May-17
24.81291	55.24804	75.969	S2B01	106	40	15-Aug-15	06-Aug-16
24.81280	55.24823	76.894	S2B03	115	57	16-Aug-15	30-Apr-17
24.81284	55.24801	76.215	S2B02	99	1226	15-Aug-15	05-Sep-16
24.81286	55.24792	75.548	S2B08	93	31155	17-Aug-15	04-May-17

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.811517995, 55.246032979, 76.654 m)				
MUG 015 (Female) 14-169							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.81271	55.24827	75.913	S2B04	261	17115	31-Jul-15	24-Jun-16
24.81291	55.24789	75.192	S2B07	242	687	12-May-15	15-May-15
24.81280	55.24823	76.894	S2B03	263	83	08-May-15	24-Jun-16
24.81341	55.24856	73.981	14-199	329	11	18-May-18	18-May-18
24.81291	55.24804	75.969	S2B01	254	8	09-May-15	27-Mar-16
24.81284	55.24801	76.215	S2B02	247	2	23-Apr-15	23-Apr-15
24.81286	55.24792	75.548	S2B08	241	12	04-Jul-15	18-Sep-15

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.813324479, 55.248781537, 76.713 m)				
MUG 021 (Male) 14-197							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.81401	55.24918	74.057	S1B02	85	331	28-Apr-16	11-May-16
24.81402	55.24929	75.273	S1B01	92	1004	07-Oct-15	01-Nov-15

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.811917051, 55.246438577, 76.482 m)				
MUG 016 (Female) 14-166							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.81280	55.24823	76.894	S2B03	205	18	11-Jun-15	10-Aug-16
24.81401	55.24918	74.057	S1B02	360	65	03-Jul-15	04-Aug-15
24.81332	55.24878	76.713	14-197	283	6	13-Jun-18	13-Jun-18
24.81333	55.24866	75.008	14-198	273	2	23-Jun-16	12-Sep-16
24.81341	55.24856	73.981	14-199	270	14	13-Jun-18	24-Jun-18
24.81165	55.24828	78.385	779	188	2593	30-Jun-17	01-Oct-17
24.81402	55.24929	75.273	S1B01	370	40	24-Oct-15	25-Oct-15
24.81284	55.24801	76.215	S2B02	188	1	24-Jun-15	24-Jun-15
24.81291	55.24804	75.969	S2B01	195	18	21-Jun-15	16-Sep-15
24.81271	55.24827	75.913	S2B04	204	18	13-Oct-15	17-Aug-16
24.81286	55.24792	75.548	S2B08	182	9	21-Jun-15	16-Sep-15

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.812859156, 55.247917303, 75.548 m)				
MUG 017 (Male) S2B08							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.81332	55.24878	76.713	14-197	101	4	11-May-18	11-May-18
24.81286	55.24792	75.548	S2B08	0	3621	28-Apr-15	18-Mar-17
24.81291	55.24789	75.192	S2B07	6	1661	19-Apr-15	20-Jun-15
24.81271	55.24827	75.913	S2B04	38	524	14-Jun-16	05-May-17
24.81280	55.24823	76.894	S2B03	32	64	15-May-15	04-May-17
24.81284	55.24801	76.215	S2B02	9	7469	23-Apr-15	04-May-17
24.81291	55.24804	75.969	S2B01	13	66	11-May-15	12-Nov-16
24.81165	55.24828	78.385	779	139	15	05-May-17	04-May-18
24.81333	55.24866	75.008	14-198	91	16	18-Apr-17	11-May-18
24.81341	55.24856	73.981	14-199	88	22	06-Sep-17	01-Dec-18

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.814006825, 55.249177571, 74.057 m)				
MUG 020 (Female) S1B02							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.81333	55.24866	75.008	14-198	91	3373	29-May-16	06-Apr-17
24.81402	55.24929	75.273	S1B01	11	2	30-Jul-15	30-Jul-15
24.81401	55.24918	74.057	S1B02	0	76	20-Jul-15	07-Aug-15
24.81430	55.24892	71.534	S1B04	41	3	20-Jul-15	20-Jul-15
24.81291	55.24804	75.969	S2B01	167	2	29-Jul-15	29-Jul-15
24.81280	55.24823	76.894	S2B03	165	312	29-Jul-15	16-Apr-17
24.81271	55.24827	75.913	S2B04	170	8148	02-Apr-17	15-Apr-17
24.81286	55.24792	75.548	S2B08	180	21	29-Jul-15	29-Jul-15

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.811917051, 55.246438577, 76.482 m)				
MUG 024 (Female) 14-166							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.81224	55.24650	74.944	14-167	36	18	18-Apr-16	25-Apr-16

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.810141428, 55.244162939, 76.881 m)				
MUG 025 (Male) 14-149							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.80940	55.24324	77.311	14-139	124	20	01-May-16	14-May-16

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.814298864, 55.248924679, 71.534 m)				
MUG 035 (Female) S1B04							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.81286	55.24792	75.548	S2B08	189	2	21-Jun-16	21-Jun-16
24.81333	55.24866	75.008	14-198	111	1	21-Jun-16	21-Jun-16
24.81402	55.24929	75.273	S1B01	48	3	07-Oct-15	07-Oct-15

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.809001001, 55.244566038, 79.755 m)				
MUG 036 (Female) 14-145							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.80900	55.24457	79.755	14-145	2	15-May-18	15-May-18	
24.80894	55.24416	79.716	14-143	41	15	14-May-18	24-May-18
24.80940	55.24324	77.311	14-139	141	23	16-May-18	10-Jun-18

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.808942879, 55.244161574, 79.716 m)				
MUG 038 (Unsure) 14-143							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.80894	55.24416	79.716	14-143		14	25-Apr-18	20-Jun-18
24.80940	55.24324	77.311	14-139	106	380	14-Aug-16	24-May-18
24.80900	55.24457	79.755	14-145	41	2	25-Apr-18	25-Apr-18

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.811524040997, 55.2460299711674, 67.894417				
MUG 048 (Male) 14-170							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.81165	55.24828	78.385	779	227	2	20-May-18	20-May-18

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.811517995, 55.246032979, 76.654 m)				
MUG 049 (Male) 14-169							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.81165	55.24828	78.385	779	227	10	22-Apr-18	22-Apr-18
24.81271	55.24827	75.913	S2B04	261	17	06-Apr-17	26-Apr-17
24.81291	55.24804	75.969	S2B01	254	1	26-Apr-17	26-Apr-17
24.81280	55.24823	76.894	S2B03	263	8	26-Apr-17	26-Apr-17

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.809400053, 55.243238349, 77.311 m)				
MUG 050 (Male) 14-139							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.80940	55.24324	77.311	14-139	0	4510	23-Oct-16	12-May-17

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.809400053, 55.243238349, 77.311 m)				
MUG 051 (Female) 14-139							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.80894	55.24416	79.716	14-143	106	103619	15-Nov-17	13-Oct-18
24.80900	55.24457	79.755	14-145	141	581	22-May-18	28-Dec-18
24.80940	55.24324	77.311	14-139		110	14-Jul-17	22-Oct-18

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.814021215, 55.249291105, 75.273 m)				
S1B01 (Female) S1B01							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.81401	55.24918	74.057	S1B02	11	25	21-Jun-15	17-Nov-15
24.81332	55.24878	76.713	14-197	92	3	08-May-18	08-May-18
24.81333	55.24866	75.008	14-198	100	23	15-Apr-17	22-Oct-17
24.81402	55.24929	75.273	S1B01	0	85	06-Jun-15	11-Nov-15
24.81341	55.24856	73.981	14-199	100	10	30-Mar-18	20-Apr-18

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.812907576, 55.247890686, 75.192 m)				
S2B07 (Female) S2B07							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.81291	55.24789	75.192	S2B07	0	47	07-Mar-15	08-Mar-15
24.81344	55.25065	77.635	14-120	284	120	11-Mar-15	12-Mar-15

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.812850513, 55.248486232, 76.043 m)				
S2B09 (Female) S2B09							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.81291	55.24789	75.192	S2B07	60	435	19-Apr-15	20-Apr-15

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.812843262, 55.248005096, 76.215 m)				
S2B02 (Female) S2B02							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.81286	55.24792	75.548	S2B08	9	139	18-May-15	05-Apr-16
24.81333	55.24866	75.008	14-198	85	4	06-Aug-17	06-May-18
24.81332	55.24878	76.713	14-197	94	1	06-May-18	06-May-18
24.81284	55.24801	76.215	S2B02	0	1331	19-Apr-15	04-Aug-16
24.81280	55.24823	76.894	S2B03	23	24	15-Jul-15	05-Sep-15
24.81271	55.24827	75.913	S2B04	30	47	05-Sep-15	04-Apr-16
24.81291	55.24789	75.192	S2B07	13	3	22-Apr-15	18-May-15
24.81341	55.24856	73.981	14-199	83	7	06-Aug-17	06-May-18
24.81401	55.24918	74.057	S1B02	175	17	20-Jul-15	20-Jul-15
24.81291	55.24804	75.969	S2B01	8	1432	28-May-15	04-Aug-16

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.808365293, 55.241853234, 78.111 m)				
WAS 064 (Male) 14-135							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.80940	55.24324	77.311	14-139	180	4145	22-Jan-16	28-Dec-18
24.80900	55.24457	79.755	14-145	282	3183	29-Nov-17	15-Jan-19
24.80894	55.24416	79.716	14-143	241	100	18-Mar-18	31-May-18

Animal ID/Sex/Original Burrow			Home Lat/Lon/Ele (24.811613143, 55.249194906, 80.189 m)				
WAS 079 (Female) 14-123							
Latitude	Longitude	Elevation	Burrow Visited	Distance (m) From Original Burrow	# Times at Burrow	First Recorded	Last Record
24.81284	55.24801	76.215	S2B02	181	1	28-Aug-16	28-Aug-16
24.81280	55.24823	76.894	S2B03	163	10	24-May-16	28-Aug-16
24.81291	55.24804	75.969	S2B01	185	1	28-Aug-16	28-Aug-16
24.81165	55.24828	78.385	779	92	131	16-Jul-17	30-Oct-18
24.81271	55.24827	75.913	S2B04	154	3	28-Aug-16	28-Aug-16

APPENDIX 3-9 - CAPTURE/RECAPTURE DATA

3.6.8 CAPTURE/RECAPTURE DATA

Table 3-48. The number of animals (n=158) that were caught different amount of times.

No. of animals	Times an animal was caught	Percentage of times a dhub was caught
79	1	50
46	2	29.1
15	3	9.5
4	4	2.5
6	5	3.8
4	6	2.5
2	7	1.3
2	8	1.3

50% of dhub were caught only once. 14 dhub (9%) were caught more than 5 times throughout the study. Multiple catches were due to the dhubs movement between burrows. Males were repeatedly caught slightly more often at 3.1% compared to females at 2.7%.

843 m travelling between burrows was the furthest recorded for a female. This was from a translocated female (AQ01). MUG 005 was the furthest a male was found from its burrow at more than 1.1 Km. Mean travel distance (excluding these two high values) was 143 m for females and 134 m for males.

Table 3-49. Female capture details, their home burrow location with the number of times the animals were caught in the capture burrow, the distance the capture burrow was from their home burrow, the first date they were caught there and last date the animal was caught in that burrow.

Dhub	Times Caught	Home Burrow	Capture Burrow	Distance	First Date	Last Date
AQ01	1	779	14-123	92.42	15-Oct-14	15-Oct-14
AQ01	1	779	14-121	843.25	25-Feb-15	25-Feb-15
AQ01	1	779	14-155	255.60	31-May-15	31-May-15
MUG 002	1	14-198	14-199	13.25	24-Mar-16	24-Mar-16
MUG 007	1	S2B04	14-199	82.18	05-Sep-15	05-Sep-15
MUG 007	1	S2B04	14-202	90.76	19-Sep-15	19-Sep-15
MUG 012	1	14-202	Dhub222	221.25	24-Mar-15	24-Mar-15
MUG 016	1	14-166	S2B06	209.99	28-Mar-16	28-Mar-16
MUG 020	2	S1B02	781	121.98	24-Sep-15	28-Mar-16
MUG 022	1	S1B01	15-028	48.84	27-Mar-16	27-Mar-16
MUG 032	1	14-170	14-130	169.41	29-Mar-16	29-Mar-16
MUG 035	1	S1B04	S1B01	48.14	24-Mar-16	24-Mar-16
S1B01	1	S1B01	S1B02	11.56	10-Mar-15	10-Mar-15
S2B02	1	S2B02	14-201	68.16	11-Sep-15	11-Sep-15
S2B07	5	S2B07	14-155	296.53	03-Mar-15	25-Feb-16
S2B07	2	S2B07	14-169	242.80	24-Mar-16	10-Jun-16
S2BO9	1	S2B09	S2B07	60.40	16-Mar-15	16-Mar-15
WAS 006	1	Dhub257	14-033	279.21	06-May-15	06-May-15
WAS 006	1	Dhub257	16-020	344.88	12-Apr-16	12-Apr-16
WAS 009	1	14-313	697	72.55	24-Mar-15	24-Mar-15
WAS 009	1	14-313	14-317	214.38	20-Mar-16	20-Mar-16
WAS 023	2	14-014	14-322	271.02	28-Sep-15	05-Apr-16
WAS 037	1	14-024	14-025	33.68	11-Apr-16	11-Apr-16
WAS 038	1	14-112	14-111	93.83	22-Sep-15	22-Sep-15
WAS 038	1	14-112	14-110	162.32	23-Mar-16	23-Mar-16
WAS 040	1	785	14-015	353.66	10-Apr-16	10-Apr-16
WAS 040	1	785	14-591	394.02	11-Apr-16	11-Apr-16
WAS 048	1	15-024	15-023	55.04	07-Apr-16	07-Apr-16
WAS 048	1	15-024	14-492	108.88	15-Jun-16	15-Jun-16
WAS 053	1	14-480	14-481	13.26	12-Apr-16	12-Apr-16
WAS 060	1	14-521	14-523	32.84	05-Apr-16	05-Apr-16
WAS 060	1	14-521	16-032	35.86	17-Apr-16	17-Apr-16
WAS 060	1	14-521	16-032	35.86	17-May-16	17-May-16
WAS 060	1	14-521	Dhub044	232.96	10-Jul-16	10-Jul-16
WAS 075	1	14-531	14-453	91.86	14-May-19	14-May-19
WAS 076	1	14-029	14-013	126.94	13-Apr-16	13-Apr-16
	Mean distance (m) from home burrow			142.5		
			SEM	18.6		

Table 3-50. Male capture details, their home burrow location with the number of times the animals were caught in the capture burrow, the distance the capture burrow was from their home burrow, the first date they were caught there and last date the animal was caught in that burrow.

Dhub	Times Caught	Home Burrow	Capture Burrow	Distance	First Date	Last Date
MUG 001	3	14-198	14-197	12.60	26-Sep-15	24-Mar-16
MUG 004	1	S1B02	14-120	161.93	27-May-15	27-May-15
MUG 004	1	S1B02	S2B05	171.22	15-Jul-15	15-Jul-15
MUG 004	2	S1B02	14-167	333.69	25-Feb-16	24-Mar-16
MUG 004	1	S1B02	S1B03	9.36	14-Jul-16	14-Jul-16
MUG 005	1	14-120	14-121	1124.09	10-Jul-15	10-Jul-15
MUG 014	2	14-168	14-163	75.71	19-Sep-15	24-Mar-16
MUG 014	1	14-168	14-167	17.43	26-Sep-15	26-Sep-15
MUG 021	1	14-197	S1B02	85.70	31-May-15	31-May-15
MUG 021	1	14-197	14-195	272.27	24-Mar-16	24-Mar-16
WAS 007	1	14-019	14-025	94.17	28-Sep-15	28-Sep-15
WAS 010	2	14-013	14-033	57.53	21-Mar-16	17-Apr-16
WAS 010	1	14-013	16-019	99.45	12-Apr-16	12-Apr-16
WAS 014	2	14-316	Dhub254	37.08	13-Sep-15	20-Mar-16
WAS 022	1	785	14-316	247.57	20-Mar-16	20-Mar-16
WAS 027	1	Dhub043	14-497	136.16	27-Jul-15	27-Jul-15
WAS 027	1	Dhub043	14-500	151.87	06-Sep-15	06-Sep-15
WAS 027	1	Dhub043	14-502	149.66	25-Feb-16	25-Feb-16
WAS 027	1	Dhub043	15-047	136.63	17-Apr-16	17-Apr-16
WAS 027	1	Dhub043	15-033	164.70	17-May-16	17-May-16
WAS 028	1	15-005	14-314	134.34	21-Sep-15	21-Sep-15
WAS 056	1	LC18	15-048	70.08	13-Oct-15	13-Oct-15
WAS 056	1	LC18	16-059	253.08	17-May-16	17-May-16
WAS 056	1	LC18	16-062	98.48	10-Jul-16	10-Jul-16
WAS 058	2	14-523	15-049	33.15	25-Feb-16	15-Mar-16
WAS 059	2	14-519	15-056	58.43	25-Feb-16	14-Apr-16
WAS 059	1	14-519	14-523	61.74	17-May-16	17-May-16
WAS 059	1	14-519	16-061	321.60	10-Jul-16	10-Jul-16
WAS 064	1	14-135	14-143	241.52	10-Dec-15	10-Dec-15
WAS 064	3	14-135	14-139	180.94	25-Feb-16	19-Mar-16
WAS 066	1	14-523	15-049	33.15	17-Apr-16	17-Apr-16
WAS 069	1	Dhub253	14-324	70.63	05-Apr-16	05-Apr-16
WAS 091	1	14-523	15-047	301.49	17-May-16	17-May-16
	Mean distance (m) from home burrow			133.5		
			SEM	16.7		

Table 3-51. The recaptured dhub females (*n=6*) and males (*n=20*) that were caught in the same burrow at each capture event.

Dhub	Sex	Times Caught	Home Burrow	Capture Burrow	First Date	Last Date
WAS 057	Female	4	14-525	14-525	13-Oct-15	17-May-16
WAS 034	Female	2	Dhub 077	Dhub 077	14-Sep-15	21-Mar-16
WAS 033	Female	2	763	763	13-Sep-15	20-Mar-16
WAS 016	Female	2	14-324	14-324	01-Apr-15	28-Sep-15
MUG 018	Female	3	14-165	14-165	17-Mar-15	24-Mar-16
WAS 033	Female	2	763	763	13-Sep-15	20-Mar-16
WAS 051	Male	2	14-182	14-182	29-Sep-15	23-Mar-16
WAS 049	Male	2	14-005	14-005	29-Sep-15	07-Apr-16
WAS 047	Male	2	14-006	14-006	28-Sep-15	05-Apr-16
WAS 043	Male	2	764	764	22-Sep-15	21-Mar-16
WAS 042	Male	2	14-113	14-113	22-Sep-15	23-Mar-16
WAS 041	Male	2	14-296	14-296	21-Sep-15	20-Mar-16
WAS 036	Male	2	761	761	15-Sep-15	20-Mar-16
WAS 035	Male	2	14-293	14-293	14-Sep-15	21-Mar-16
WAS 032	Male	2	784	784	13-Sep-15	22-Mar-16
WAS 031	Male	2	761	761	08-Sep-15	21-Mar-16
WAS 030	Male	2	14-293	14-293	06-Sep-15	05-Apr-16
WAS 036	Male	2	761	761	15-Sep-15	20-Mar-16
WAS 035	Male	2	14-293	14-293	14-Sep-15	21-Mar-16
WAS 032	Male	2	784	784	13-Sep-15	22-Mar-16
WAS 031	Male	2	761	761	08-Sep-15	21-Mar-16
WAS 030	Male	2	14-293	14-293	06-Sep-15	05-Apr-16
WAS 015	Male	3	14-314	14-314	01-Apr-15	05-Apr-16
MUG 034	Male	2	15-046	15-046	26-Sep-15	29-Mar-16
MUG 029	Male	2	14-127	14-127	19-Sep-15	24-Mar-16
MUG 025	Male	2	14-149	14-149	18-Sep-15	27-Mar-16

CHAPTER 4: VEGETATION SURVEY

4.1 INTRODUCTION

The UAE is predominantly arid, much of it is classified as hyperarid (Boer, 1997) and consists of a low-lying coastal plain which merges into the rolling sand dunes of the Rub al-Khali desert. Mountains (the highest of which is 1,934 metres at Jebel Jais) skirt the eastern border with Oman. In many areas near the coast, the sand is stabilised by vegetation, although the natural flora has been altered in recent times by extensive grazing of domesticated animals and other anthropogenic factors (Irani, 2001; Gallacher & Hill, 2006b, a; Gallacher & Hill, 2008).

The Arabian Peninsula, including UAE, experiences some of the most extreme climatic conditions found on the Earth and is characterized by low, erratic rainfall, high evaporation rates and amongst the highest temperatures on Earth (Boer, 1997; Zahran, 1997; El-Nesr *et al*, 2010; Ghazanfar & Fisher, 2013). Recent studies predict, by 2050 a temperature increase of between 2.5 to 3.7 °C in summer, and 2.0 to 3.1 °C in winter (Hemming *et al*, 2007) due to climate change. Sunday *et al* (2014) argue that heat safety margins often increase markedly with latitude, implying that tropical species such as *Uromastyx* spp. might be relatively more vulnerable to climate warming than those species living at higher latitudes. According to Elhakeem *et al* (2015), the higher temperatures will increase the vapour pressure, which along with the changes in atmospheric circulation patterns will likely have a considerable effect on the intensity, frequency and spatial variability of precipitation. The region will likely get drier, with significant rainfall declines in the wet season outweighing slight increases during the drier summer months. This has been supported by Al Sarmi & Washington (2011) where they examined trends in temperature and precipitation parameters for the Arabian Peninsula during the last two to three decades. They concluded that there was a general warming pattern of the Arabian Peninsula, with the mean annual temperature for the UAE (Dubai) suggests an increase rate of 0.81°C/decade. Although statistically insignificant, their study showed that the mean annual precipitation changes showed a decreasing trend. This reduction in precipitation will have a knock on effect as the main source of groundwater recharge to the relatively shallow aquifers is from localised rain storms (Elhakeem *et al*, 2015) with a subsequent decrease in the species, distribution and density of the flora of the UAE. However, fogs occur in winter and spring and can contribute a more regular source of water to the flora, than precipitation. In many instances small micro-environments develop under ghaf (*Prosopis cineraria*) trees from the moisture falling from the leaves after these fogs. Bouskila (1983) believed that the distance to the nearest acacia tree (*Acacia tortilis*) was important in the distribution of dhub burrows.

Flora found in the study areas are faced with quite a number of environmental stresses such as the aforementioned high temperatures, irradiance, drought and salinity (Karim & Dakheel, 2006; Manousaki & Kalogerakis, 2011; Cybulska *et al*, 2014; Gairola *et al*, 2019). In general, these arid land plants can be classified as either Mesophytes (which are usually weeds associated with irrigation) and Xerophytes which are the drought resistant plants outside irrigated areas. With regards to salinity, they can be generally split into glycophytes (show little tolerance to elevated root-zone salinity) and halophytes, those adapted to the saline soils of the UAE. Within each group there is a tolerance gradient, and salinity tolerance among plants is distributed along a gradient from extreme glycophytes to extreme halophytes (Karim & Dakheel, 2006). Most key plant species inhabiting the margins of saline habitats are halophytic perennial succulent dwarf shrubs. Either leaf succulents with woody stems or stem succulents, constitute the predominant life form. Trees are largely absent from aeolianite substrates with the exception of members of the genus *Tamarix* (Brown, 2006).

Historical annual rainfall in the UAE rarely exceeded 120 mm per year and usually occurs between November and April. With a growing population expected to hit 10.4 million by 2030 (Macrotrends, 2023), compared to 9.5 million in 2023, the UAE is under pressure to find more cost-effective ways of sourcing fresh water than its traditional yet expensive method of desalination. With this in mind the UAE Government have been upping their efforts to increase the amount of rain through cloud seeding. The National Centre of Meteorology (NCM) conducted 242 cloud seeding operations in 2017 alone, an increase from the 177 in 2016. The majority of these are conducted in the middle of July and September as there is a higher frequency of suitable clouds (Godinez, 2018). Further data from the NCM showed a maximum mean rainfall between 2003 to 2018 for the area of Seeh Al Salam, Dubai, UAE (less than 30 Km from either study site) of 14.8 mm for March (NCM, 2019). On 9th March 2016 a 24 hour high was reached when 287 millimetres of rain fell in an area covering Dubai and Al Ain (Samoglou, 2016; Townsend, 2017).

While many of the *Uromastyx* species such as *Uromastyx acanthinura* and *Uromastyx ornata* inhabit (Amer *et al*, 2010) rocky terrain, allowing these species to use the rocks as suitable burrows, *U. aegyptia* usually dig their burrows, sometimes to depths of over 1.5 m (Figure 4-1) (O'Donovan *pers obs*).



Figure 4-1. Example of the depth which had to be dug to retrieve an animal from its burrow (a), with a dhub outside its burrow, showing the substrate type (b).

Many of these dhub burrows are situated in areas of aeolianite sheets, while others dig in the hard gravel sands of the desert. Sand dunes or areas of loose sand are never used as burrow sites. Not much is known about the relationship between burrow situation/location and its proximity to dhubs' main food source.

Being exclusively herbivorous as adults, dhub require suitable areas of usable vegetation, however, food sources vary and are dependent on availability and times of the year. As natural habitat degradation is a regular phenomenon that occurs in arid deserts throughout the world (El-Keblawy, 2017) and that dhub depend on food resources sourced over a small area as well as the fact that primary productivity in dhub habitats is low and displays robust seasonal and annual differences (Al-Sayegh *et al*, 2020) it was important to determine what potential food sources were available to the animals. In addition to the role of vegetation in stabilisation of the substrate and certain species being a food source, dhubs also use vegetation for basking. Furthermore Sunday *et al* (2014) argue that heat safety margins often increase markedly with latitude, implying that tropical species such as *Uromastyx* spp. might be relatively more vulnerable to the forementioned climate warming than those species living at higher latitudes.

4.1.1 OBJECTIVE

Vegetation monitoring programmes generally are designed to detect change over time. The collection and analysis of vegetation data provides the principal form of ecosystem description and classification (Kent, 2011). As this was a survey restricted to one time period it was intended to serve as a snapshot of what plant species were available to the *Uromastyx* within their normal foraging range i.e. the vegetation type and abundance within a 40 m (50 paces) distance of preselected *Uromastyx* burrows in the two survey sites, as this was estimated to be the average distance dhub travelled while foraging

(O'Donovan *pers obs*). From these data it was hoped that a suitable combination of substrate type and vegetation cover/availability could be determined to indicate optimum areas for translocation projects. This also presented an opportunity to investigate the vegetation status of two protected areas within the Emirate of Dubai.

Emphasis was placed on the percentage plant cover and diversity of species/species richness at the survey sites and a floristic vegetation description was used as per Kent (2011). From the resultant data, plant community preferences based on presence or absence from burrows would be identified.

4.2 MATERIALS AND METHODS

4.2.1 SITE DESCRIPTION

Although there is no exact habitat classification for Dubai, similar classification for the Emirate of Abu Dhabi described these areas as sand sheets and dunes with distinct shrub or dwarf shrub (Al Dhaheri *et al*, 2017). In brief, WAS contained sandy plains consisting of a thin layer of mobile (wind-blown) sand over eroded cemented cross-bedded sand dunes, the cemented dunes being mostly eroded to a plain, but with occasional low promontories. MUG is described as having gravel platforms developed by disintegration and erosion of underlying cemented lake deposits.

4.2.2 SUBSTRATE TYPE

Both sites are dominated by soft sand dunes interspersed with eroded and broken fragments of cemented sand or lake deposits. For convenience, two main substrate types, sand and gravel were identified (the term gravel was used in this context for visualisation purposes, but the substrate itself is not as porous as traditional gravel and is in fact fragmented parts of the cemented sand or fragmented parts of the hard lake sediment deposits). These were in themselves broken down further into subtypes (Table 4-1) and shown below (Figure 4-2a to g).

Table 4-1. Different substrate subtypes with number of 10 x 10 m quadrats surveyed and the percentage of observations they were responsible for.

Substrate subtype	# of quadrats	% of Recorded plants
Gravel	21	20
Gravel/Cemented Sand	1	<1
Gravel/Sand	8	7.5
Sand	61	57
Sand/Gravel	7	6.6
Sand/Gravel/Rock*	1	<1
Sand/Cemented Sand	7	6.6

**Rock in this context was a thick, exposed cross section of cemented dune sand.*



a



b



c



d



e



f



g

Figure 4-2. Substrate types, (a) Gravel*, (b) Gravel/Cemented Sand, (c) Gravel/Sand, (d) Sand, (e) Sand/Gravel, (f) Sand/Gravel/Cemented Gravel and (g) Sand/Rock**
*Fragmented cemented dune sand/lake deposit. **Thick sequence of cemented dune sand.

4.2.3 PRECIPITATION

Precipitation data was sourced from Davis Vantage Pro2 weather station situated in Mugatrah site.

4.2.4 SAMPLING PROTOCOL

Sampling was carried out between 8th May 2016 through to 4th August 2016. These months were chosen as it was when equipment for the survey had been sourced and also represented the hottest part of the year when vegetation would potentially be scarce.

Three strata within the two sites were identified: where burrows were Abandoned (open but no animal is in residence, Active (still in use) and Filled In (the burrow is filled in with sand and there was no evidence of animals in the area) (see Figure 4-3). The proportions of the vegetation samples to be examined were determined as follows.

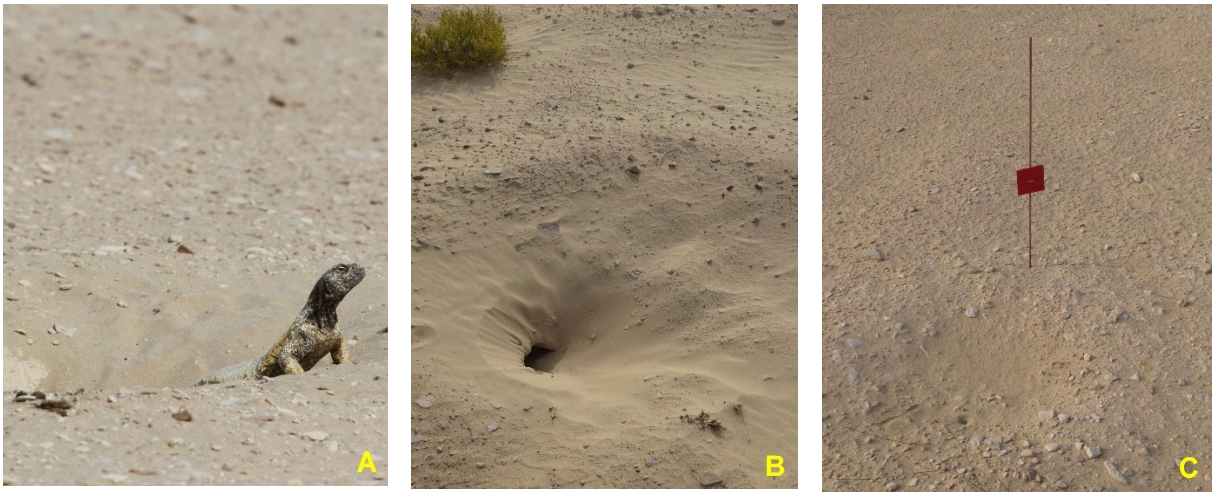


Figure 4-3. Burrow type Active (A), Abandoned (B) and Filled In (C).

Taking 25% of the total number of burrows surveyed as the number of burrows to sample, the proportions were determined as per Table 4-2.

Table 4-2. The number of burrows to be used by site for each stratum.

Site	# of Burrows	Survey Size	Abandoned			Active			Filled In		
			#	%	Sample Size	#	%	Sample Size	#	%	Sample Size
MUG	460	115*	31	6.7	8	121	26.3	30	305	66.3	76
WAS	311	78*	18	5.7	4	144	46.3	36	149	47.9	37

** Due to rounding, the suggested sample size was 2 higher than the actual calculations.*

All data collected during the survey portions (burrow, dhub, RFID, vegetation, etc.) of this study were stored in specific Microsoft Access databases. While calculating the number of samples required

(Table 4-2), a specific MS Access query was written to the list and the burrow data was sorted by site, burrow and status.

MiniTab v 18 was used (Calc, Random Data, Sample From Columns) to generate the random numbers to choose the burrow numbers. MiniTab was again used (Calc, Random Data, Uniform with a lower endpoint of 1 and upper endpoint of 360) to generate the bearings to be taken from each burrow (APPENDIX 4-1)

Once the burrow details were determined it was imported back into MS Access for further processing and to attach the correct coordinates. This was then saved as a CSV file and imported into GPSBabel (GPSBabel v 1.5.3 https://www.gpsbabel.org/index.html). GPSBabel was then able to export it as a KML file which was imported into Garmin Basecamp (Garmin Inc. https://www.garmin.com/en-US/shop/downloads/basecamp) and uploaded to the Garmin GPS. The GPX file with the burrow details was then imported into ArcGIS 10.2 and the location maps of the vegetation quadrats to be surveyed - Figure 4-4 (Mugatrah - MUG) and Figure 4-5 (Wadi Al Safa - WAS)- were generated.

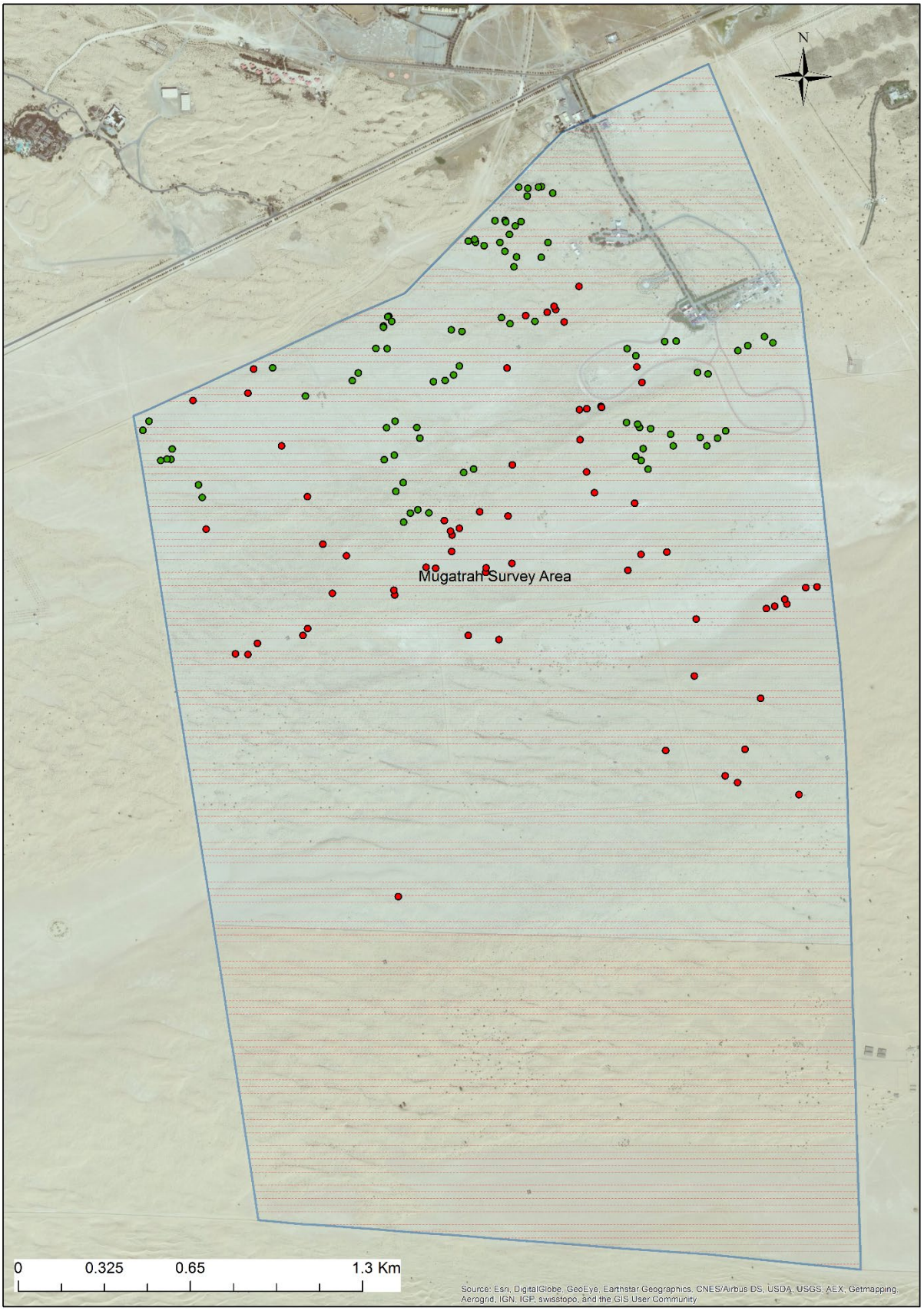


Figure 4-4. Site layout of Mugatrah with the vegetation quadrats not surveyed red dots, surveyed quadrats green dots and complete survey area shaded in blue. Total area of MUG was 933 Ha. (ESRI 2018)

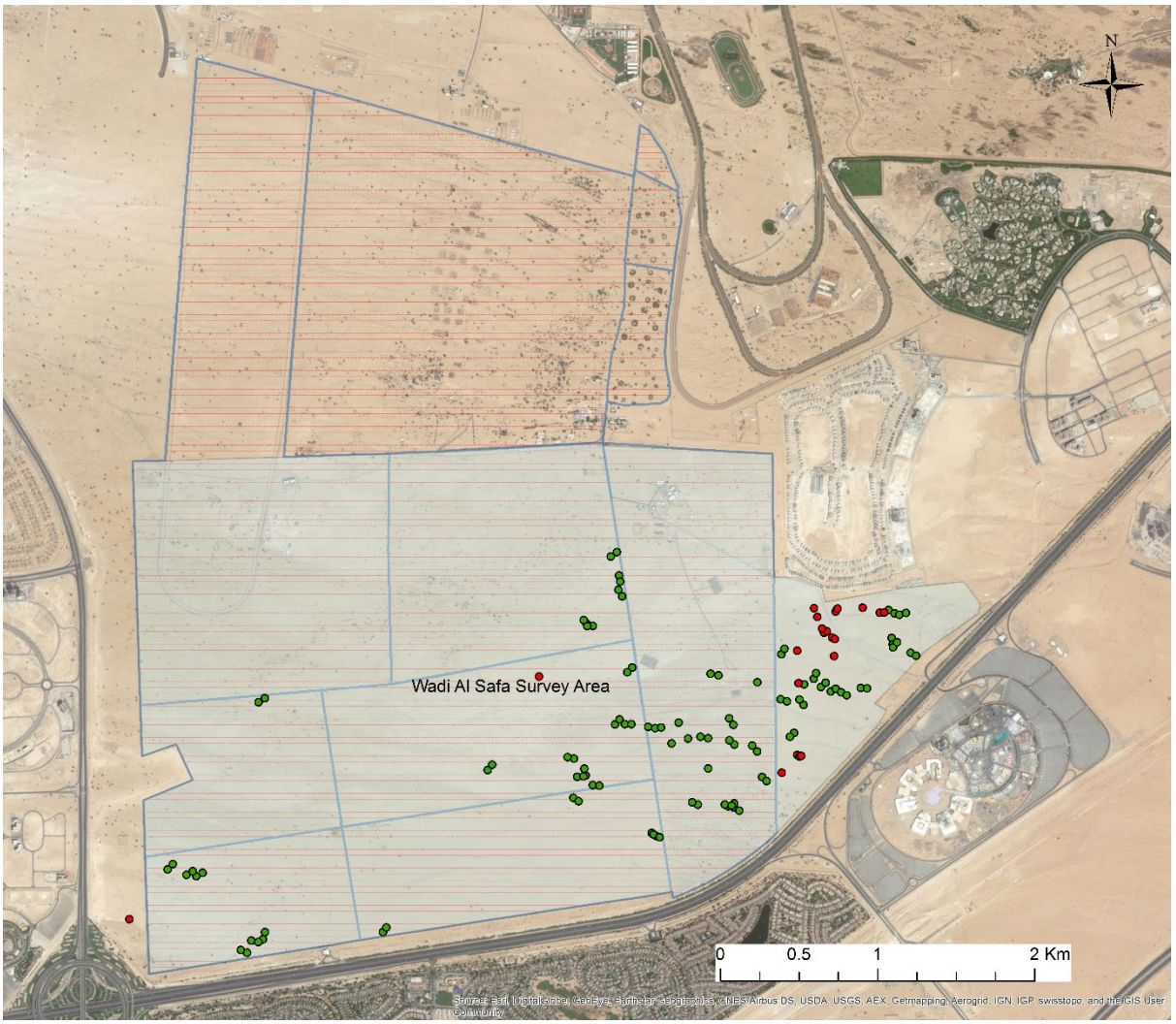


Figure 4-5. Site layout of Wadi Al Safa with the vegetation quadrats not surveyed red dots, surveyed quadrats green dots and complete survey area shaded in blue. (ESRI 2018)
WAS Total Area: 1853 Ha. Total Burrow Survey Area: 1,307 Ha. Survey Area outside WAS to the East of 106 Ha (included in 1307 Ha)

Each site was surveyed in a similar manner. The burrow was approached on foot and a note recorded in the Survey Collection Log (APPENDIX 4-8) as to the status of the burrow at that time. The date, location, burrow number and bearing were also recorded. Using the GPS, the correct bearing was followed for 50 paces (approx. 40 m). This distance was chosen as it brought the survey away from the burrow but was also within the observed foraging range for the species (O'Donovan *unpublished data*).

4.2.5 SAMPLING METHOD

At 50 paces a GPS recording of the sample start (bottom left corner of the survey quadrat) was taken for future resampling and inclusion in future maps. A marker was placed as well as a steel pin to hold the rope to demarcate the survey quadrat of 10 m x 10 m. This first line of the quadrat followed the same bearing as that from the burrow and was placed to the right of the recorder.

The different substrate types were determined subjectively by the amount of each substrate type in the survey quadrat. For example, Gravel/Sand would primarily contain gravel with some sand whereas, Sand/Gravel would have the reverse, primarily sand with some gravel.

The four corners were squared using cut timber to get the angles correct (Figure 4-6a). These quadrats were further subdivided arbitrarily but as equally as possible into a further 16 smaller quadrats (Figure 4-6b) to assist in accurate recording. This was completed by drawing 4 x 4 intersecting lines in the sand within the quadrat. Care was taken to avoid damaging any of the smaller species present. This helped to demarcate areas of heavy vegetation as well as visualising % coverage for each species.



Figure 4-6a. Aerial image of the 10 m x 10 m quadrat design used for the survey.

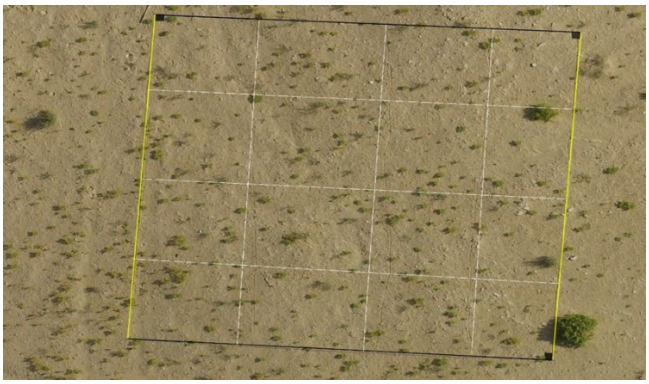


Figure 4-6b. Breakout of sub quadrats within the main quadrat area.

The density of plant species, a direct count of each species present, was recorded. Percentage cover was a visual estimation of the amount of the quadrat occupied by each species of plant. As there was a single vegetation layer, percentage cover did not exceed 100%. The study was undertaken using a Proportional Random Stratified Sample protocol, as described above, based on the Spring 2016 burrow survey. A total of 106 quadrats were surveyed.

Data once collected on the recording log were transferred to the bespoke MS Access database where they could be manipulated and exported as required. Exported data were saved as an MS Excel spreadsheet which could be imported into statistics packages (MiniTab 18 and MedCalc v 18.10) as well as PC Ord.

Burrow status was recorded as either Active, Abandoned or Filled In as per Figure 4-3.

Species Identification Issues

Identification of the different species of vegetation was assisted by Jongbloed *et al* (2003) and in particular through correspondence with Ms Valerie Chalmers from the Dubai Natural History Group. 38 species were identified to species level while three species were identified to genus level only.

Attempts were made initially to identify *Tribulus terrestris, Tribulus pendratus* and *Tribulus omanense* to species level, but as there was some confusion as to differentiating some of the individuals it was decided to group them to genus level and report them as such. There was a similar issue with *Tetraena simplex and Tetraena qatarensis,* so these were reported to genus level only. The final species *Cleome* was identified to genus but not to species level.

4.2.6 ANALYSIS

Data was analysed using PC Ord V7.0. The data collected represented a sparse dataset (Peck, 2016) with 78.8% of the cells empty. While one could have run a power transformation in PC Ord (McCune & Mefford, 2018) to adjust for these zero values, a log transformation (log (x+1)) was carried out to cater for the zero values and reduce the potential distance scales between counts.

4.3 RESULTS

4.3.1 PRECIPITATION

As can be seen from the historical data yearly maxima for the duration of this study have been very low, apart from March 2016 (Table 4-3).

Table 4-3**.** Monthly rainfall (mm) readings* during the study period for Mugatrah (NR= No Records).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2013	NR	NR	0.0	6.8	0.2	0.0	0.0	0.0	2.0	0.2	1.8	0.4	11.4
2014	1.2	3.6	12.2	0.4	0.2	0.2	0.0	0.0	0.0	0.0	0.4	0.0	18.2
2015	9.0	1.2	0.6	0.8	0.0	0.0	0.0	0.0	0.2	0.2	1.4	0.6	14.0
2016	3.6	1.2	218.8	2.2	0.2	0.0	0.0	0.0	0.0	0.2	0.2	0.6	227.1
Min	1.2	1.2	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	
Max	9.0	3.6	218.8	6.8	0.2	0.2	0.0	0.0	2.0	0.2	1.8	0.6	
Mean	4.6	2.0	57.9	2.6	0.2	0.1	0.0	0.0	0.6	0.2	1.0	0.4	

**Source Wadi Al Safa Wildlife Centre data from Davis Vantage Pro2 weather station.*

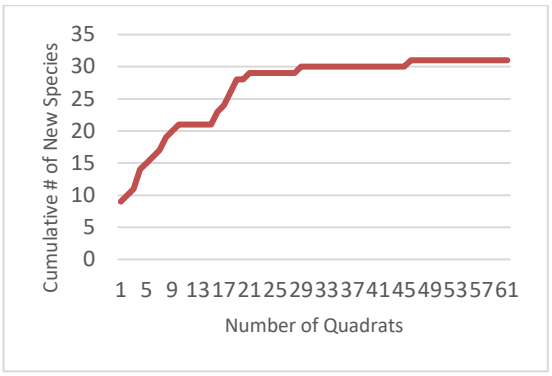
4.3.2 SPECIES AREA CURVES

During the study period, there was a total of 106 quadrats which were surveyed (Table 4-4). One of the important factors which had to be considered was whether enough quadrats had been sampled for each substrate type to deliver an accurate reflection of the vegetation communities of the sites. As such, a post hoc set of species area curves (the relationship between the number of species of plants and the size of a specific area) was undertaken (Figure 4-7 and APPENDIX 4-2) which, with a flattening of the line, showed that enough quadrats for each of the substrate types was undertaken for the relatively low species richness seen in this area.

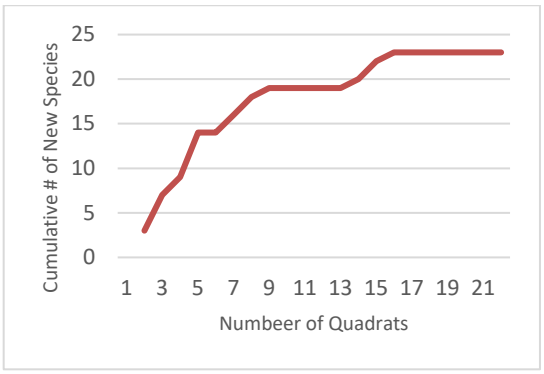
Table 4-4. Number of quadrats sampled per substrate type and site.

Site	Total	Gravel	[a]G/S	[b]G/CS	Sand	[c]S/G	[d]S/CS	[e]S/G/R
MUG	51	14	5		27	3	1	1
WAS	55	7	3	1	34	4	6	

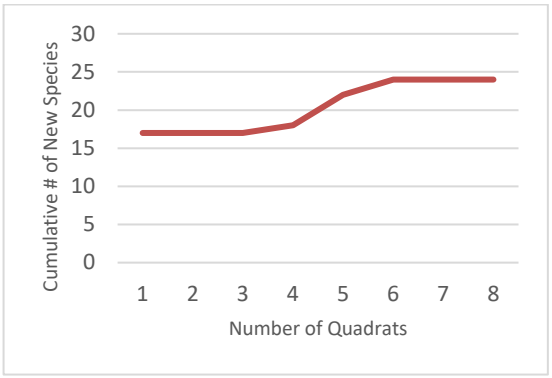
[a]G/S=Gravel/Sand, [b]G/Sab=Gravel/Cemented Sand, [c]S/G= Sand/Gravel, [e]S/CS= Sand/Cemented Sand, [e]S/G/R= Sand/Gravel/Rock, MUG=Mugatrah, WAS=Wadi Al Safa.



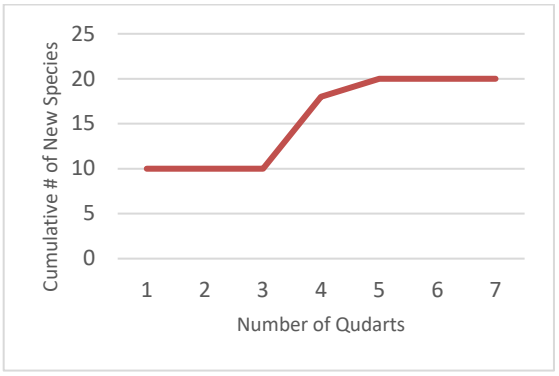
A



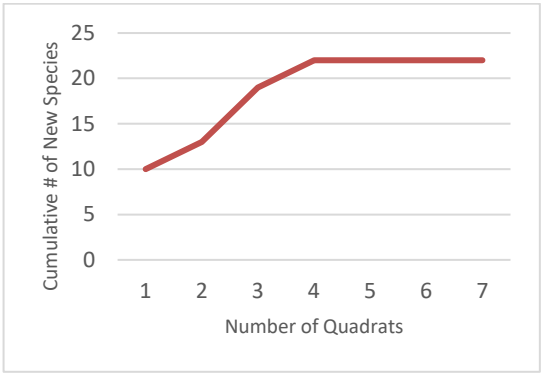
B



C



D



E

Figure 4-7. Species area curves for the five* main substrate types recorded (a. Sand, b. Gravel, c. Gravel/Sand, d. Sand/Gravel and e. Sand/Cemented Sand). The Y axis for each of the substrates is the cumulative number of new species against the x axis of number of quadrats completed (number of quadrats x 10 = the cumulative area in m^2).
*As there was only one quadrat recorded for Gravel/Cemented Sand and Sand/Gravel/Rock, there were no Species Area Curves completed.

4.3.3 SPECIES AND SUBSTRATE

More than 44,000 individual plants were counted (see Table 4-6 for details). 38 different species of plants were recorded during the survey which lasted from 8th May 2016 through to 4th August 2016 (Table 4-5).

These data showed that there were only seven species common to all substrate subtypes, *Arnebia hispidissima, Fagonia bruguieri, Monsonia nivea, Panicum turgidum, Stipagrostis plumosa, Tetraena* spp. and *Tribulus* spp. and nine species found on a single substrate *Aristida abnormis, Calotropis*

procera, Chrozophora oblongifolia, Cleome sp.*, Cyperus conglomeratus, Haloxylon salicornicum, Leptadenia pyrotechnica, Prosopis cineraria* and *Sesuvium verrucosum* (see Table 4-7 and below for further analysis of substrate type where each was found).

4.3.4 SPECIES AND OCCURRENCE IN QUADRATS

During the study period, out of the total of 106 quadrats examined, the most commonly found species was *Tribulus* spp., (94 quadrats) while species such as *Aristida abnormis*, *Cleome* sp., *Haloxylon salicornicum*, *Leptadenia pyrotechnica*, *Prosopis cineraria* and *Sesuvium verrucosum* were only recorded in one quadrat throughout the study (Table 4-5).

4.3.5 SPECIES AND PLANT TYPE

During the data collection, a total of 29 perennial and 12 annual species were recorded (Table 4-5). Of the top 20 most common species, 6 of these were annual plants. The top 10 most common plants were dominated by 3 different families, the Poaceae (4), Zygophyllaceae (3), and Boraginaceae (2), all small sized salt tolerant plants.

Table 4-5. 41 species recorded and the number of quadrats in which they were recorded in Wadi Al Safa (WAS) and Mugatrah (MUG) during the study from 8th May 2016 to 4th August 2016. Life Cycle showed whether they were Annual (A) or Perennial (P) and the Rank determined how common they were in respect to the number of quadrats they were recorded in (*n=106*). *Confirmed forage species in **bold**.*

Family	Species	Life Cycle	Description (Height)	MUG	WAS	Total	Rank
Zygophyllaceae	***Tribulus* spp**.	A	Prostrate to spreading (40 cm)	47	47	94	1
Zygophyllaceae	*Tetraena* spp.	P	Prostrate to spreading (80 cm)	27	40	67	3
Zygophyllaceae	***Fagonia bruguieri***	P	Woody base with thorns (40 cm)	33	27	60	4
Polygonaceae	***Calligonum comosum***	P	Woody base, stems branched and erect (150-200 cm)	2	2	4	29
Poaceae	***Stipagrostis plumosa***	P	Tufted, tubular roots (20 cm)	42	47	89	2
Poaceae	***Panicum turgidum***	P	Woody rooting parts, erect (100 cm)	36	22	58	5
Poaceae	*Eragrostis barrelieri*	A	Grass (5-50 cm)	26	23	49	9
Poaceae	***Pennisetum divisum***	P	Woody rooting parts, erect (150 cm)	33	10	43	10
Poaceae	*Tragus racemosus*	A	Tufted and spreading (30 cm)	0	8	8	24
Poaceae	*Coelachyrum piercii*	P	Erect, forming tussocks (45 cm)	0	3	3	32
Poaceae	*Aristida abnormis*	A	Erect (40 cm)	1	0	1	41
Plantaginaceae	*Plantago ovata*	A	Virtually no stem up to 10 cm high (10 cm)	0	16	16	16
Plantaginaceae	*Plantago ciliata*	A	Virtually no stem (5 cm)	0	7	7	26
Neuradaceae	*Neurada procumbens*	A	Stems, prostrate or spreading (20 cm)	9	17	26	14
Molluginaceae	*Gisekia pharnaceoides*	A	Slender stems up to 20 cm (20 cm)	11	4	15	17
Molluginaceae	*Limeum arabicum*	P	Stems intricately tangled, erect (80 cm)	13	1	14	18
Geraniaceae	*Monsonia nivea*	P	Silver-grey, woody base, erect or spreading (30 cm)	32	24	56	7
Fabaceae	*Indigofera intricata*	P	Woody, spreading (70 cm)	11	15	26	13
Fabaceae	*Indigofera colutea*	P	Woody, spreading (50 cm)	1	2	3	31
Fabaceae	*Prosopis cineraria*	P	Tree (10-25 m)	0	1	1	40
Euphorbiaceae	*Chrozophora oblongifolia*	P	Woody base stems much branched erect (80 cm)	0	5	5	28
Cyperaceae	*Cyperus conglomeratus*	P	Cyperus (50 cm)	2	0	2	35
Cleomaceae	*Dipterygium glaucum*	P	Slender stems up to 80 cm (80 cm)	22	1	23	15
Cleomaceae	*Cleome* sp.	A	Erect (50 cm)	0	1	1	39
Cistaceae	***Helianthemum lippii***	P	Woody (30 cm)	20	18	38	11

Table 4-5. (c*ontinued*) 41 species recorded and the number of quadrats in which they were recorded in Wadi Al Safa (WAS) and Mugatrah (MUG) during the study from 8th May 2016 to 4th August 2016. Life Cycle showed whether they were Annual (A) or Perennial (P) and the Rank determined how common they were in respect to the number of quadrats they were recorded in (*n=106*). *Confirmed forage species in **bold**.*

Family	Species	Life Cycle	Description (Height)	MUG	WAS	Total	Rank
Caryophyllaceae	*Polycarpaea repens*	P	Woody base or spreading (30 cm)	0	35	35	12
Brassicaceae	*Savignya parviflora*	A	Stems slender branched from base, erect (20-35 cm)	7	2	9	22
Boraginaceae	*Arnebia hispidissima*	A	Stem stiff, erect (20 cm)	27	30	57	6
Boraginaceae	***Heliotropium kotschyi***	P	Woody (60 cm)	27	27	54	8
Boraginaceae	*Heliotropium digynum*	P	Woody (40-60 cm)	10	3	13	19
Boraginaceae	*Moltkiopsis ciliata*	P	Woody base, stems much branched, erect (25 cm)	7	2	9	21
Asteraceae	*Launaea mucronata*	P	Stems branching, erect (80 cm)	6	2	8	23
Asteraceae	*Atractylis carduus*	P	Stems erect (15 cm)	2	3	5	27
Asteraceae	*Launaea capitata*	A	Very flat on the ground (1-5 cm)	2	0	2	34
Apocynaceae	*Calotropis procera*	P	Shrub or small tree (250-500 cm)	0	2	2	33
Apocynaceae	*Leptadenia pyrotechnica*	P	Stems branching, erect (250-300 cm)	1	0	1	38
Amaranthaceae	*Cornulaca monacantha*	P	Erect, much branched (80 cm)	10	0	10	20
Amaranthaceae	*Aerva javanica*	P	Straggly bush (100 cm)	1	6	7	25
Amaranthaceae	*Anabasis setifera*	P	Stems much branched (50 cm)	0	3	3	30
Amaranthaceae	*Haloxylon salicornicum*	P	Woody (100 cm)	0	1	1	37
Aizoaceae	*Sesuvium verrucosum*	P	(30 cm)	1	0	1	36

4.3.6 RELATIVE ABUNDANCE OF PLANTS PER SPECIES

Of the 44,000 individual plants that were counted, nearly a third (14,335) belong to *Tetraena* spp, (Table 4-6) followed by *Monsonia nivea* with 15% of the total. The next three species, which are forage species, make up 30% of the total counted plants. Only 14 of the recorded species were recorded in more than 25% of the quadrats. 10 of the top 12 most common species were perennial plants and included seven of the eight confirmed forage species.

Table 4-6. Top 30 species recorded where there were more than 10 plants found with the total number of plants that were counted in Wadi Al Safa and Mugatrah during the study from 8th May 2016 to 4th August 2016 (n=106). *Confirmed forage species in **bold.***

Rank	Species	Life Cycle	Total	MUG	WAS	# Quadrats
1	*Tetraena* spp.	Perennial	14,335	5,547	8,788	67
2	*Monsonia nivea*	Perennial	6,726	4,606	2,120	56
3	***Stipagrostis plumosa***	Perennial	5,105	1,086	4,019	89
4	***Fagonia bruguieri***	Perennial	4,143	3,684	459	60
5	***Tribulus* spp.**	Perennial	3,982	1,869	2,113	94
6	*Arnebia hispidissima*	Annual	3,437	3,101	336	57
7	*Polycarpaea repens*	Perennial	1,966	0	1,966	35
8	***Helianthemum lippii***	Perennial	953	608	345	38
9	*Eragrostis barrelieri*	Annual	625	344	281	49
10	***Panicum turgidum***	Perennial	540	482	58	58
11	***Heliotropium kotschyi***	Perennial	540	357	183	54
12	***Pennisetum divisum***	Perennial	490	464	26	43
13	*Neurada procumbens*	Annual	282	104	178	26
14	*Indigofera intricata*	Perennial	196	132	64	26
15	*Plantago ovata*	Annual	135	0	135	16
16	*Cornulaca monacantha*	Perennial	95	95	0	10
17	*Dipterygium glaucum*	Perennial	93	92	1	23
18	*Indigofera colutea*	Perennial	85	3	82	3
19	*Savignya parviflora*	Annual	56	41	15	9
20	*Heliotropium digynum*	Perennial	48	44	4	13
21	*Gisekia pharnaceoides*	Annual	43	22	21	15
22	*Moltkiopsis ciliata*	Perennial	27	24	3	9
23	*Limeum arabicum*	Perennial	27	25	2	14
24	*Aristida abnormis*	Annual	24	24	0	1
25	*Atractylis carduus*	Perennial	24	19	5	5
26	*Aerva javanica*	Perennial	17	2	15	7
27	*Launaea mucronata*	Short-Perennial	16	11	5	8
28	*Chrozophora oblongifolia*	Perennial	14	0	14	5
29	*Tragus racemosus*	Annual	14	0	14	8
30	*Plantago ciliata*	Annual	12	0	12	7

4.3.7 SUBSTRATE TYPES

Sand had by far the greater diversity of species with 33 species recorded from 61 quadrats (Table 4-7 and Figure 4-8) whereas the Gravel substrate had 25 species from 21 quadrats (Table 4-8 and Figure 4-9), demonstrating two different primary substrate types. For the sand substrate 4 of the top 6 most recorded species were grasses. On the gravel substrate *S. plumosa* was the only grass species in the top 6 and came in as the 6th most commonly found species. In both substrates, the species commonly foraged by dhub were present.

Table 4-7. 33 different species recorded on sand substrate from 61 quadrats (MUG n=27 and WAS n=34 quadrats) with the number of quadrats that had the species and the percentage number of times each species was recorded from that substrate type. Confirmed forage species in **bold.**

Species	# of Quadrats	MUG	WAS	% Times Recorded
***Tribulus* spp.**	58	26	32	95.1
Stipagrostis plumosa	53	22	31	86.9
Eragrostis barrelieri	40	18	22	65.6
Panicum turgidum	39	23	16	63.9
Heliotropium kotschyi	35	19	16	57.4
Pennisetum divisum	27	22	5	44.3
Polycarpaea repens	26	0	26	42.6
Tetraena spp.	26	4	22	42.6
Fagonia bruguieri	20	10	10	32.8
Indigofera intricata	19	6	13	31.1
Monsonia nivea	19	9	10	31.1
Arnebia hispidissima	18	4	14	29.5
Neurada procumbens	18	4	14	29.5
Dipterygium glaucum	13	12	1	21.3
Limeum arabicum	12	11	1	19.7
Heliotropium digynum	10	8	2	16.4
Gisekia pharnaceoides	9	5	4	14.8
Plantago ovata	9	0	9	14.8
Helianthemum lippii	7	3	4	11.5
Moltkiopsis ciliata	7	6	1	11.5
Tragus racemosus	6	0	6	9.8
Chrozophora oblongifolia	5	0	5	8.2
Aerva javanica	4	0	4	6.6
Launaea mucronata	4	3	1	6.6
Plantago ciliata	4	0	4	6.6
Cornulaca monacantha	3	3	0	4.9
Atractylis carduus	2	0	2	3.3
Calligonum comosum	2	0	2	3.3
Calotropis procera	2	0	2	3.3
Coelachyrum piercii	2	0	2	3.3
Cyperus conglomeratus	2	2	0	3.3
Indigofera colutea	2	0	2	3.3
Launaea capitata	1	1	0	1.6

There was a greater number of species recorded in WAS compared to MUG. *H. kotschyi, P. divisum*

and *P. turgidum* which are three of the confirmed forage species were found more frequently in MUG than WAS. *Tribulus* spp. was frequently found on both sites and the frequency followed closely that of the overall species list.

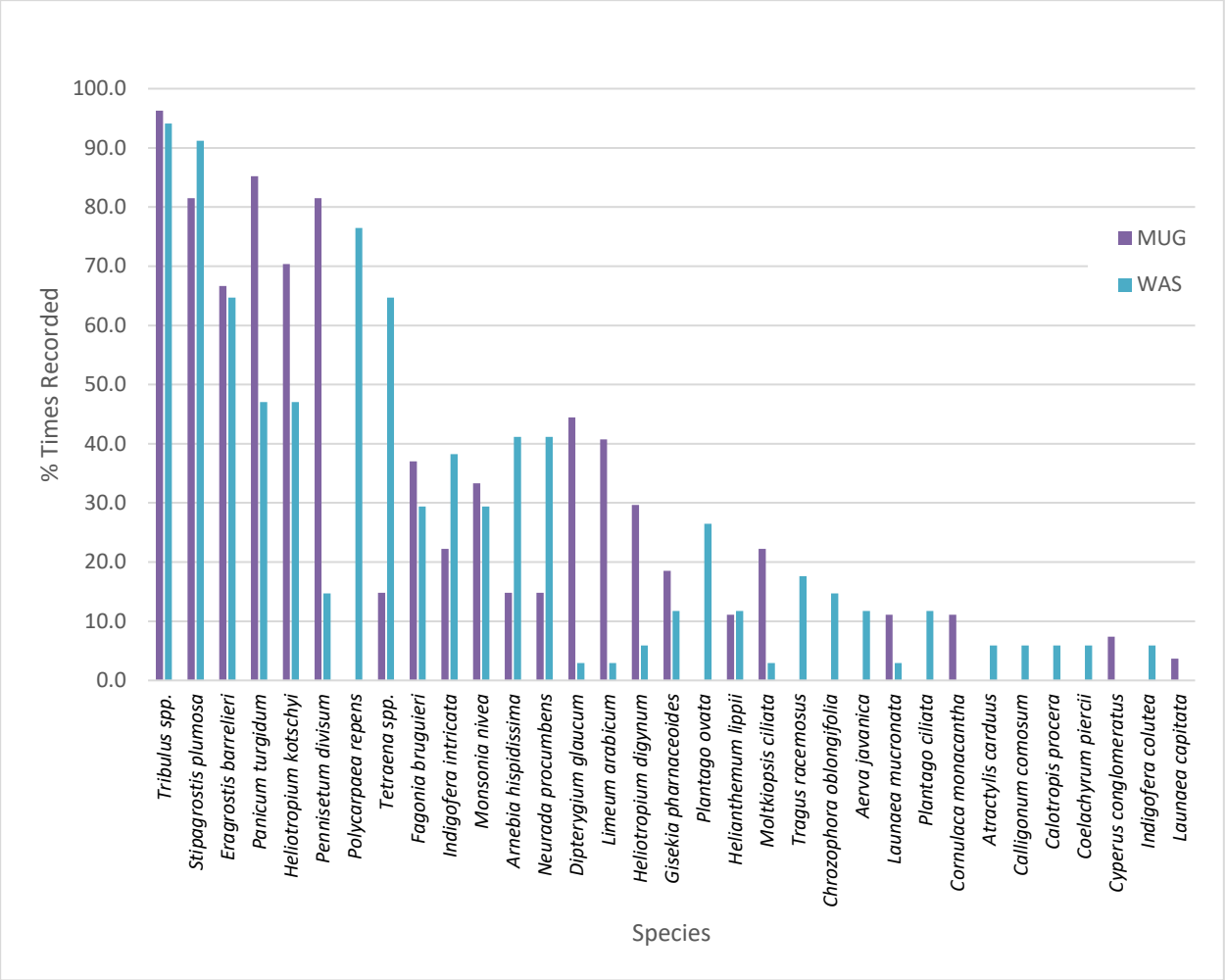


Figure 4-8. Percentage of times each of the 33 species was recorded from the sand substrate for WAS and MUG from 8th May 2016 to 4th August 2016 (*N*=106).

Of the eight confirmed forage species, seven are found on the gravel substrate and make up more than 50% of the species recorded in over 25% of the quadrats. APPENDIX 4-3 demonstrates the species found and the percentage number of quadrats they were recorded in throughout the study for the mixed substrate types.

Table 4-7, Table 4-8 and Figure 4-9 demonstrate two different primary substrate types. For the sand substrate 4 of the top 6 most recorded species were grasses. On the gravel substrate *S. plumosa* was the only grass species in the top 6 and came in as the 6th most commonly found species. In both substrates, the species commonly foraged by dhub were present.

Table 4-8**.** 25 different species recorded on gravel substrate (MUG n=14 and WAS n=7 quadrats) with the percentage number of times each species was recorded from that substrate type.
Confirmed forage species in **bold.**

Species	**# of Quadrats**	**MUG**	**WAS**	**% Times Recorded**
Tetraena spp.	21	14	7	100
Arnebia hispidissima	20	14	6	95
Monsonia nivea	20	14	6	95
Fagonia bruguieri	19	13	6	90
Helianthemum lippii	17	11	6	81
Stipagrostis plumosa	17	12	5	81
***Tribulus* spp.**	15	11	4	71
Savignya parviflora	8	6	2	38
Panicum turgidum	6	5	1	29
Heliotropium kotschyi	5	3	2	24
Neurada procumbens	5	4	1	24
Pennisetum divisum	5	4	1	24
Cornulaca monacantha	4	4	0	19
Dipterygium glaucum	4	4	0	19
Indigofera intricata	3	3	0	14
Plantago ovata	3	0	3	14
Atractylis carduus	2	1	1	10
Eragrostis barrelieri	2	2	0	10
Gisekia pharnaceoides	2	2	0	10
Polycarpaea repens	2	0	2	10
Aerva javanica	1	1	0	5
Coelachyrum piercii	1	0	1	5
Heliotropium digynum	1	1	0	5
Plantago ciliata	1	0	1	5
Prosopis cineraria	1	0	1	5

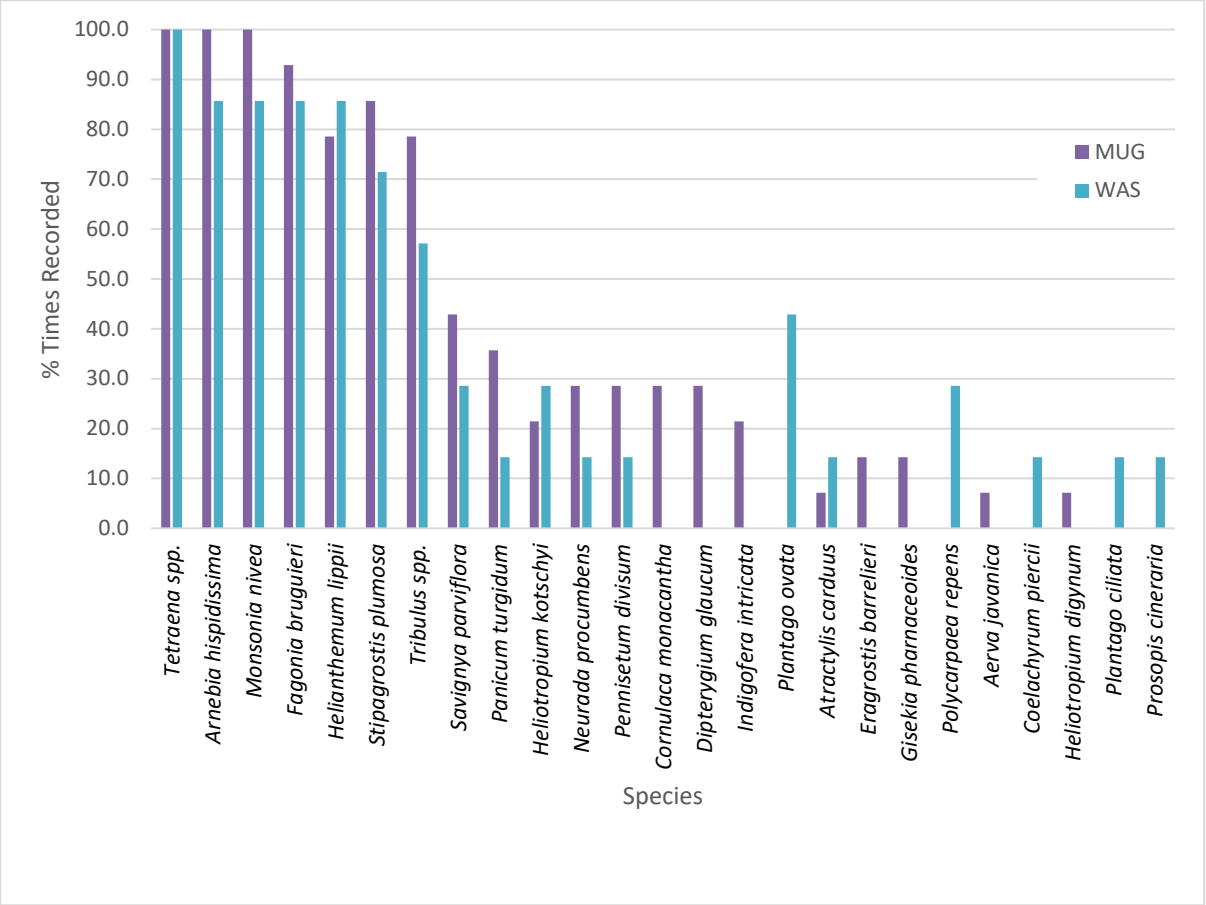


Figure 4-9. Percentage of times each of the 25 species was recorded from the gravel substrate for WAS and MUG.

The top 10 most common species were found over all substrate types where more than one quadrat was recorded (Table 4-9). Those areas where only one quadrat was recorded had 17 different species between the two substrate types. These species were also from only 4 different Families.

There was only one species, *Savignya parviflora,* found solely where gravel was the primary substrate, while there were seven species, *Chrozophora oblongifolia, Calotropis procera, Cyperus conglomeratus, Aristida abnormis, Cleome* sp.*, Haloxylon salicornicum, Sesuvium verrucosum* found only on substrates with sand as the primary substrate.

When species presence or absence was examined for each site, there were differences in the number of plant species counted at both sites as MUG had 30 species and WAS had 35 species.

Table 4-9. Species presence or absence (pink shade) from the seven different substrate types with the number of quadrats each species was found in, throughout the study period.

Family	Species	Gravel	[a]G/S	[b]G/CS	Sand	[c]S/G	[d]S/CS	[e]S/G/R
Zygophyllaceae	*Tribulus* spp.	15	6	1	58	6	7	1 (8)
Poaceae	*Stipagrostis plumosa*	17	6	1	53	4	7	1
Zygophyllaceae	*Tetraena* spp.	21	8	1	26	5	5	1
Zygophyllaceae	*Fagonia bruguieri*	19	8	1	20	6	5	1 (106)
Poaceae	*Panicum turgidum*	6	6	1	39	2	3	1
Boraginaceae	*Arnebia hispidissima*	20	8	1	18	5	4	1 (17)
Geraniaceae	*Monsonia nivea*	20	8	1	19	4	3	1 (56)
Boraginaceae	*Heliotropium kotschyi*	5	6	0	35	2	5	1 (62)
Poaceae	*Eragrostis barrelieri*	2	4	0	40	2	1	0
Poaceae	*Pennisetum divisum*	5	5	0	27	3	2	1
Cistaceae	*Helianthemum lippii*	17	6	1	7	4	3	0
Caryophyllaceae	*Polycarpaea repens*	2	0	1	26	1	5	0
Neuradaceae	*Neurada procumbens*	5	2	0	18	0	1	0
Fabaceae	*Indigofera intricata*	3	1	0	19	1	2	0
Cleomaceae	*Dipterygium glaucum*	4	3	0	13	2		1
Plantaginaceae	*Plantago ovata*	3	1	1	9	1	1	0
Molluginaceae	*Gisekia pharnaceoides*	2	1	0	9	3	0	0
Molluginaceae	*Limeum arabicum*	0	1	0	12	0	0	1
Boraginaceae	*Heliotropium digynum*	1	1	0	10	0	1	0
Amaranthaceae	*Cornulaca monacantha*	4	3	0	3	0	0	0
Brassicaceae	*Savignya parviflora*	8	1	0	0	0	0	0
Boraginaceae	*Moltkiopsis ciliata*	0	1	1	7	0	0	0
Asteraceae	*Launaea mucronata*	0	2	0	4	1	1	0
Poaceae	*Tragus racemosus*	0	0	0	6	1	1	0
Amaranthaceae	*Aerva javanica*	1	0	1 (3)	4	0	1	0
Plantaginaceae	*Plantago ciliata*	1	0	0	4	0	2	0
Asteraceae	*Atractylis carduus*	2	0	0	2	1	0	0
Euphorbiaceae	*Chrozophora oblongifolia*	0	0	0	5	0	0	0
Polygonaceae	*Calligonum comosum*	0	1	0	2	1	0	0
Poaceae	*Coelachyrum piercii*	1	0	0	2	0	0	0
Amaranthaceae	*Anabasis setifera*	0	0	1 (1)		1	1	0
Fabaceae	*Indigofera colutea*	0	1	0	2	0	0	0
Apocynaceae	*Calotropis procera*	0	0	0	2	0	0	0
Asteraceae	*Launaea capitata*	0	1	0	1	0	0	0
Cyperaceae	*Cyperus conglomeratus*	0	0	0	2	0	0	0
Fabaceae	*Prosopis cineraria*	1	0	0	0	0	0	0
Aizoaceae	*Sesuvium verrucosum*	0	0	0	0	0	1	0
Amaranthaceae	*Haloxylon salicornicum*	0	0	0	0	0	1	0
Apocynaceae	*Leptadenia pyrotechnica*	0	1	0	0	0	0	0
Cleomaceae	*Cleome* sp.	0	0	0	0	0	1	0
Poaceae	*Aristida abnormis*	0	0	0	0	1	0	0

[a]G/S=Gravel/Sand, [b]G/CS=Gravel/Cemented Sand, [c]S/G= Sand/Gravel, [d]S/CS= Sand/Cemented Sand, [e]S/G/R= Sand/Gravel/Rock,

In general, the number of species on gravel type substrates were greater in MUG than WAS, while for

the sand substrate, there were more species recorded by sand substrate type in WAS than MUG (Table 4-10).

Table 4-10. The number of different plant species recorded for each substrate type and site.

Site	Gravel	[a]G/S	[b]G/CS	Sand	[c]S/G	[d]S/CS	[e]S/G/CS
MUG	20	24	0	22	16	10	11
WAS	18	12	13	30	14	22	0

[a]G/S=Gravel/Sand, [b]G/CS=Gravel/Cemented Sand, [c]S/G= Sand/Gravel, [d]S/CS= Sand/Cemented Sand, [e]S/G/CS= Sand/Gravel/Cemented Sand, MUG=Mugatrah, WAS=Wadi Al Safa.

Of the 41 species counted, there were 16 unique species, WAS had eleven and MUG had five, they did not contribute a great number to the actual overall records (Table 4-11). The eight confirmed forage species were distributed across both sites.

Table 4-11. Unique species from the two different sites (combined for all substrates) with the number of quadrats they were recorded in (numbers of plants recorded in brackets) throughout the study period.

Family	Species	# of Quadrats	MUG	WAS
Caryophyllaceae	*Polycarpaea repens*	35	0	35 (*1966*)
Plantaginaceae	*Plantago ovata*	16	0	16 (*135*)
Amaranthaceae	*Cornulaca monacantha*	10	10 (*95*)	0
Poaceae	*Tragus racemosus*	8	0	8 (*14*)
Plantaginaceae	*Plantago ciliata*	7	0	7 (*12*)
Euphorbiaceae	*Chrozophora oblongifolia*	5	0	5 (*14*)
Amaranthaceae	*Anabasis setifera*	3	0	3 (*4*)
Poaceae	*Coelachyrum piercii*	3	0	3 (*4*)
Apocynaceae	*Calotropis procera*	2	0	2 (*2*)
Asteraceae	*Launaea capitata*	2	2 (*2*)	0
Cyperaceae	*Cyperus conglomeratus*	2	2 (5*)*	0
Aizoaceae	*Sesuvium verrucosum*	1	1 (*3*)	0
Amaranthaceae	*Haloxylon salicornicum*	1	0	1 (*1*)
Apocynaceae	*Leptadenia pyrotechnica*	1	1 (*1*)	0
Cleomaceae	*Cleome* sp.	1	0	1 (*2*)
Fabaceae	*Prosopis cineraria*	1	0	1 (*1*)
Poaceae	*Aristida abnormis*	1	1 (*24*)	0

While the number of species counted differed, the mean number of species counted in each quadrat (Figure 4-10) was larger in Mugatrah (*M = 9.2; SE = 0.5*) compared to Wadi Al Safa (*M = 8.3; SE = 0.4*).

Similarly, when one looks at the mean number of plants counted (all species combined) there was greater abundance (Figure 4-11) in MUG (*M = 447.1; SE = 60.9*) when compared to WAS (*M = 386.9; SE = 38.6*).

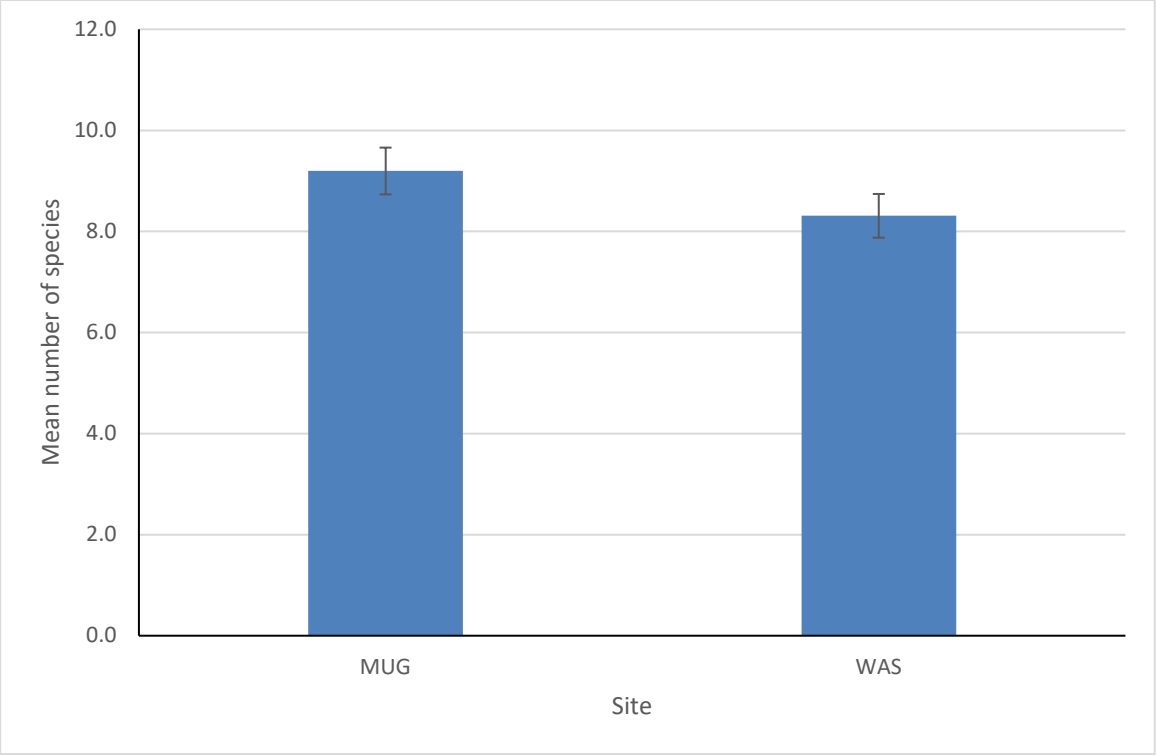


Figure 4-10. The mean number of species counted per quadrat (all substrates combined) for MUG and WAS with standard errors throughout the study period.

Figure 4-12 shows the 10 species which contributed 95% of the total plant numbers throughout the study. *P. repens* was only found in Wadi Al Safa while Mugatrah appears to have had greater diversity (overall) in its top plant communities.

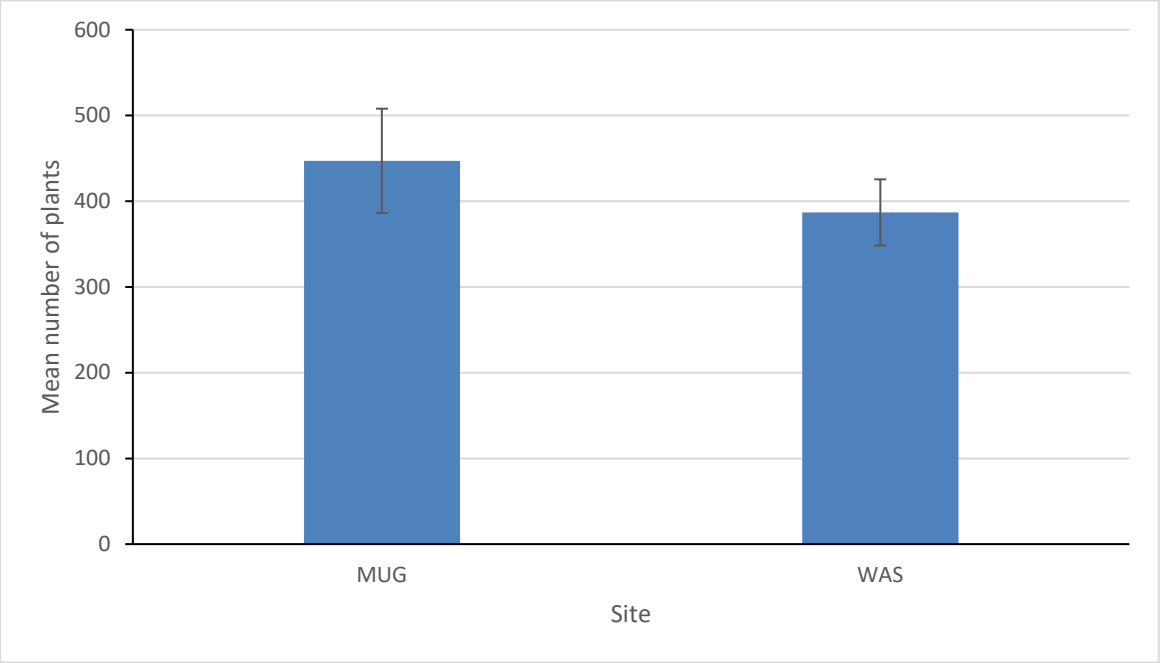


Figure 4-11. The mean number of plants counted per quadrat (substrates combined) for MUG and WAS with standard errors throughout the study period.

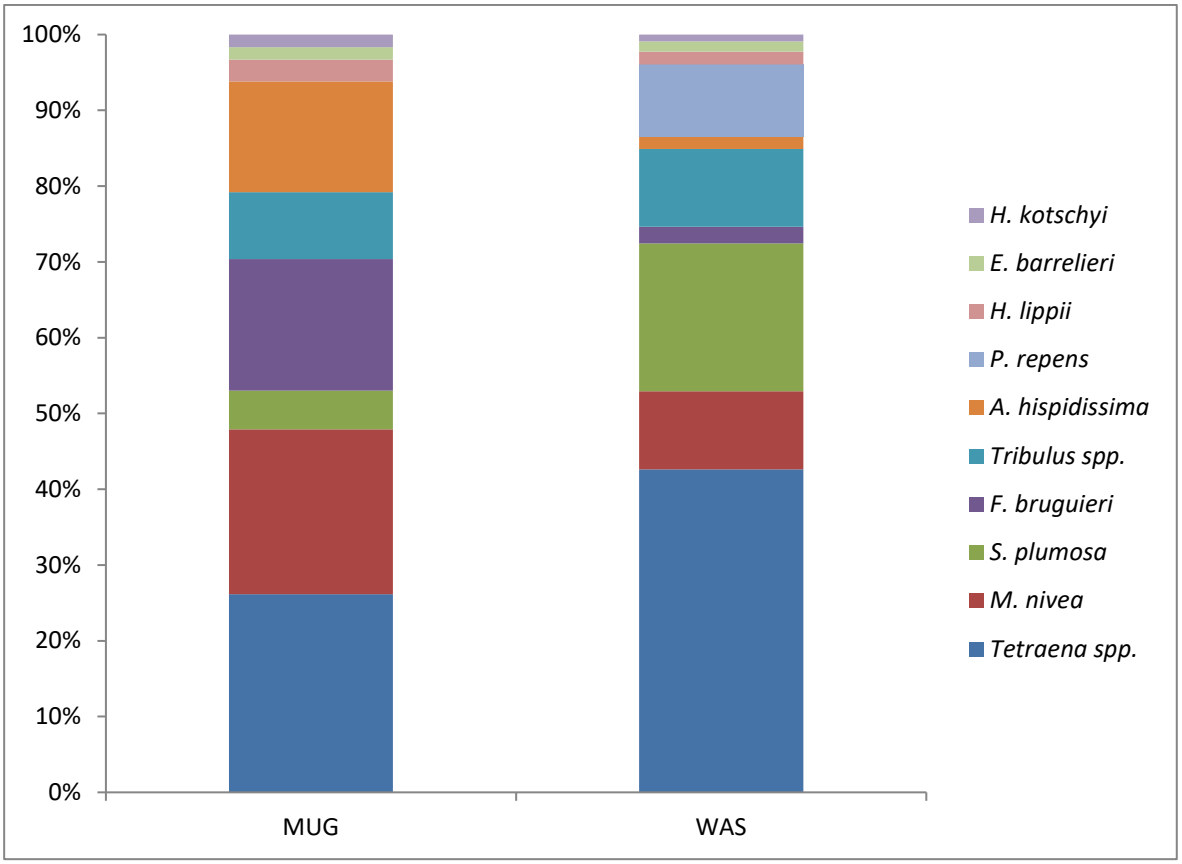


Figure 4-12. Percentage plant abundance of the top 10 plant species which contributed 95% of the plant counts during the study for Wadi Al Safa and Mugatrah.

4.3.8 PLANT ABUNDANCE

To determine possible causal factors, these data were examined in a detrended correspondence analysis (DCA) in PC Ord V 7.07 (McCune & Mefford, 2018), and vegetation grouping through the sub categories of substrate were examined, there was considerable overlap (Figure 4-13). However, there were clear groupings within the gravel and sand substrates themselves with gravel/sand and sand/gravel being closely aligned with gravel. The sand substrate had a slight overlap due perhaps to the plants found in the transition area between the gravel plains and sand dunes.

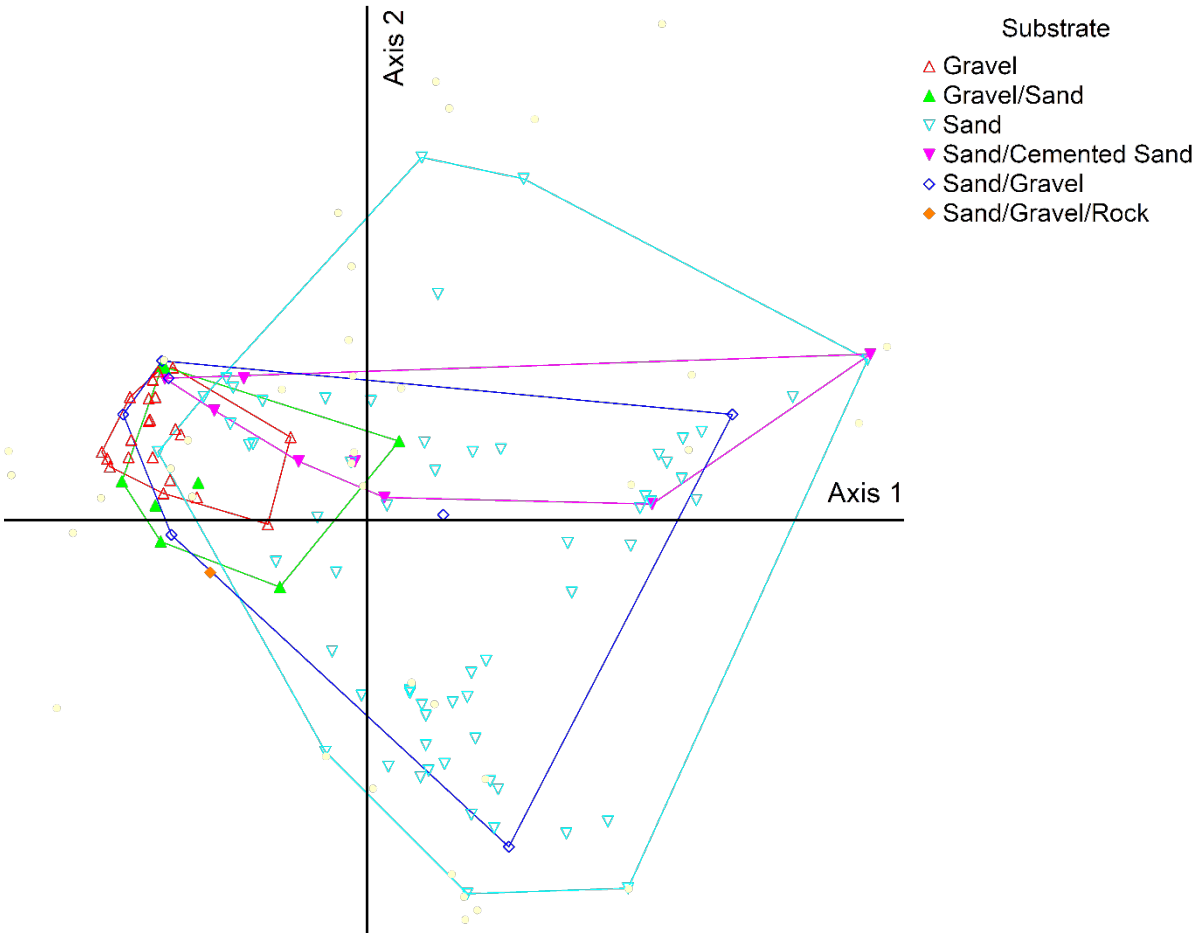


Figure 4-13. DCA for all vegetation quadrats by substrate type.

To examine this further, statistical significance between plant species and the substrates that they were recorded on was examined. The non-parametric Kruskal-Wallis test was used to look at the significance between the medians of the samples. Firstly, all samples which had sand as a primary substrate type were examined (APPENDIX 4-4 and APPENDIX 4-5). Only two species *Panicum turgidum* and *Stipagrostis plumosa* showed a statistically significant difference between the sand and gravel substrate types. For *P. turgidum* it was found that there was a significant difference between the presence in WAS and MUG, ($H(23.97)=4$, $p<0.001$) (Table 4-12 and Figure 4-14).

Table 4-12. Summary statistics for *Panicum turgidum* found on all sites with sand as the primary substrate.

Substrate	Number	Mean	Min	Max	Range	Variance	[a]COV	[b]SD	[c]SEM	[d]Med	[e]IQR
MS	23	16.8	2.0	56.0	54.0	146.5	71.9	12.1	2.5	15.0	18.0
MS/G	2	9.5	2.0	17.0	15.0	112.5	111.6	10.6	7.5	9.5	
MS/G/R	1	1.0	1.0	1.0	0.0					1.0	
WS	16	3.1	1.0	22.0	21.0	26.1	166.7	5.1	1.3	2.0	1.8
WS/CS	3	1.7	1.0	3.0	2.0	1.3	69.3	1.2	0.7	1.0	2.0

*Number of quadrats; [a] coefficient of variation; [b] standard deviation; [c] standard error; [d] median, [e]Inter quartile range
MS=Mugatrah Sand; MS/G=Mugatrah Sand/Gravel; MS/G/R=Mugatrah Sand/Gravel/Rock; WS= Wadi Al Safa Sand; WS/S= Wadi Al Safa Sand/Cemented Sand.

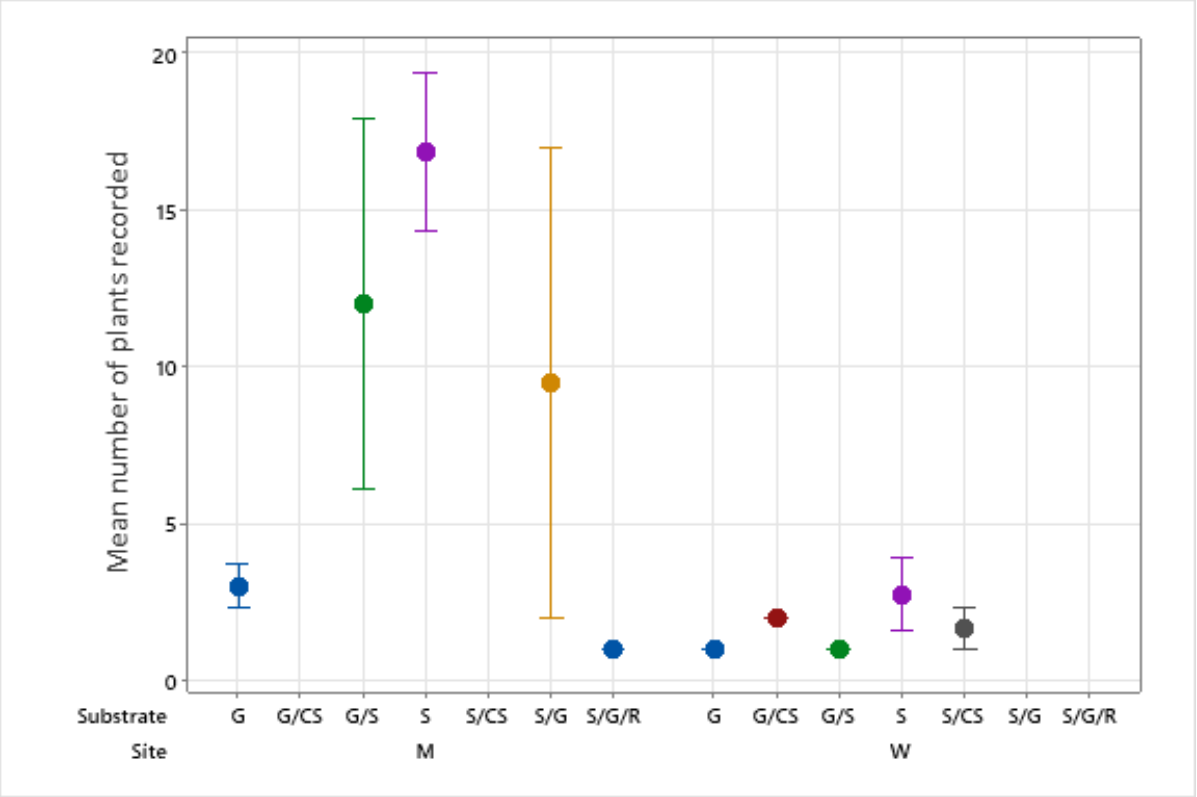


Figure 4-14. Distribution of *P. turgidum* found on all sites with sand and gravel as the primary substrate.
(G=Gravel; G/S=Gravel/Sand; G/Sab=Gravel/Cemented Sand; S=Sand; S/G=Sand/Gravel; S/G/R= Sand/Gravel/Rock; S/S=Sand/Cemented Sand)

These data show that *P. turgidum*, was far more common in MUG where it was found on most of the sand and gravel subtypes, than WAS with negligible numbers on any of the gravel based substrate. There was a median of 2.0 (SD±5.1) plants on the sand substrate in WAS compared to a median of 15.0 (SD±12.1) plants for MUG.

Stipagrostis plumosa (H(17.37)=6, p=0.008) (Table 4-13 and Figure 4-15) was also significantly different between the subgroups and in particular the sand substrate. The summary statistics for *S. plumosa* (Table 4-13) indicate that it is not as widespread in Mugatrah, being recorded only from the sand areas. In Wadi Al Safa it is found over a much wider habitat range, but still primarily on the sand.

Table 4-13. Summary statistics for *Stipagrostis plumosa* found on all sites with sand as the primary substrate.

	Number	Mean	Min	Max	Range	Variance	[a]COV	[b]SD	[c]SEM	[d]Med	[e]IQR
MS	22	28.9	1.0	228.0	227.0	3245.9	197.4	57.0	12.1	5.0	26.8
MS/G	1										
MS/G/R	1										
MS/CS	1										
WS	31	94.6	3.0	390.0	387.0	13288.8	121.8	115.3	20.7	26.0	140.0
WS/G	3	103.0	41.0	227.0	186.0	11532.0	104.3	107.4	62.0	41.0	186.0
WS/CS	6	62.7	1.0	197.0	196.0	5731.9	120.8	75.7	30.9	36.0	116.5

[a] coefficient of variation; [b] standard deviation; [c] standard error; [d] median, [e]Inter quartile range

MS=Mugatrah Sand; MS/G=Mugatrah Sand/Gravel; MS/G/R=Mugatrah Sand/Gravel/Rock; MS/CS=Mugatrah Sand/Cemented Sand; WS= Wadi Al Safa Sand; WS/G= Wadi Al Safa Sand/Gravel; WS/S= Wadi Al Safa Sand/ Cemented Sand.

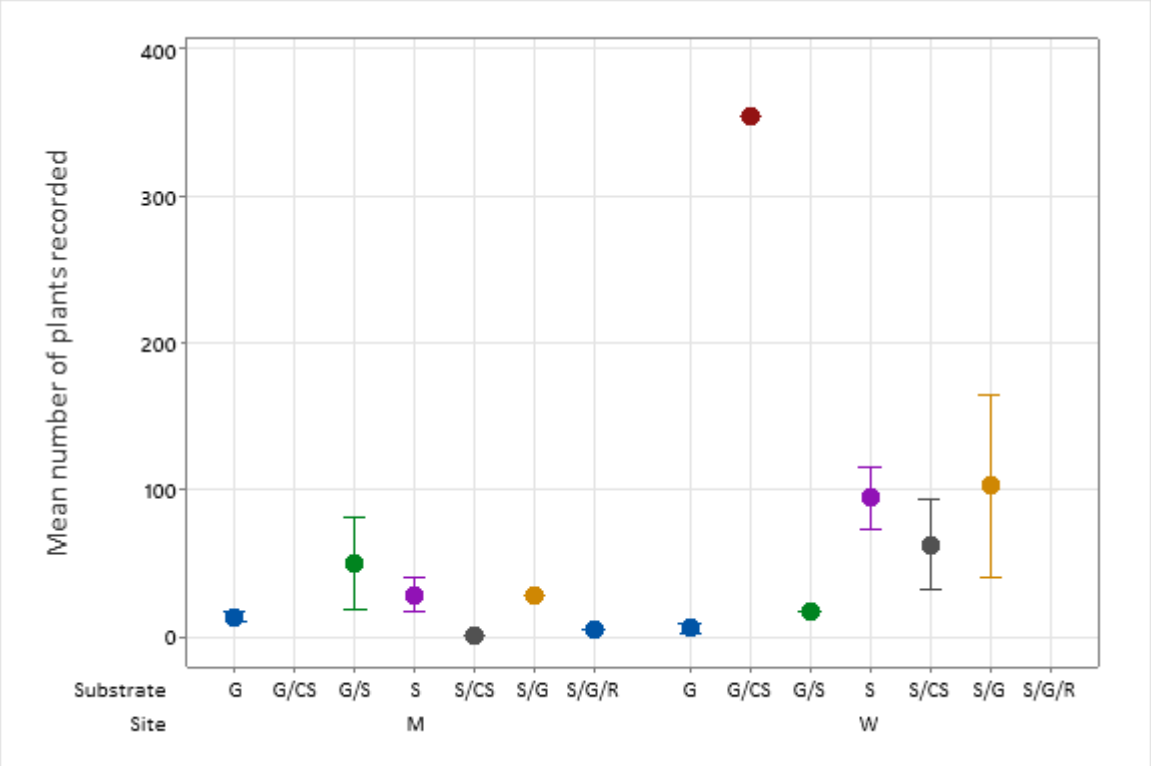


Figure 4-15. Distribution of *S. plumosa* found on all sites with sand and gravel as the primary substrate. (G=Gravel; G/S=Gravel/Sand; G/Sab=Gravel/Cemented Sand; S=Sand; S/G=Sand/Gravel; S/G/R= Sand/Gravel/Rock; S/S= Sand/Cemented Sand)

While there were a number of outliers for the sand substrate in both sites, if they were removed these did not adjust the statistical significance in any major way. The median number of plants (*Med=5.0* plants*; SD=57.0* plants) for MUG sand substrate is far less than the equivalent substrate WAS sand (*Med=26.0* plants; *SD=115.3* plants) suggesting a preference for the Wadi Al Safa site. However, when one examines the details for the gravel sites *S. plumosa* (H(7.57)=4, p=0.109) did not shown any statistical difference between the subgroups, primarily due to low data numbers (APPENDIX 4-5).

The same comparative process was undertaken for the substrate gravel. Here, it was found that *A.*

hispidissima (Table 4-14) (H(18.54)=3, p<0.001), *Fagonia bruguieri* (Table 4-15) (H(14.71)=4, p=0.005 and *Tribulus* spp. (Table 4-16) (H(10.66)=4, p=0.031) were all significantly different within the subgroups examined.

Table 4-14. Summary statistics for *Arnebia hispidissima* found on all sites with gravel as the primary substrate for each site.

	Number	Mean	Min	Max	Range	Variance	[a]COV	[b]SD	[c]SEM	[d]Med	[e]IQR
MG	14	180.7	40.0	759.0	719.0	34162.5	102.3	184.8	49.4	127.0	178.5
MG/S	5	53.0	11.0	129.0	118.0	2839.5	100.5	53.3	23.8	24.0	97.5
WG	6	18.2	1.0	37.0	36.0	235.0	84.4	15.3	6.3	19.0	30.8
WG/S	3	7.0	2.0	17.0	15.0	75.0	123.7	8.7	5.0	2.0	15.0
WG/CS	1	2.0	2.0	2.0	0.0					2.0	

[a] coefficient of variation; [b] standard deviation; [c] standard error; [d] median, [e]Inter quartile range
MG=Mugatrah Gravel; MG/S=Mugatrah Gravel/Sand; WG= Wadi Al Safa Gravel; WG/S= Wadi Al Safa Gravel/Sand; WG/Sab= Wadi Al Safa Gravel/Cemented Sand.

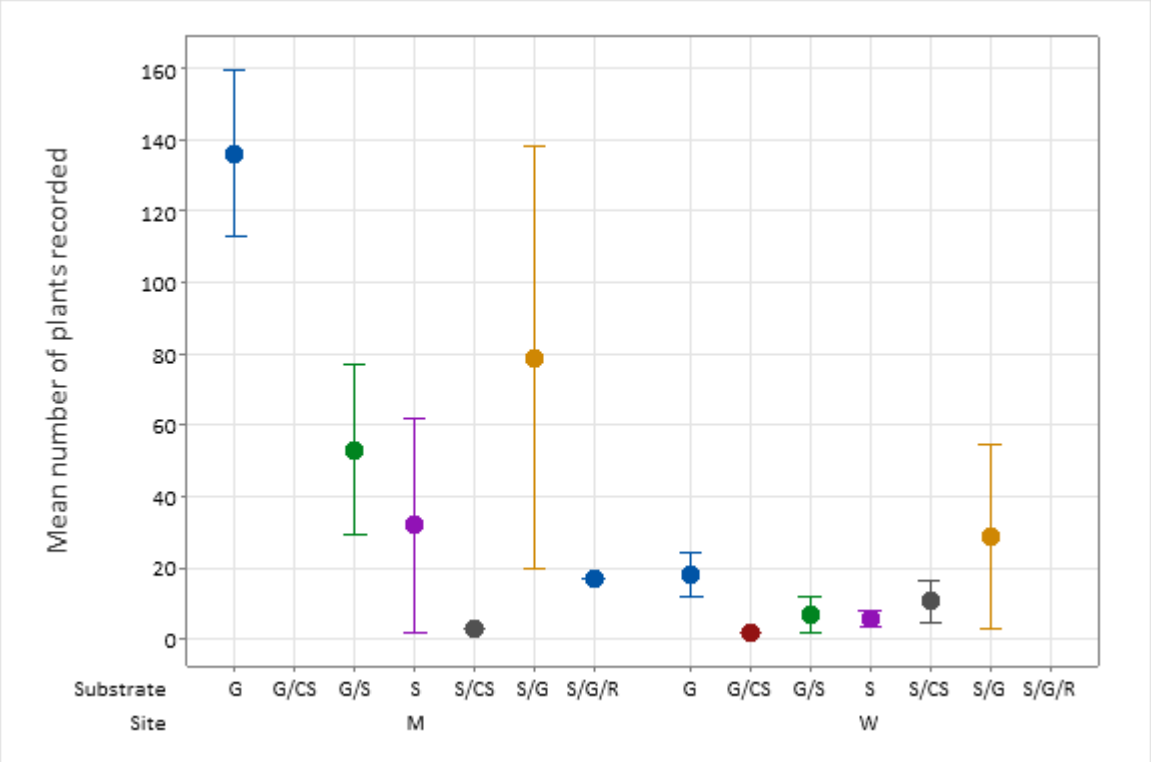


Figure 4-16. Distribution of *A. hispidissima* found on all substrate types in MUG and WAS. (G=Gravel; G/S=Gravel/Sand; G/Sab=Gravel/*Cemented Sand*; S=Sand; S/G=Sand/Gravel; S/G/R= Sand/Gravel/Rock; S/S=Sand/*Cemented Sand*).
One outlier for the gravel substrate of 759 (more than four times larger than the standard deviation (SD=184.4)) was removed from the data.

When Figure 4-16 and Table 4-14 are compared, it is obvious that while *A. hispidissima* was recorded over most substrate types, it was recorded more frequently on the gravel in MUG (*Med=127.0;*

SD=184.8) than the same substrate in WAS (*Med=19.0.2; SD=15.3*). In WAS, it was more frequent on the sand, while it is primarily a gravel species in Mugatrah. As with the previous two species, *A. hispidissima* was found more frequently in MUG and contributed to approximately 8% of overall plant cover compared to 0.5% in WAS.

F. bruguieri was recorded on all substrate (Table 4-15 and Figure 4-17) types where there was more than one quadrat surveyed. It was recorded in greater abundance in MUG (*Med=103.0; SD=120.8*) than WAS (*Med=19.5; SD=24.9*).

Table 4-15. Summary statistics for *Fagonia bruguieri* found on all sites with gravel as the primary substrate.

	Number	Mean	Min	Max	Range	Variance	[a]COV	[b]SD	[c]SEM	[d]Med	[e]IQR
MG	13	140.8	10.0	409.0	399.0	14601.5	85.8	120.8	33.5	103.0	182.5
MG/S	5	263.8	108.0	527.0	419.0	30685.7	66.4	175.2	78.3	163.0	307.0
WG	6	30.0	12.0	76.0	64.0	621.2	83.1	24.9	10.2	19.5	37.8
WG/S	3	35.3	4.0	95.0	91.0	2672.3	146.3	51.7	29.8	7.0	91.0
WG/CS	1	2.0	2.0	2.0	0.0					2.0	

[a] coefficient of variation; [b] standard deviation; [c] standard error; [d] median, [e]Inter quartile range
MG=Mugatrah Gravel; MG/S=Mugatrah Gravel/Sand; WG= Wadi Al Safa Gravel; WG/S= Wadi Al Safa Gravel/Sand; WG/CS=Wadi Al Safa Gravel/Cemented Sand

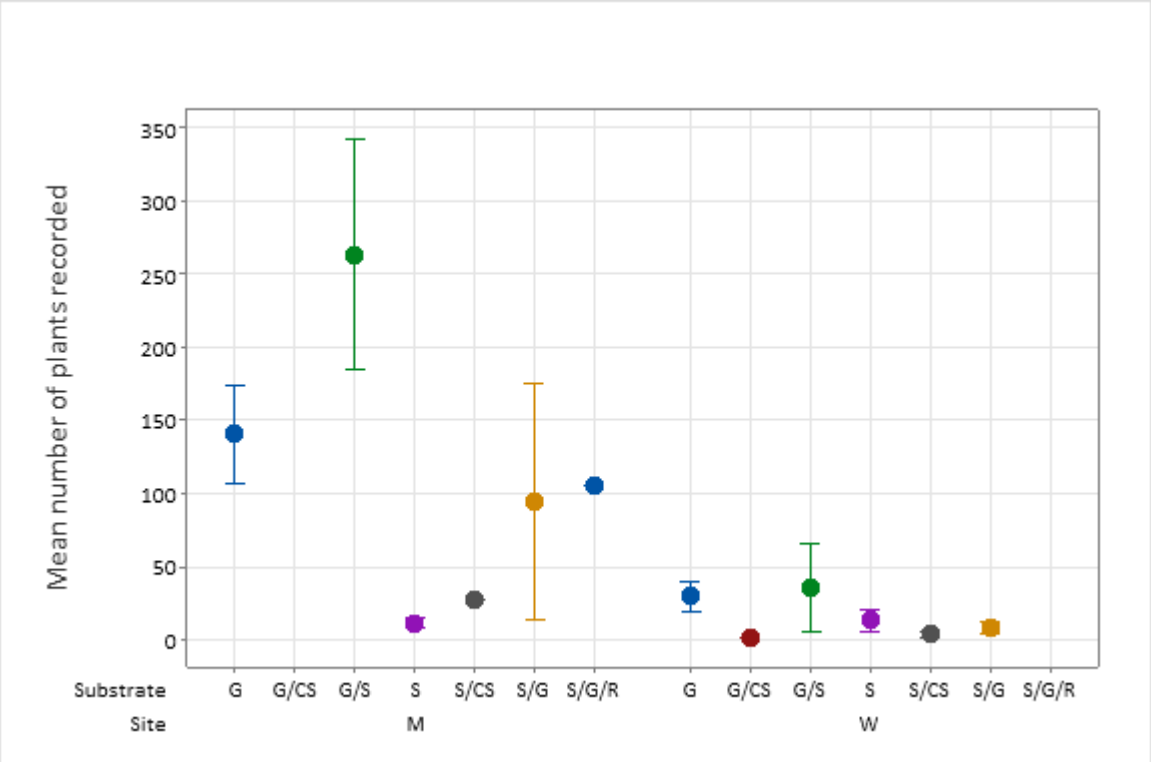


Figure 4-17. Distribution of *F. bruguieri* found on all sites with gravel as the primary substrate. (G=Gravel; G/S=Gravel/Sand; G/Sab=Gravel/*Cemented Sand*; S=Sand; S/G=Sand/Gravel; S/G/R= Sand/Gravel/Rock; S/S=Sand/*Cemented Sand*)

While there was a statistical significance found for *Tribulus* spp. on the gravel substrate (H(10.72)=4, p=0.030), as with *A. hispidissima*, there was no statistical significance between the subgroups for *Tribulus* spp. on the sand substrate (H(12.46)=6, p=0.052).

Table 4-16 and Figure 4-18, suggests that *Tribulus* is a species which can be found on most substrate types, but it does appear to prefer a substrate with a sand component. Substrate preference between

Table 4-16. Summary statistics for *Tribulus* spp. found on all sites with gravel as the primary substrate.

	Number	Mean	Min	Max	Range	Variance	[a]COV	[b]SD	[c]SEM	[d]Med	[e]IQR
MG	11	15.9	1.0	106.0	105.0	958.7	194.6	31.0	9.3	5.0	10.0
MG/S	5	55.0	17.0	119.0	102.0	2604.5	92.8	51.0	22.8	20.0	93.5
WG	4	50.3	17.0	133.0	116.0	3067.6	110.2	55.4	27.7	25.5	88.8
WG/S	1	72.0	72.0	72.0	0.0					72.0	
WG/CS	1	182.0	182.0	182.0	0.0					182.0	

[a] coefficient of variation; [b] standard deviation; [c] standard error; [d] median, [e]Inter quartile range
MG=Mugatrah Gravel; MG/S=Mugatrah Gravel/Sand; WG= Wadi Al Safa Gravel; WG/S= Wadi Al Safa Gravel/Sand; WG/Sab=Wadi Al Safa Gravel/Cemented Sand

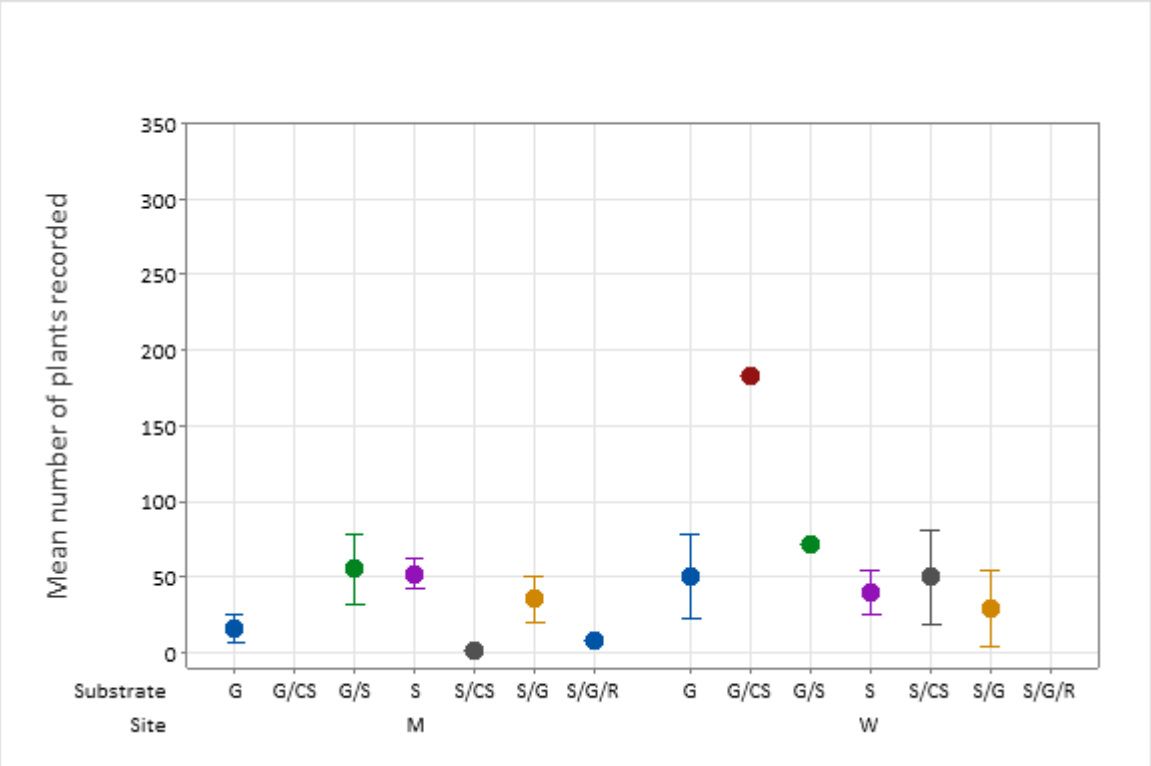


Figure 4-18. Distribution *Tribulus* spp. found on all sites with gravel as the primary substrate. (G=Gravel; G/S=Gravel/Sand; G/Sab=Gravel/Cemented sand; S=Sand; S/G=Sand/Gravel; S/G/R= Sand/Gravel/Rock; S/S=Sand/*Cemented Sand*).

sites appear to reverse though as it was primarily recorded on the gravel substrate in MUG (n=11), while they were recorded primarily on the sand substrate in WAS (n=14). *Tribulus* contributed 11.8% of plant cover recorded in MUG compared to 4.9% in WAS.

4.3.9 SUBSTRATE POOLING

When the results for the DCA are compared it can be seen that there is a more distinct grouping when the substrate types are pooled to either sand or gravel. This showed that while there was an overlap in some quadrats, there appeared to be a definite difference or perhaps more specificity between gravel communities, with these being grouped together more than sand communities. The plant communities associated with the sand substrate do appear to have a wider substrate preference (Figure 4-19).

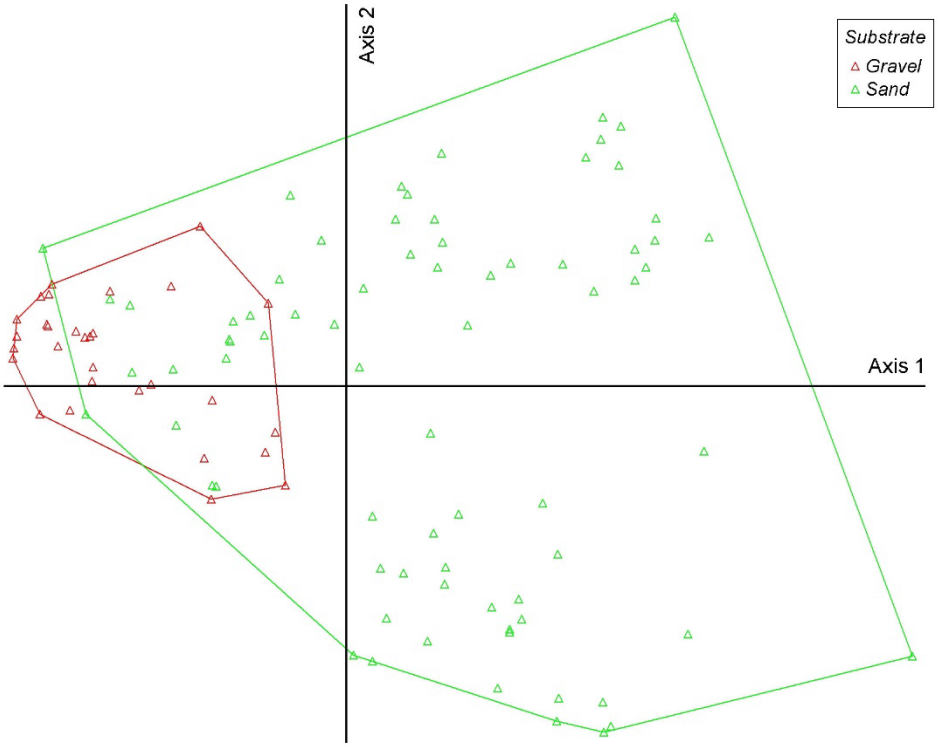


Figure 4-19. DCA of vegetation types and main substrate categories sand and gravel.

Having looked at all the data, it was decided to merge all the quadrats with sand as the primary substrate together as sand and all substrates with gravel as the primary substrate as gravel.

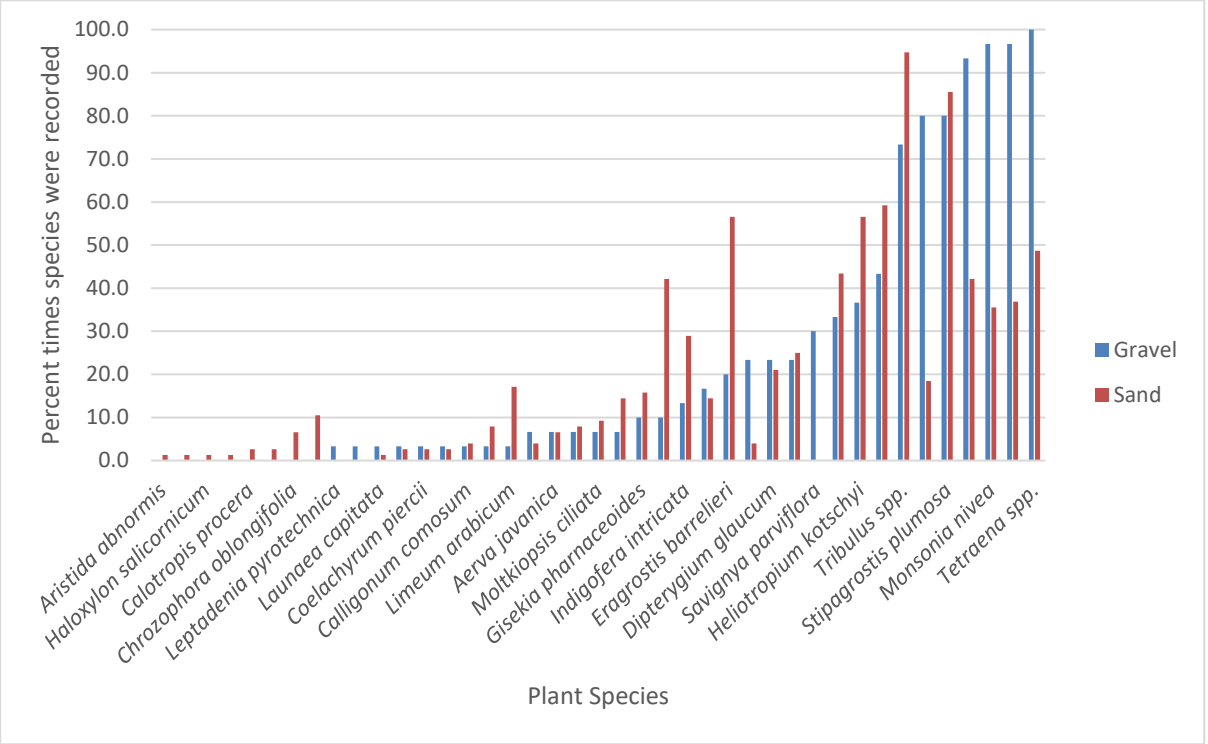


Figure 4-20. Percent number of times a species was recorded in a quadrat for gravel and sand.

Although the gravel substrate yielded a lower number of recorded species (n=33) in comparison to the sand substrate (n=38), a higher proportion of species were consistently observed in the quadrats on the gravel substrate than sand (Figure 4-19 and Figure 4-20).

There were seven species found on the sand substrate which were not recorded on the gravel substrate. Although these were unique species to both sites, they contributed less than 0.3% to the number of plants recorded in total.

Table 4-17. Eight unique species found only on the Sand and 3 unique species found on the Gravel substrate respectively.

	Sand		Gravel	
Family	Species	Plants	Species	Plants
Aizoaceae	*Sesuvium verrucosum*	3		
Amaranthaceae	*Haloxylon salicornicum*	1		
Apocynaceae	*Calotropis procera*	2	*Leptadenia pyrotechnica*	1
Brassicaceae			*Savignya parviflora*	56
Cleomaceae	*Cleome* sp.	2		
Cyperaceae	*Cyperus conglomeratus*	5		
Euphorbiaceae	*Chrozophora oblongifolia*	14		
Fabaceae			*Prosopis cineraria*	1
Poaceae	*Aristida abnormis*	24		

Looking at whether there is any difference and using the DCA between plant communities in MUG and WAS, (Figure 4-21) it is shown that while there are similarities in the plant communities, there are also distinct differences between both sites.

This is supported by Table 4-18 where ($H(30.92) = 3$, $p < 0.001$) suggesting a statistical difference between sites and substrates. When one looks closely at the difference between gravel substrates in MUG and WAS ($H(2.79) = 1$, $p = 0.095$) and sand substrate in MUG and WAS ($H(0.03) = 1$, $p = 0.853$) there is no statistical difference between the substrates suggesting that the difference is at the site level.

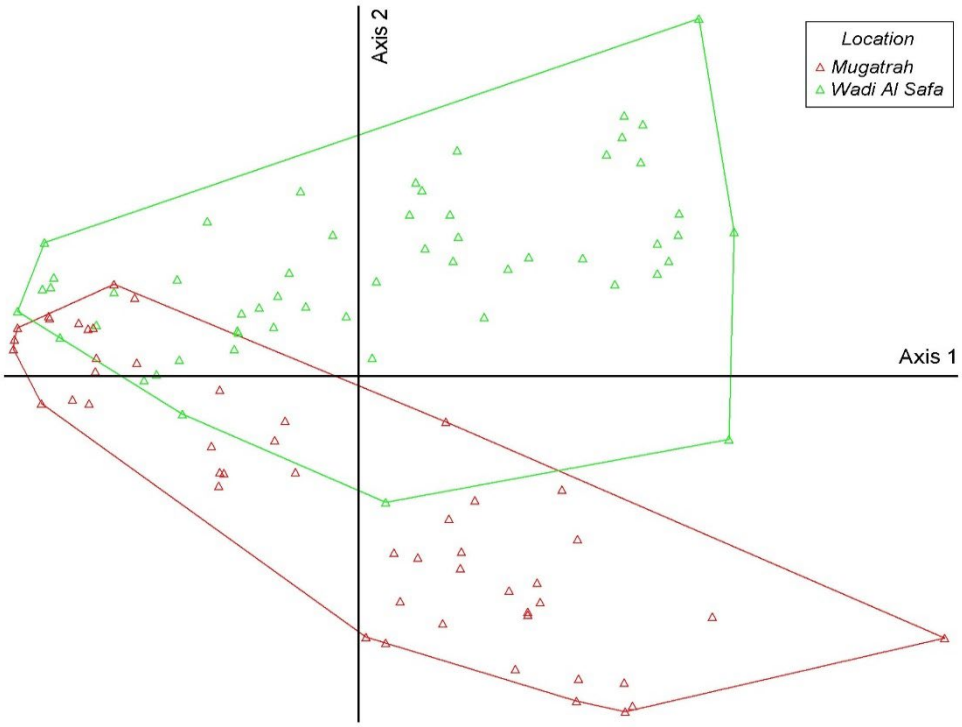


Figure 4-21. DCA of plant communities comparing Mugatrah to Wadi Al Safa.

Table 4-18. Kruskal-Wallis test results for differences in the median values for plants across both sites and substrate type.

Location	N	Median	Ave Rank	Z
MG	196	15.5	551.2	5.17
MS	273	6.0	433.2	-2.23
WG	94	11.5	490.6	1.04
WS	363	5.0	431.9	-2.88

MG=Mugatrah Gravel; MS=Mugatrah Sand; WG=Wadi Al Safa Gravel; WS= Wadi Al Safa Sand.

Overall 926 463.5

H	DF	P	
30.92	3	< 0.001	Adjusted for ties

4.3.10 Burrows and Plant Communities

Looking further at whether there was any difference between the number of plants recorded and whether a burrow was active, abandoned or filled in showed no significant difference (Table 4-19) between the burrow status' and locations.

Table 4-19. Kruskal-Wallis test results for differences in the median values for the number of plants recorded for the different burrow status'.

Location	N	Median	Ave Rank	Z
Abandoned	72	7.5	480.5	0.56
Active	432	6.0	456.1	-0.78
Filled	422	6.0	468.1	0.48

Overall 926 463.5

H	DF	P	
0.75	2	0.686	Adjusted for ties

These data demonstrated that there was no statistical difference between the burrow status and number of plants associated with them.

However, looking at the differences between each species of plant in Mugatrah and its associated burrow status showed significant differences for *F. bruguieri* ($H(20.82)=4$, $p<0.001$) and *S. plumosa*

(H(11.16)=5, p=0.048). Similarly, the results for Wadi Al Safa show a statistically significant difference for *S. plumosa* (H(11.16)=5, p=0.048).

A final outcome of the DCA analysis suggested that the plant communities present did not affect the presence of *Uromastyx* (Figure 4-22). Active burrows were present across all substrate types with no major substrate type appearing to influence whether a burrow was active, abandoned or inactive.

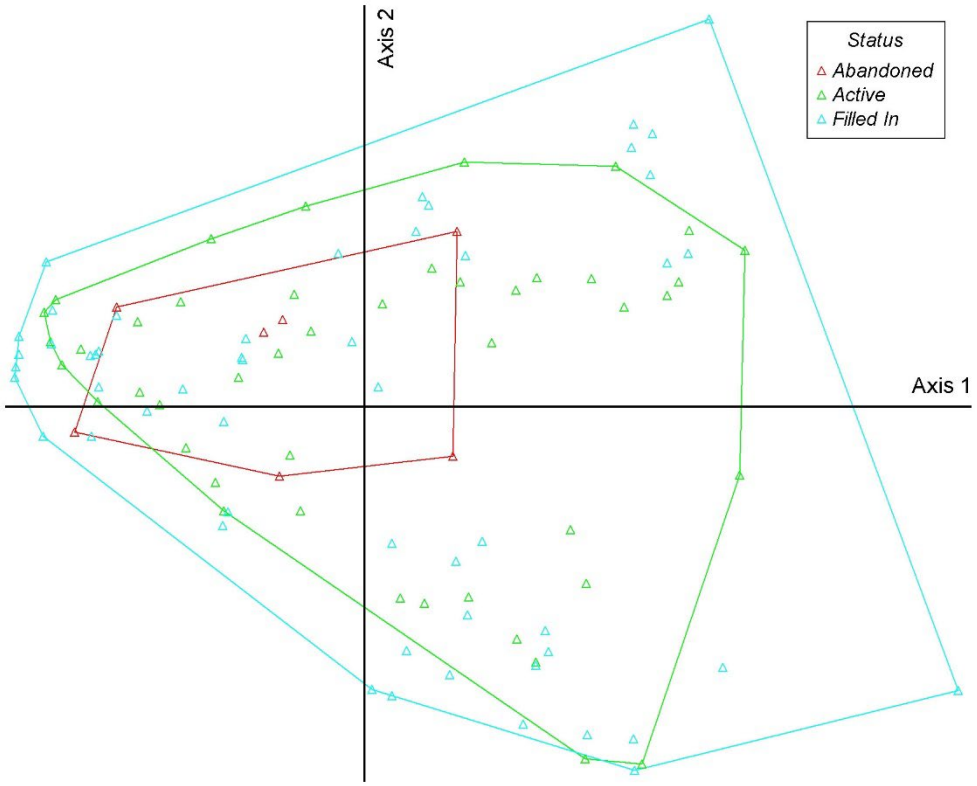


Figure 4-22. DCA showing burrow status for each quadrat sampled.

4.4 DISCUSSION

4.4.1 SEED BANK

Due to a concern of the Dubai Government that they might be losing some of their plant biodiversity and as a method of ensuring the continued existence of native flora of the country, the Dubai Government have targeted the seed bank through the increased use of cloud seeding (H. H. Sh Hamdan Bin Rashid Al Maktoum, Deputy Ruler of Dubai, *pers comm*). Seeds of desert species, if undisturbed, are able to lie dormant in the seed bank for many decades, germinating later under the correct conditions (Gardner & Howarth, 2009) and for many plants, seeds can be the most prevalent form of the species (Kemp, 1989). In fact Al-Hazmi (2001) found that seeds made up over 70% of the stomach contents of dhub during the Summer of their study.

While 2010 to 2015 had been close to drought conditions, (with marked reductions in vegetation availability), the extreme precipitation levels in March 2016 probably increased the species abundance recorded during the vegetation survey of 2016 to the 40+ species recorded. Caution must be noted though as this was one period in time and post heavy rain, vegetation cover would most likely be a lot different where rainfall was minimal as is often the case (Cunningham, 2001a).

As both study sites were situated away from the coast (11 Km for WAS and 30 Km for MUG), most of the plant species recorded were primarily species found on sand/sandy plains as per Jongbloed *et al* (2003). While there were differences between the plant species recorded between sites, this is the first study which looked at the plant species differences, between substrate types. Based on the fact that a large number of quadrats were recorded in the sand substrate (WAS=62% and MUG 51%) would suggest that the burrows were predominantly close (within 40+ metres) to sand. Being a fossorial species, dhub prefer hard gravel plains or cemented sand formations where the substrate is more consistent as dhub do not burrow on loose sand (*pers obs*) (Wilms *et al*, 2010). During the current study, most dhub went into the sand dunes to feed rather than stay on the gravel plains (*pers obs*). It was important therefore to look at forage plant species within these areas. As moving away from the safety of the burrow put them at risk of predation, it would suggest that plant species found predominantly on the sand would be their preferred forage item highlighting the interdependence between the substrate types for the survival of the species.

4.4.2 PLANT FAMILIES

During the data collection, a total of 41 plant species, which is similar to others (Bouskila, 1986; Al-Hazmi, 2001) were recorded and of these, there were 29 perennial and 12 annual species recorded. Of

the top 20 most common species, 14 of these were perennial plants. Al-Hazmi (2001) had an almost equal split with 27 perennial and 24 annual species in his study and while others mention the number of species, the breakdown is not readily available (Bouskila, 1986). The variety of species was most likely related to the rains several months before. The top 10 most common plants were dominated by four different families, the Poaceae (4), Zygophyllaceae (3), Boraginaceae (2), and Geraniaceae (1) all of which are small sized salt tolerant plants (Jongbloed *et al*, 2003; Karim & Dakheel, 2006).

It can also be seen that *P. turgidum* was found in much lower numbers than *S. plumosa*. This was primarily due to the size of the plant and historical grazing by camels and other ungulates. Furthermore, *S. plumosa* appears to be more common in WAS on the gravel substrate where it was possibly better able to survive the herbivory of the different livestock species. *S. plumosa*, while significantly different at both sites, might be affected by the low numbers of records for the gravel substrate type. As this was a preliminary study, further data dredging (Zuur *et al*, 2010) could provide guidance for future work. However, these results should be viewed cautiously and inferences about the broader population should also be made with care.

4.4.3 Absent Plant Species

Perhaps one of the more interesting observations from the number of plants counted was the absence of *P. repens* from the MUG site. The majority of times this species was encountered in WAS, was on the sand substrate. It was a single representative of the Caryophyllaceae family and perhaps as a Perennial it had not emerged as yet in MUG or had already completed its life cycle.

Also missing from MUG were members of the genus *Plantago*. While there were two different species found in WAS, there were none in MUG. As a plant genus found from the northern parts of West Africa through the Arabian Peninsula to Pakistan it has been described as locally common (Jongbloed *et al*, 2003) with Norton *et al* (2009) stating that a single plant was found during a survey of western Qatar in 2007. This would suggest that the genus can be patchy in its distribution. Both *P. repens* and *Plantago* sp. were recorded as forage plants in other studies.

4.4.4 Forage Plants

Following foraging tracks at the study sites members of the Poaceae such as *P. divisum, P. turgidum* and *S. plumosa* make up a proportion of the preferred plant species in the current study which is similar to other studies (Bouskila, 1986; Cunningham, 2001b). While Robinson (1995) suggested that these species might be too fibrous for dhubs to feed on, it is believed that when the annuals available to dhub such as *A. hispidissima*, *N. procumbens* etc. die off, then these species become important.

Bouskila (1986) and Al-Hazmi (2001) both suggest seasonal selection in the forage species eaten by dhub and perennial species such as *H. kotschyi* and *Tribulus* spp. appear to be important all year around. *Tetraena* spp., as one of the most common species (found in 67 quadrats and a total of 14,335 plants counted) there was little evidence of herbivory from *Uromastyx* or any of the native livestock. While there was no direct observation of dhub eating *Tetraena* spp., other authors have reported it as a forage plant which dhub eat (Bouskila, 1985; Jongbloed, 1997). This was not the case at the sites in the current study, as following the forage tracks (*pers obs*), this genus was rarely eaten and then, only eaten under pressure when no other forage was available. It was seen more commonly being used by dhub as a basking area rather than a forage item Figure 4-23. In fact, Khan *et al* (2015) suggests that *Tetraena* spp. contain a number of toxic chemicals which would have to be removed before considering the species suitable as a fodder crop. This is perhaps why it is so common as very few species will actually eat it.



Figure 4-23. Dhub (left) and *Phrynocephalus arabicus* (right) basking on *Tetraena qatarensis* .

S. plumosa, H. kotschyi (Figure 4-25)*, F. bruguieri, Tribulus* spp.*, C. comosum, P. turgidum,* (Figure 4-24), P*. divisum* and *H. lippii* were the species where direct observations of being eaten was recorded (the animal had stopped at the plant) (*per obs*).

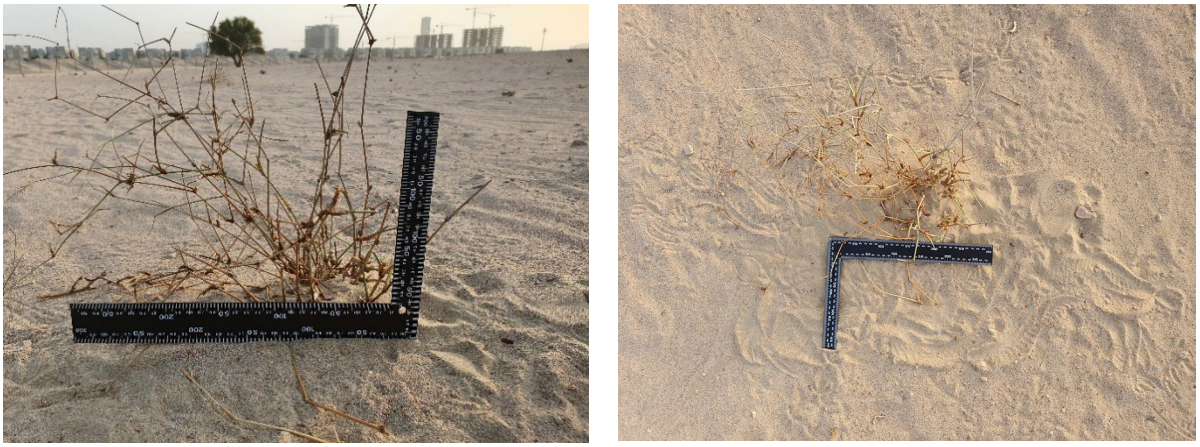


Figure 4-24. *P. turgidum* with dhub tracks showing where the animal stopped to forage.

4.4.5 UNIQUE SPECIES

Of the 16 unique species, WAS had eleven and MUG had five. Overall, with the exception of *P. repens*, these species were recorded at a rate of less than 10 per quadrat and did not contribute a great number to the actual overall records. While both sites were quasi protected, each did have livestock grazing to varying degrees, MUG had the least amount of grazing of the two sites. Predominantly, camels (in low densities of approx. 20 camels) were released within MUG from April through to September each year during the study period (*pers obs*). This has been a common feature for more than 10 years. All other ungulate species were removed from the area. On the other hand, certain areas in WAS have had a mix of heavy grazing from domesticated camels and native ungulates (*Oryx leucoryx, Gazella marica* and *Gazella gazella*) in particular, over a more continual basis.

While there were more species recorded in WAS than MUG, counts per quadrat were slightly higher in MUG. AlRashidi *et al* (2021) found significant effects of soil type and vegetation cover on burrow parameters. A similar situation was observed by Gallacher & Hill (2006b) who suggested that vegetation differences in their study area was due to the level of camel grazing. Al-Sayegh *et al* (2020) also showed that plant species are adversely affected by livestock grazing. While plant species can tolerate and biodiversity sometimes benefits from herbivory in that dominant species are usually eaten first, allowing subordinate species to survive, continual heavy grazing will affect the number and dominance of certain species. This can be seen by the reduced number of Poaceae species in WAS compared to MUG and the larger numbers of *Tetraena* spp. found in WAS compared to MUG which could be directly related to grazing pressure.

Of the seven species common to all substrate types, these, with the exception of *Tetraena* spp., were all considered important forage plants in other studies. Bouskila (1986) recorded 38 species of plants in the diet of his study animals, while Robinson (1995) found dhub foraged on 15 of the 39 species he recorded. Both authors suggest that dhub will climb into trees or bushes to forage as in Figure 4-26 showing one climbing into a *L. pyrotechnica* bush for seed pods. As a direct monitoring of faecal pellets was not part of this study, it is difficult to state the exact species foraged and the quantities consumed. It would however, be reasonable to speculate that dhub are rather fluid in their foraging (as evidenced by others (Bouskila, 1985; Robinson, 1995; Al-Hazmi, 2001)) requirements and would be quite open with regards the forage species they consume. As such they would have foraged on more than the 8 species directly recorded. It has been reported in other *Uromastyx* species that between 3 and 10 species are consumed and these depend on locality and season (Bendami *et al*, 2018).



Figure 4-25. Dhub eating *H. kotschyi.*

Of particular interest is the low abundance and frequency of recording for *Haloxylon salicornicum* which Tamer (2009) suggested recorded the highest Significant Important Value Index (SIVI) for the gravel plains in his study in Dubai Desert Conservation Reserve. It was recorded from one plot out of the 106 sampled in the current study.



Image Dr Jamie Samour

Figure 4-26. Dhub climbing in *L. pyrotechnica* for seed pods (Jamie Samour).

Of the 41 species recorded, as mentioned above 8 were definitively identified as being consumed by dhub, while 12 other species have been identified in the diet of dhub from other studies (Bouskila, 1985; Robinson, 1995; Jongbloed, 1997; Al-Hazmi, 2001; Cunningham, 2001a; Al-Sayegh *et al*, 2020). This gives the species a potential 20 different forage plants identified across both sites.

As part of the current study, the use of translocation as a conservation strategy for the species was a primary driver for this research. While the vegetation study above was not an exhaustive one, it did give an indication of what species were present in both sites and by association, if present in a translocation site, should provide sufficient foraging potential to any release animals.

Given protection, many plant species have the ability to regenerate and as there are large numbers of seeds in the seed bank, other species are capable of regenerating from underground roots where the

main body might have been completely degraded (Brown & Al-Mazrooei, 2003).

More recently, video footage (Chapter 2) has shown that dhub in the UAE will continually lick at the ground while moving out of their burrow to a basking location. From the footage it is not know whether this is for seeds which might have been blown close to the burrow or for ants which were very common around the burrows and a behaviour also observed for *Uromastyx nigriventris* in Morocco (Bendami *et al*, 2018). It is believed that this is a foraging strategy and they are eating seeds which are blown on the wind.

As with many parts of the world, human interference such as the erection of buildings, fences and roads, the inclusion of grazing species such as camels and other ungulates or the exclusion of others such as gazelle and other natural herbivores, which has modified the plant communities being studied, has been observed at both study sites. There is also paucity of vegetation studies within the Emirate of Dubai and when the Dubai Municipality GIS Department were requested to supply maps of the study sites with vegetation classification, all that was provided were the maps with plantations that they supervised of non-native road-side shrub and plant species. When compared to some of the other studies looking at vegetation type in relation to dhub, this study equates well, having identified 41 species with a potential of 20 forage plant species identified.

4.4.6 CONCLUSION

While the current study was undertaken after an extreme rain episode in 2016, the species abundance recorded would most probably have been the exception rather than the norm. However, the UAE has continued with its cloud seeding strategy with Rubin (2022) reporting that in early 2022, cloud seeding coincided with a storm that produced about 140 mm of rain in three days — more rain than the United Arab Emirates often gets in a year.

The current study has identified the potential forage species required for dhub in the study location. However, there are various influencing factors which determine the food and foraging behaviour of any species such as time of day, season, rainfall and other environmental factors. Robinson (1995) suggests that a 1Kg dhub at 40 °C would require 3.7g of food per day based on an energy expenditure of approx 11.8 kcal whereas a small 65g dhub (550 cal) would require 0.17g per day. Although primary productivity in dhub habitats is low, dhub do not spend a lot of time foraging and on average are away from their burrow for less than 10 minutes (Chapter 2). The rest of the time is spent close to the burrow basking or sub-surface. Nussear *et al* (1998) suggested that differences in diet quality in chuckwallas (*Sauromalus obesus*) had negligible effects on their resting metabolic rates and body

temperatures.

Having a food source directly available near the burrow entrance may lower ecological stress for dhub due to the supposedly relative low costs associated with foraging (Wilms *et al*, 2009). With the eight species definitely confirmed and using the 12 confirmed forage species from other studies (see above) it can be stated that if given a protected area with suitable gravel plains and sand dunes, translocated dhub would have adequate forage available to survive.

Dhub depend on food resources of a small area (see average forage track length, Chapter 3) and while natural habitat degradation is a regular phenomenon that occurs in arid deserts throughout the world, increased desertification is one of the main types of land degradation in these environments (El-Keblawy, 2017). Perhaps a new concern should be the effects of continued cloud seeding and whether this will change the species availability for species such as dhub.

While it was easy to identify forage species on sand substrate by following the dhub tracks and recording the species of plant it stops at to forage, tracking on the gravel was a little more difficult and sometimes proved inconclusive. Only one of the 8 confirmed forage species, *Calligonum comosum*, was not recorded at both sites and it was only recorded on the sand substrate. While it is described as widespread and common in sand dunes and plains (Jongbloed *et al*, 2003), its absence, along with the near absence of *Haloxylon salicornicum* (1 in 106 quadrats) from the study site would not have a major impact on the forage availability for dhub but maybe more of an indicator of the health of the environment itself.
As this study was one season in one year, a more detailed study looking at the possible changes associated with increased rainfall would be a worthy continuation.

> "*I asked how much rain was required to produce grazing and he answered it is no use if it does not go into the sand this far" and he indicated his elbow. "How long does it have to rain to do that?" "A heavy shower is enough. That would produce grazing that was better than nothing, but it would die within the year unless there were more rain. If we get really good rain, a whole day and night of rain, the grazing will remain green for three and even four years*" (Thesiger, 1959).

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4.6 APPENDIX

APPENDIX 4-1 – BURROW SELECTION

Table 4-20. Selected burrows to survey with the direction (bearing) required for abandoned burrows in WAS.

Burrow	Status	Site	Bearing °
15-330	Abandoned	Wadi Al Safa	95
14-171	Abandoned	Wadi Al Safa	286
14-491	Abandoned	Wadi Al Safa	358
785	Abandoned	Wadi Al Safa	119

Table 4-21. Selected burrows to survey with the direction (bearing) required for active burrows in WAS.

Burrow #	Status	Site	Bearing
14-004	Active	Wadi Al Safa	274
14-006	Active	Wadi Al Safa	213
14-025	Active	Wadi Al Safa	317
14-026	Active	Wadi Al Safa	322
14-027	Active	Wadi Al Safa	70
14-028	Active	Wadi Al Safa	152
14-029	Active	Wadi Al Safa	27
14-033	Active	Wadi Al Safa	202
14-110	Active	Wadi Al Safa	22
14-113	Active	Wadi Al Safa	141
14-114	Active	Wadi Al Safa	124
14-116	Active	Wadi Al Safa	77
14-176	Active	Wadi Al Safa	141
14-247	Active	Wadi Al Safa	297
14-293	Active	Wadi Al Safa	66
14-296	Active	Wadi Al Safa	169
14-307	Active	Wadi Al Safa	327
14-324	Active	Wadi Al Safa	346
14-327	Active	Wadi Al Safa	353
14-331	Active	Wadi Al Safa	291
14-464	Active	Wadi Al Safa	112
14-469	Active	Wadi Al Safa	118
14-470	Active	Wadi Al Safa	247
14-471	Active	Wadi Al Safa	257
14-472	Active	Wadi Al Safa	300
15-003	Active	Wadi Al Safa	290
15-018	Active	Wadi Al Safa	320
15-033	Active	Wadi Al Safa	295
15-049	Active	Wadi Al Safa	225
15-056	Active	Wadi Al Safa	92
15-057	Active	Wadi Al Safa	249
16-017	Active	Wadi Al Safa	106
16-018	Active	Wadi Al Safa	99
16-046	Active	Wadi Al Safa	229
16-047	Active	Wadi Al Safa	137
16-049	Active	Wadi Al Safa	234
16-051	Active	Wadi Al Safa	228
16-055	Active	Wadi Al Safa	287
763	Active	Wadi Al Safa	139
Hassan01	Active	Wadi Al Safa	354
LC18	Active	Wadi Al Safa	116

Table 4-22. Selected burrows for survey with the direction (bearing) required for filled in burrows in WAS.

Burrow #	Status	Site	Bearing
14-012	Filled In	Wadi Al Safa	21
14-118	Filled In	Wadi Al Safa	122
14-175	Filled In	Wadi Al Safa	147
14-251	Filled In	Wadi Al Safa	57
14-252	Filled In	Wadi Al Safa	62
14-298	Filled In	Wadi Al Safa	110
14-299	Filled In	Wadi Al Safa	154
14-320	Filled In	Wadi Al Safa	48
14-342	Filled In	Wadi Al Safa	18
14-449	Filled In	Wadi Al Safa	104
14-457	Filled In	Wadi Al Safa	37
14-468	Filled In	Wadi Al Safa	155
14-480	Filled In	Wadi Al Safa	126
14-488	Filled In	Wadi Al Safa	30
14-490	Filled In	Wadi Al Safa	67
14-502	Filled In	Wadi Al Safa	10
14-508	Filled In	Wadi Al Safa	16
14-521	Filled In	Wadi Al Safa	115
14-522	Filled In	Wadi Al Safa	150
14-533	Filled In	Wadi Al Safa	56
14-534	Filled In	Wadi Al Safa	20
14-535	Filled In	Wadi Al Safa	140
15-002	Filled In	Wadi Al Safa	13
15-010	Filled In	Wadi Al Safa	56
15-024	Filled In	Wadi Al Safa	55
15-026	Filled In	Wadi Al Safa	118
587	Filled In	Wadi Al Safa	94
697	Filled In	Wadi Al Safa	87
759	Filled In	Wadi Al Safa	42
762	Filled In	Wadi Al Safa	127
Aband011	Filled In	Wadi Al Safa	103
Dhub002	Filled In	Wadi Al Safa	20
Dhub003	Filled In	Wadi Al Safa	55
Dhub038	Filled In	Wadi Al Safa	93
Dhub053	Filled In	Wadi Al Safa	116
Dhub262	Filled In	Wadi Al Safa	121
J018	Filled In	Wadi Al Safa	69
LC19	Filled In	Wadi Al Safa	40
S3B03	Filled In	Wadi Al Safa	81

Table 4-23. Selected burrows for survey with the direction (bearing) required for abandoned burrows in MUG.

Burrow #	Status	Site	Bearing
14-238	Abandoned	Mugatrah	206
14-262	Abandoned	Mugatrah	268
14-357	Abandoned	Mugatrah	51
14-392	Abandoned	Mugatrah	343
14-422	Abandoned	Mugatrah	242
708	Abandoned	Mugatrah	160
738	Abandoned	Mugatrah	258
775	Abandoned	Mugatrah	278
S1B02	Abandoned	Mugatrah	254

Table 4-24. Selected burrows for survey with the direction (bearing) required for active burrows in MUG.

Burrow #	Status	Site	Bearing
14-129	Active	Mugatrah	29
14-138	Active	Mugatrah	135
14-139	Active	Mugatrah	26
14-160	Active	Mugatrah	125
14-167	Active	Mugatrah	349
14-221	Active	Mugatrah	247
14-230	Active	Mugatrah	290
14-234	Active	Mugatrah	178
14-259	Active	Mugatrah	130
14-260	Active	Mugatrah	143
14-266	Active	Mugatrah	314
14-396	Active	Mugatrah	44
14-423	Active	Mugatrah	234
15-028	Active	Mugatrah	124
16-034	Active	Mugatrah	236
16-035	Active	Mugatrah	19
16-042	Active	Mugatrah	326
609	Active	Mugatrah	84
656	Active	Mugatrah	118
685	Active	Mugatrah	257
707	Active	Mugatrah	77
740	Active	Mugatrah	173
751	Active	Mugatrah	20
753	Active	Mugatrah	207
778	Active	Mugatrah	191
779	Active	Mugatrah	130
Dhub193	Active	Mugatrah	78
Dhub224	Active	Mugatrah	305
S1B01	Active	Mugatrah	221
S2B04	Active	Mugatrah	290
S2B08	Active	Mugatrah	185

Table 4-25. Selected burrows for survey with the direction (bearing) required for filled in burrows in MUG.

Burrow #	Status	Site	Bearing
14-122	Filled In	Mugatrah	17
14-123	Filled In	Mugatrah	135
14-137	Filled In	Mugatrah	91
14-144	Filled In	Mugatrah	171
14-147	Filled In	Mugatrah	98
14-152	Filled In	Mugatrah	113
14-157	Filled In	Mugatrah	310
14-161	Filled In	Mugatrah	157
14-207	Filled In	Mugatrah	213
14-210	Filled In	Mugatrah	207
14-216	Filled In	Mugatrah	260
14-217	Filled In	Mugatrah	110
14-222	Filled In	Mugatrah	304
14-224	Filled In	Mugatrah	202
14-232	Filled In	Mugatrah	115
14-233	Filled In	Mugatrah	203
14-243	Filled In	Mugatrah	239
14-269	Filled In	Mugatrah	207
14-280	Filled In	Mugatrah	42
14-281	Filled In	Mugatrah	139
14-284	Filled In	Mugatrah	344
14-285	Filled In	Mugatrah	283
14-287	Filled In	Mugatrah	229
14-290	Filled In	Mugatrah	110
14-363	Filled In	Mugatrah	117
14-365	Filled In	Mugatrah	0
14-367	Filled In	Mugatrah	199
14-368	Filled In	Mugatrah	0
14-369	Filled In	Mugatrah	87
14-370	Filled In	Mugatrah	310
14-374	Filled In	Mugatrah	221
14-383	Filled In	Mugatrah	257
14-384	Filled In	Mugatrah	30
14-386	Filled In	Mugatrah	152
14-398	Filled In	Mugatrah	58
14-400	Filled In	Mugatrah	90
14-408	Filled In	Mugatrah	25
14-415	Filled In	Mugatrah	333
14-435	Filled In	Mugatrah	170
14-439	Filled In	Mugatrah	7
15-031	Filled In	Mugatrah	137
601	Filled In	Mugatrah	338

Table 4-25. Selected burrows for survey with the direction (bearing) required for filled in burrows in MUG (continued).

Burrow #	Status	Site	Bearing
610	Filled In	Mugatrah	29
613	Filled In	Mugatrah	314
620	Filled In	Mugatrah	206
625	Filled In	Mugatrah	315
629	Filled In	Mugatrah	47
639	Filled In	Mugatrah	130
641	Filled In	Mugatrah	249
649	Filled In	Mugatrah	205
652	Filled In	Mugatrah	349
653	Filled In	Mugatrah	221
657	Filled In	Mugatrah	110
661	Filled In	Mugatrah	22
667	Filled In	Mugatrah	159
669	Filled In	Mugatrah	137
670	Filled In	Mugatrah	170
675	Filled In	Mugatrah	67
676	Filled In	Mugatrah	127
683	Filled In	Mugatrah	37
684	Filled In	Mugatrah	269
686	Filled In	Mugatrah	196
689	Filled In	Mugatrah	254
693	Filled In	Mugatrah	158
710	Filled In	Mugatrah	151
714	Filled In	Mugatrah	301
730	Filled In	Mugatrah	111
734	Filled In	Mugatrah	111
735	Filled In	Mugatrah	136
736	Filled In	Mugatrah	97
739	Filled In	Mugatrah	71
749	Filled In	Mugatrah	337
754	Filled In	Mugatrah	238
Dhub021	Filled In	Mugatrah	233
Dhub097	Filled In	Mugatrah	23
Dhub098	Filled In	Mugatrah	96
Dhub104	Filled In	Mugatrah	79
Dhub105	Filled In	Mugatrah	213
Dhub111	Filled In	Mugatrah	190
Dhub115	Filled In	Mugatrah	224
I166	Filled In	Mugatrah	195
S2B09	Filled In	Mugatrah	210

APPENDIX 4-2 – SPECIES AREA CURVES

Species Area Curve

Using the example in http://www.nrri.umn.edu/worms/research/methods_curves.html, the samples are as follows:

Table 4-26. Number of burrows sampled for each substrate type.

Substrate Type	MUG	WAS	Total
Sand	27	34	61
Gravel	14	7	21
Gravel/Sand	5	3	8
Sand/Gravel	3	4	7
Sand/Cemented sand	1	6	7
Gravel/Cemented sand		1	1
Sand/Gravel/Rock	1		1
Total	51	55	106

Table 4-27. Species abundance for substrate type Sand/Cemented sand (CS) (n=7)

Survey Date	Sample ID	Burrow	Substrate type	No. Species	Area (m^2)	$\bar{x}$ Plant Richness	Standard Error
18-May-16	3	762	Sand/CS	10	10	10.00	
06-Jun-16	23	14-129	Sand/CS	10	20	10.00	0.00
07-Jun-16	30	16-018	Sand/CS	16	30	12.00	2.00
09-Jun-16	39	697	Sand/CS	11	40	11.75	1.44
09-Jun-16	44	14-521	Sand/CS	5	50	10.40	1.75
14-Jun-16	59	14-118	Sand/CS	7	60	9.83	1.54
15-Jun-16	68	14-464	Sand/CS	5	70	9.14	1.47

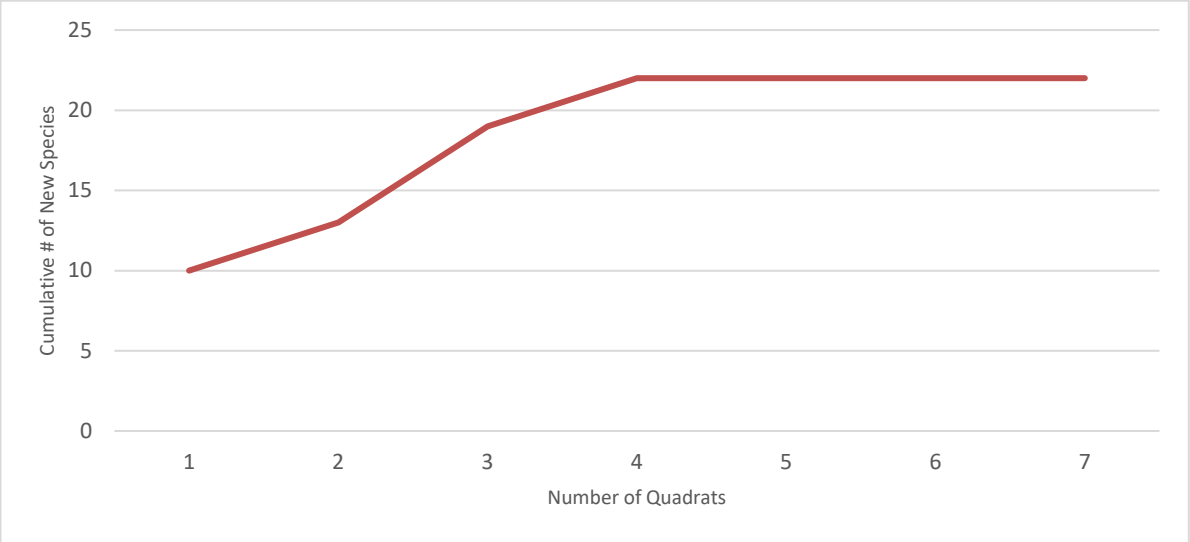


Figure 4-27. Species area curve for substrate type Sand/Cemented sand (*n=6*)

Table 4-28. Species abundance for substrate type Sand/Gravel (n=7)

Survey Date	Sample ID	Burrow	Substrate type	No. Species	Area (m^2)	$\bar{x}$ Plant Richness	Standard Error
26-May-16	8	14-370	Sand/Gravel	10	10	10.00	
06-Jun-16	27	14-252	Sand/Gravel	3	20	6.50	3.50
07-Jun-16	28	14-342	Sand/Gravel	6	30	6.33	2.03
09-Jun-16	38	14-320	Sand/Gravel	12	40	7.75	2.02
15-Jun-16	76	16-051	Sand/Gravel	5	50	8.50	1.66
18-Jun-16	90	14-287	Sand/Gravel	8	60	7.33	1.36
29-Jul-16	99	656	Sand/Gravel	13	70	8.14	1.40

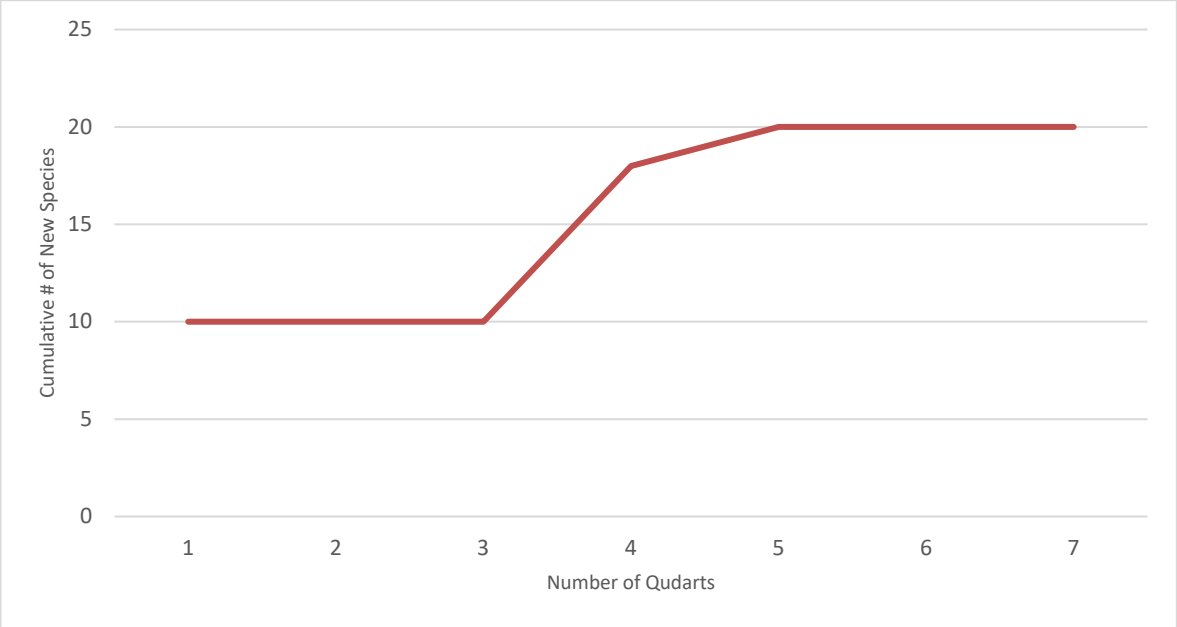


Figure 4-28. Species area curve for substrate type Sand/Gravel

Table 4-29. Species abundance for substrate type Gravel/Sand (n=8)

Survey Date	Sample ID	Burrow	Substrate type	No. Species	Area (m^2)	$\bar{x}$ Plant Richness	Standard Error
03-Jun-16	20	S2B04-O	Gravel/Sand	17	10	10.00	
06-Jun-16	24	14-247	Gravel/Sand	7	20	12.00	5.00
06-Jun-16	25	15-003	Gravel/Sand	7	30	10.33	3.33
09-Jun-16	37	15-010	Gravel/Sand	11	40	10.50	2.36
16-Jun-16	79	779	Gravel/Sand	14	50	12.50	1.96
17-Jun-16	81	14-266	Gravel/Sand	14	60	11.67	1.67
18-Jun-16	87	14-284	Gravel/Sand	8	70	11.14	1.50
30-Jul-16	101	14-384	Gravel/Sand	14	80	11.50	1.35

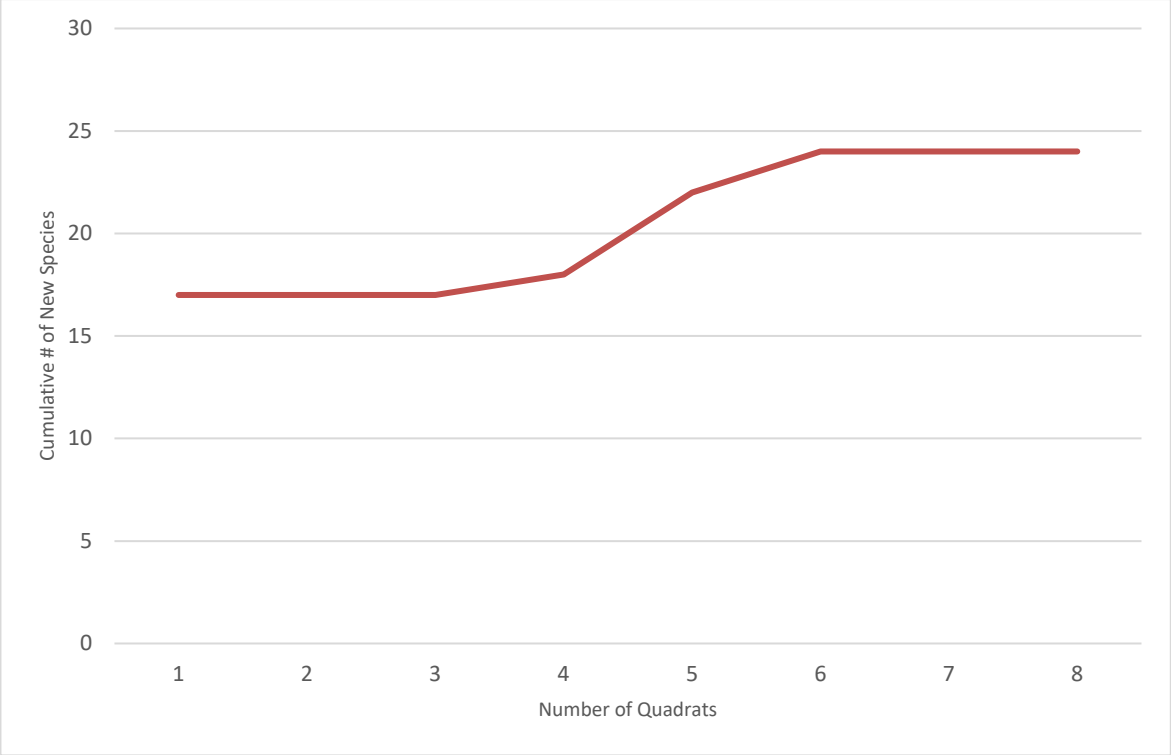


Figure 4-29. Species area curve for substrate type Gravel/Sand

Table 4-30. Species abundance for substrate type Sand (n=61)

Survey Date	Sample ID	Burrow	Substrate type	No. Species	Area (m^2)	$\bar{x}$ Plant Richness	Standard Error
16-May-16	2	785	Sand	7	10	7.00	
16-May-16	5	14-029	Sand	10	20	8.50	1.50
18-May-16	1	14-033	Sand	9	30	8.67	0.88
24-May-16	6	S3B03	Sand	12	40	9.50	1.04
24-May-16	7	14-012	Sand	9	50	9.40	0.81
26-May-16	10	14-144	Sand	6	60	8.83	0.87
26-May-16	11	14-369	Sand	10	70	9.00	0.76
02-Jun-16	12	S1B01	Sand	8	80	8.88	0.67
02-Jun-16	13	15-028	Sand	12	90	9.22	0.68
03-Jun-16	17	S1B02	Sand	10	100	9.30	0.62
03-Jun-16	18	778	Sand	8	110	9.18	0.57
03-Jun-16	19	S2B08	Sand	10	120	9.25	0.52
03-Jun-16	21	S2B04	Sand	8	130	9.15	0.49
03-Jun-16	22	14-167	Sand	15	140	9.57	0.62
06-Jun-16	14	S2B09	Sand	6	150	9.33	0.62
06-Jun-16	16	14-123	Sand	9	160	9.31	0.58
07-Jun-16	29	Dhub003	Sand	11	170	9.41	0.56
07-Jun-16	31	14-327	Sand	10	180	9.44	0.53
07-Jun-16	35	14-298	Sand	16	190	9.79	0.60
09-Jun-16	40	LC18	Sand	9	200	9.75	0.58
09-Jun-16	41	LC19	Sand	9	210	9.71	0.55
09-Jun-16	42	Hassan01	Sand	10	220	9.73	0.52
09-Jun-16	43	15-056	Sand	6	230	9.57	0.53
11-Jun-16	49	14-396	Sand	8	240	9.50	0.51
12-Jun-16	51	14-331	Sand	14	250	9.68	0.52
13-Jun-16	53	14-004	Sand	5	260	9.50	0.53
13-Jun-16	54	Dhub262	Sand	6	270	9.37	0.53
13-Jun-16	55	14-028	Sand	6	280	9.25	0.52
13-Jun-16	56	14-025	Sand	9	290	9.24	0.50
13-Jun-16	57	14-175	Sand	10	300	9.27	0.49
14-Jun-16	58	14-171	Sand	8	310	9.23	0.47
14-Jun-16	60	14-114	Sand	5	320	9.09	0.48
14-Jun-16	61	14-116	Sand	9	330	9.09	0.46
14-Jun-16	62	14-113	Sand	7	340	9.03	0.45
14-Jun-16	63	14-176	Sand	5	350	8.91	0.45
14-Jun-16	64	Dhub053	Sand	8	360	8.89	0.44
14-Jun-16	65	16-046	Sand	13	370	9.00	0.44
14-Jun-16	66	16-047	Sand	12	380	9.08	0.44
15-Jun-16	67	14-457	Sand	7	390	9.03	0.43
15-Jun-16	69	15-018	Sand	7	400	8.98	0.42
15-Jun-16	70	14-480	Sand	4	410	8.85	0.43
15-Jun-16	71	14-488	Sand	5	420	8.76	0.43
15-Jun-16	72	15-024	Sand	7	430	8.72	0.42

Table 30 (continued). Species abundance for substrate type Sand.

Survey Date	Sample ID	Burrow	Substrate type	No. Species	Area (m2)	$\bar{x}$ Plant Richness	Standard Error
15-Jun-16	73	587	Sand	3	440	8.59	0.43
15-Jun-16	74	14-490	Sand	9	450	8.60	0.42
15-Jun-16	75	16-017	Sand	6	460	8.54	0.42
16-Jun-16	78	14-161	Sand	11	470	8.60	0.41
17-Jun-16	82	14-269	Sand	9	480	8.60	0.40
18-Jun-16	85	14-280	Sand	9	490	8.61	0.39
18-Jun-16	88	14-285	Sand	7	500	8.58	0.39
18-Jun-16	89	14-290	Sand	10	510	8.61	0.38
18-Jun-16	91	601	Sand	3	520	8.50	0.39
05-Jul-16	93	14-398	Sand	4	530	8.42	0.39
29-Jul-16	95	I166	Sand	4	540	8.33	0.39
29-Jul-16	96	14-138	Sand	12	550	8.40	0.39
29-Jul-16	97	14-139	Sand	11	560	8.45	0.39
29-Jul-16	98	653	Sand	9	570	8.46	0.38
30-Jul-16	103	14-386	Sand	1	580	8.33	0.39
04-Aug-16	104	14-152	Sand	7	590	8.31	0.39
04-Aug-16	105	14-157	Sand	8	600	8.30	0.38
04-Aug-16	106	14-160	Sand	6	610	8.26	0.38

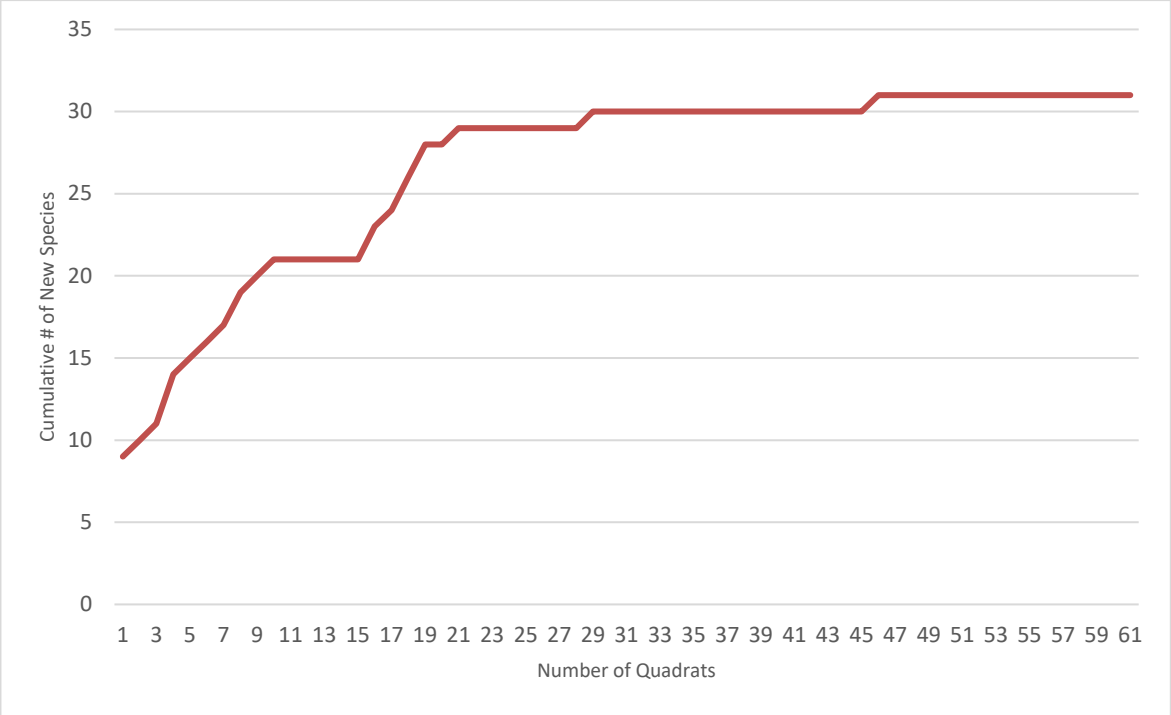


Figure 4-30. Species area curve for substrate type Sand

Table 4-31. Species abundance for substrate type Gravel (n=21)

Survey Date	Sample ID	Burrow	Substrate type	No. Species	Area (m^2)	$\bar{x}$ Plant Richness	Standard Error
08-May-16	4	14-006	Gravel	3	10	3.00	
26-May-16	9	14-374	Gravel	6	20	4.50	1.50
06-Jun-16	26	14-251	Gravel	5	30	4.67	0.88
07-Jun-16	32	14-293	Gravel	14	40	7.00	2.42
07-Jun-16	33	14-296	Gravel	10	50	7.60	1.96
07-Jun-16	34	763	Gravel	9	60	7.83	1.62
09-Jun-16	36	14-299	Gravel	10	70	8.14	1.40
10-Jun-16	45	14-147	Gravel	8	80	8.13	1.22
10-Jun-16	46	14-207	Gravel	8	90	8.11	1.07
11-Jun-16	47	14-435	Gravel	7	100	8.00	0.97
11-Jun-16	48	14-422	Gravel	11	110	8.27	0.92
11-Jun-16	50	14-423	Gravel	8	120	8.25	0.84
16-Jun-16	77	Dhub224	Gravel	10	130	8.38	0.78
17-Jun-16	80	14-243	Gravel	15	140	8.86	0.86
17-Jun-16	83	14-262	Gravel	16	150	9.33	0.93
17-Jun-16	84	14-259	Gravel	10	160	9.38	0.88
18-Jun-16	86	14-281	Gravel	8	170	9.29	0.83
03-Jul-16	92	759	Gravel	5	180	9.06	0.81
29-Jul-16	94	14-137	Gravel	5	190	8.84	0.80
30-Jul-16	100	14-357	Gravel	7	200	8.75	0.76
30-Jul-16	102	14-383	Gravel	10	210	8.81	0.73

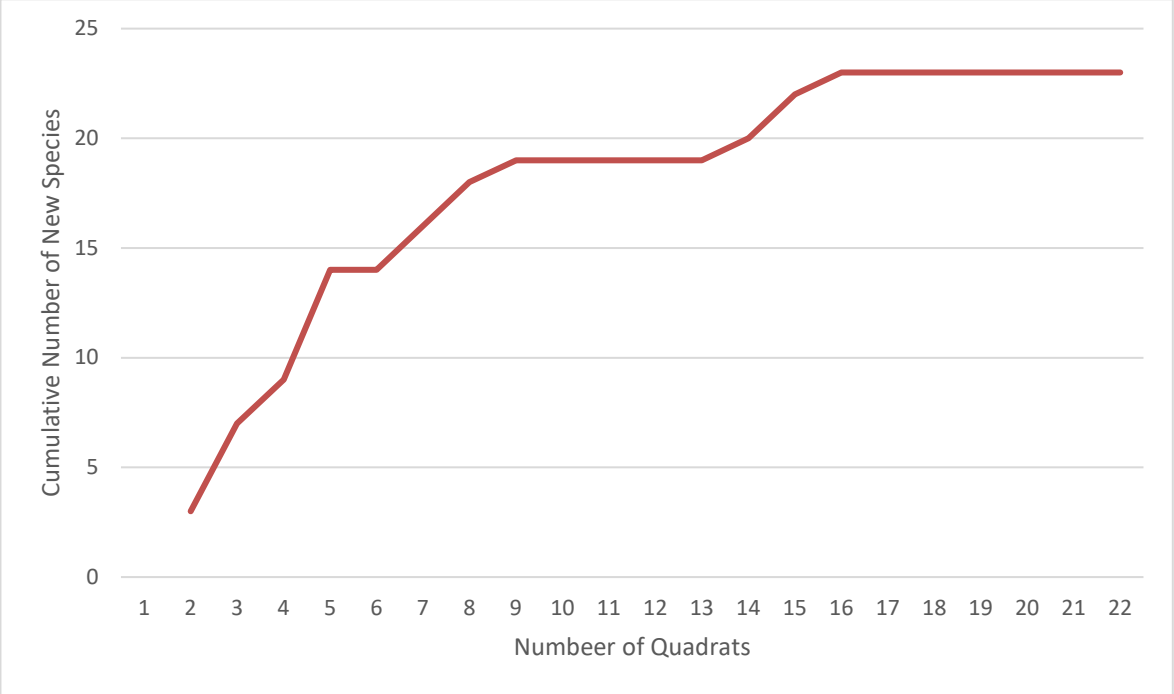


Figure 4-31. Species area curve for substrate type Gravel

APPENDIX 4-3 - SUBSTRATES

Gravel Substrates

Table 4-32. 13 species recorded on gravel/cemented sand substrate (n=1 quadrat) with the percentage number of times each species was recorded (combined for WAS and MUG) from that substrate type.

Species	Recorded	%
Aerva javanica	1	100
Anabasis setifera	1	100
Arnebia hispidissima	1	100
Fagonia bruguieri	1	100
Helianthemum lippii	1	100
Moltkiopsis ciliata	1	100
Monsonia nivea	1	100
Panicum turgidum	1	100
Plantago ovata	1	100
Polycarpaea repens	1	100
Stipagrostis plumosa	1	100
Tetraena spp.	1	100
Tribulus spp.	1	100

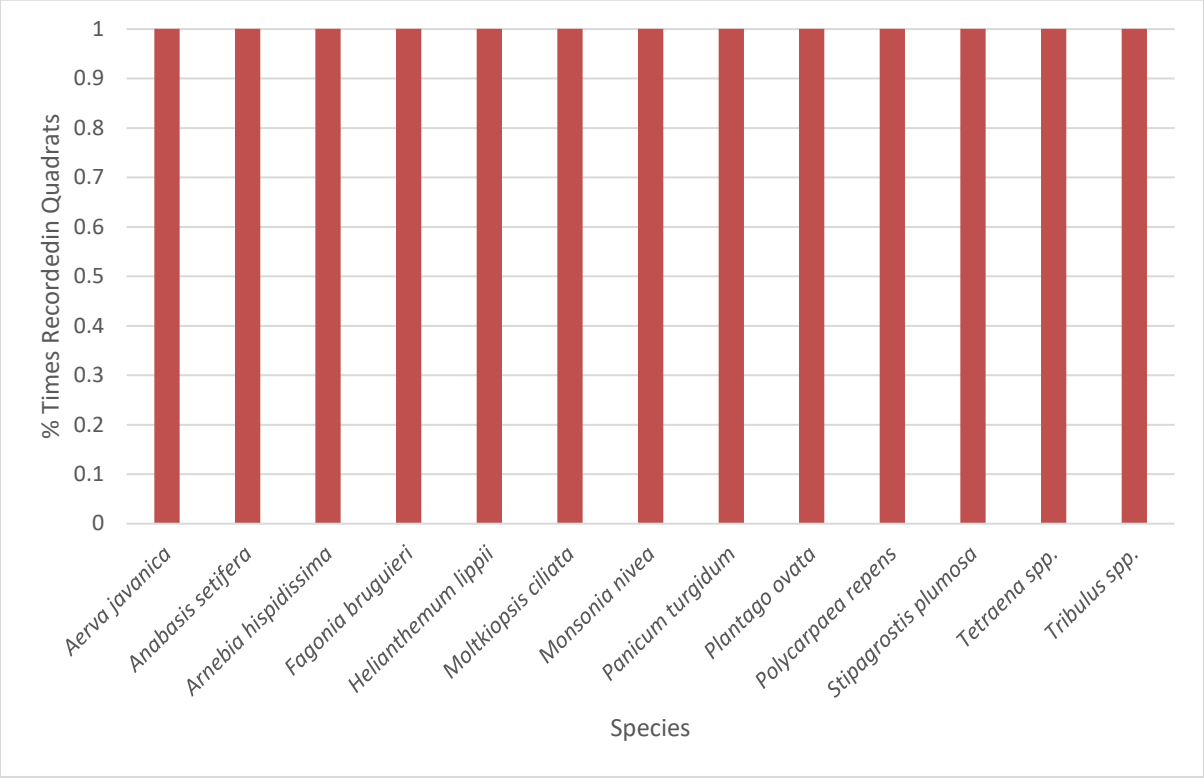


Figure 4-32. Percentage of times (combined for WAS and MUG) each of the 13 species was recorded from the gravel/cemented sand substrate.

Table 4-33. 26 species recorded on gravel/sand substrate (n=8 quadrats) with the percentage number of times each species was recorded (combined for WAS and MUG) from that substrate type.

Species	Recorded	%
Arnebia hispidissima	8	100
Fagonia bruguieri	8	100
Monsonia nivea	8	100
Tetraena spp.	8	100
Helianthemum lippii	6	75
Heliotropium kotschyi	6	75
Panicum turgidum	6	75
Stipagrostis plumosa	6	75
Tribulus spp.	6	75
Pennisetum divisum	5	62.5
Eragrostis barrelieri	4	50
Cornulaca monacantha	3	37.5
Dipterygium glaucum	3	37.5
Launaea mucronata	2	25
Neurada procumbens	2	25
Calligonum comosum	1	12.5
Gisekia pharnaceoides	1	12.5
Heliotropium digynum	1	12.5
Indigofera colutea	1	12.5
Indigofera intricata	1	12.5
Launaea capitata	1	12.5
Leptadenia pyrotechnica	1	12.5
Limeum arabicum	1	12.5
Moltkiopsis ciliata	1	12.5
Plantago ovata	1	12.5
Savignya parviflora	1	12.5

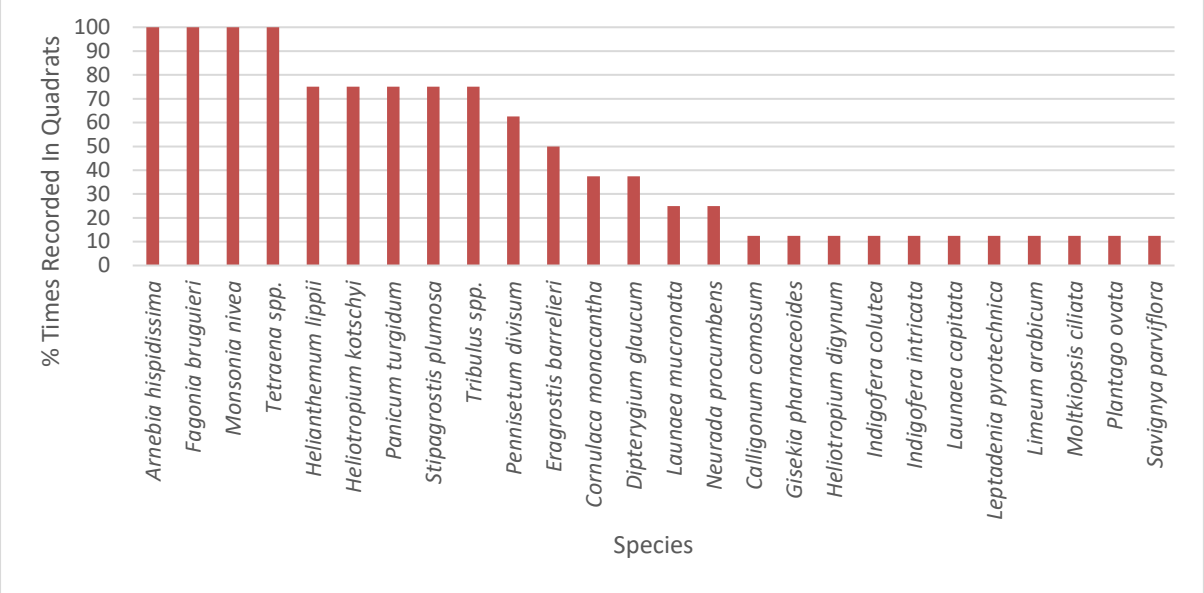


Figure 4-33. Percentage of times (combined for WAS and MUG) each of the 26 species was recorded from the gravel/sand substrate.

Sand Substrate

Table 4-34. 22 species recorded on Sand/Gravel substrate (n=7 quadrats) with the percentage number of times each species was recorded from that substrate type.

Species	Recorded	%
Fagonia bruguieri	6	85.7
Tribulus spp.	6	85.7
Arnebia hispidissima	5	71.4
Tetraena spp.	5	71.4
Helianthemum lippii	4	57.1
Monsonia nivea	4	57.1
Stipagrostis plumosa	4	57.1
Gisekia pharnaceoides	3	42.9
Pennisetum divisum	3	42.9
Dipterygium glaucum	2	28.6
Eragrostis barrelieri	2	28.6
Heliotropium kotschyi	2	28.6
Panicum turgidum	2	28.6
Anabasis setifera	1	14.3
Aristida abnormis	1	14.3
Atractylis carduus	1	14.3
Calligonum comosum	1	14.3
Indigofera intricata	1	14.3
Launaea mucronata	1	14.3
Plantago ovata	1	14.3
Polycarpaea repens	1	14.3
Tragus racemosus	1	14.3

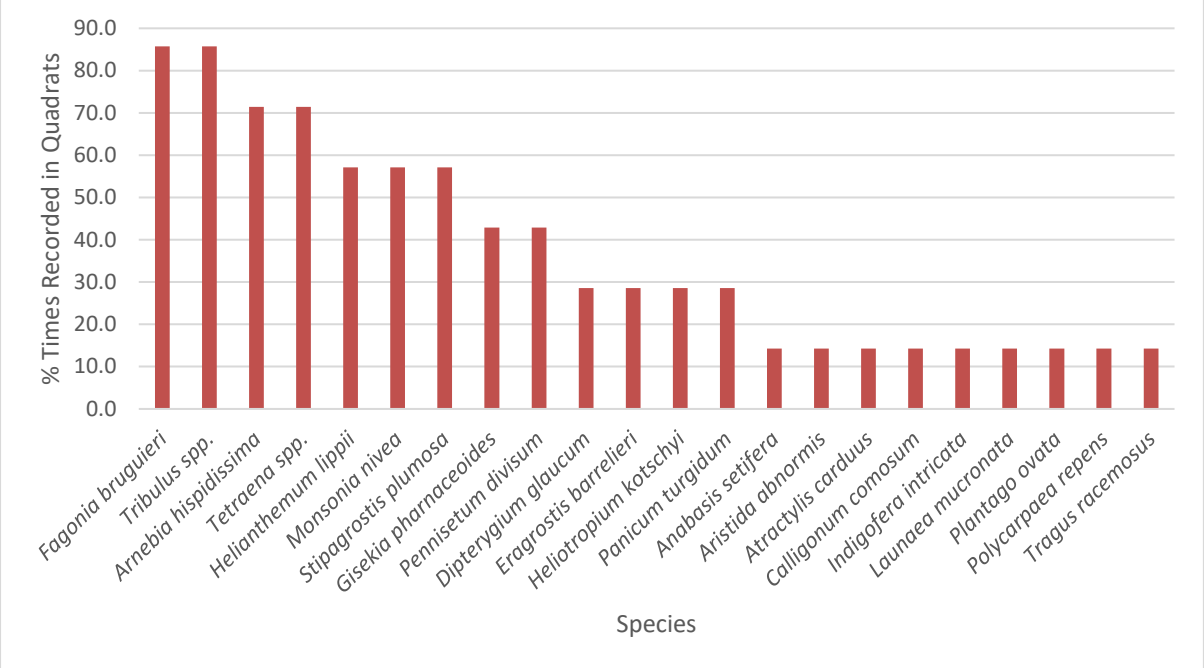


Figure 4-34. Percentage of times (combined for WAS and MUG) each of the 22 species was recorded from the sand/gravel substrate.

Table 4-35. 24 species recorded on sand/cemented sand (n=7 quadrats) with the percentage number of times each species was recorded from that substrate type.

Species	Recorded	%
Stipagrostis plumosa	7	100
Tribulus spp.	7	100
Fagonia bruguieri	5	71
Heliotropium kotschyi	5	71
Polycarpaea repens	5	71
Tetraena spp.	5	71
Arnebia hispidissima	4	57
Helianthemum lippii	3	43
Monsonia nivea	3	43
Panicum turgidum	3	43
Indigofera intricata	2	29
Pennisetum divisum	2	29
Plantago ciliata	2	29
Aerva javanica	1	14
Anabasis setifera	1	14
Cleome sp.	1	14
Eragrostis barrelieri	1	14
Haloxylon salicornicum	1	14
Heliotropium digynum	1	14
Launaea mucronata	1	14
Neurada procumbens	1	14
Plantago ovata	1	14
Sesuvium verrucosum	1	14
Tragus racemosus	1	14

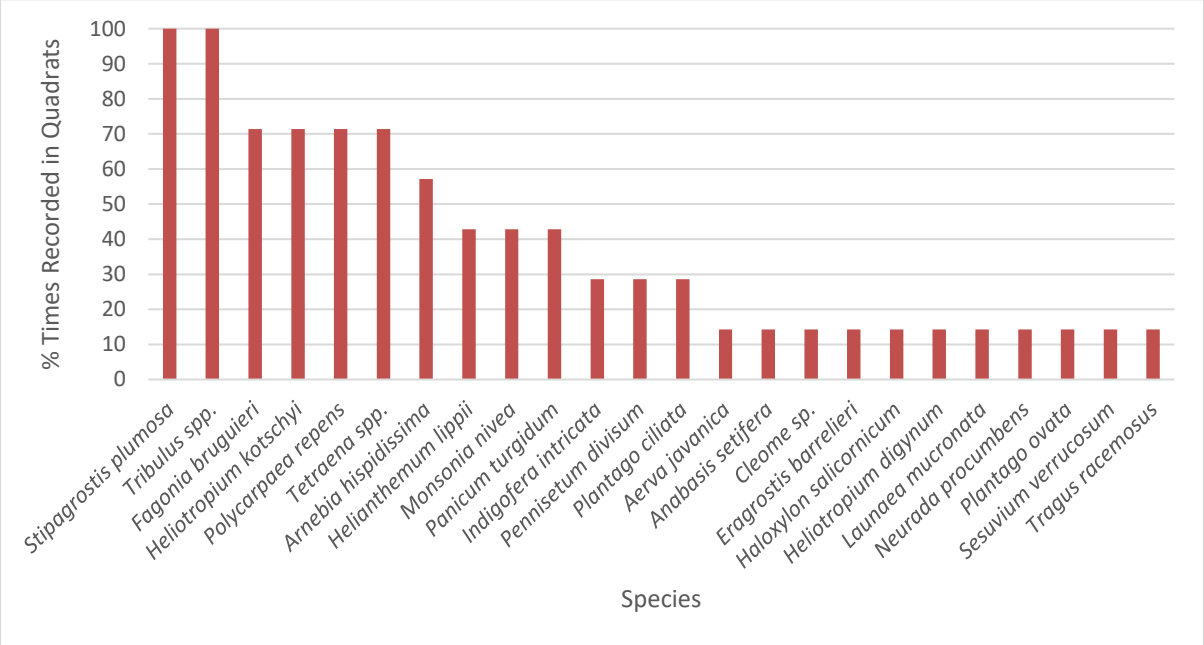


Figure 4-35. Percentage of times (combined for WAS and MUG) each of the 24 species was recorded from the sand/cemented sand substrate.

Table 4-36. 10 species recorded on Sand/Gravel/Rock substrate (n=1 quadrats) with the percentage number of times each species was recorded from that substrate type.

Species	Recorded	%
Arnebia hispidissima	1	100
Dipterygium glaucum	1	100
Fagonia bruguieri	1	100
Heliotropium kotschyi	1	100
Limeum arabicum	1	100
Monsonia nivea	1	100
Panicum turgidum	1	100
Pennisetum divisum	1	100
Stipagrostis plumosa	1	100
Tetraena spp.	1	100

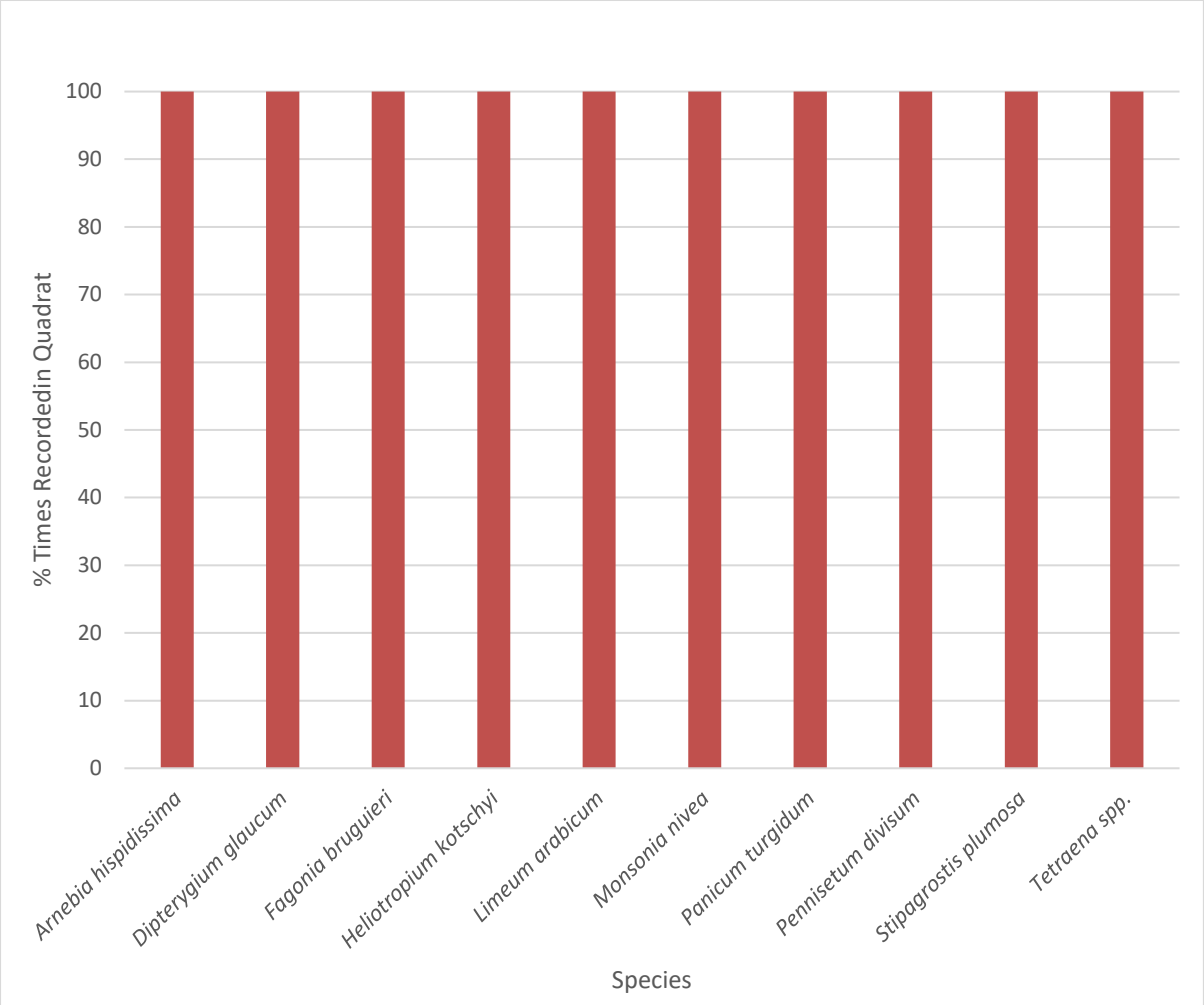


Figure 4-36. Percentage of times (combined for WAS and MUG) each of the 10 species was recorded from the Sand/Gravel/Rock substrate.

APPENDIX 4-4 – SUMMARY STATISTICS

Summary Statistics

Table 4-37. Descriptive statistics for plant species recorded in Mugatrah for substrate type gravel.

Species	#*	Mean	Min	Max	Range	Variance	[a]COV	[b]SD	[c]SE	[d]Med
Aerva javanica	1	2.0	2.0	2.0	0.0					2.0
Arnebia hispidissima	14	180.7	40.0	759.0	719.0	34162.5	102.3	184.8	49.4	127.0
Atractylis carduus	1	2.0	2.0	2.0	0.0					2.0
Cornulaca monacantha	4	11.5	1.0	42.0	41.0	413.7	176.9	20.3	10.2	1.5
Dipterygium glaucum	4	2.5	1.0	4.0	3.0	3.0	69.3	1.7	0.9	2.5
Eragrostis barrelieri	2	2.5	1.0	4.0	3.0	4.5	84.9	2.1	1.5	2.5
Fagonia bruguieri	13	140.8	10.0	409.0	399.0	14601.5	85.8	120.8	33.5	103.0
Gisekia pharnaceoides	2	3.5	2.0	5.0	3.0	4.5	60.6	2.1	1.5	3.5
Helianthemum lippii	11	47.5	1.0	341.0	340.0	9771.9	207.9	98.9	29.8	16.0
Heliotropium digynum	1	16.0	16.0	16.0	0.0					16.0
Heliotropium kotschyi	3	3.0	2.0	4.0	2.0	1.0	33.3	1.0	0.6	3.0
Indigofera intricata	3	3.7	1.0	7.0	6.0	9.3	83.3	3.1	1.8	3.0
Monsonia nivea	14	227.6	1.0	551.0	550.0	43709.2	91.8	209.1	55.9	152.0
Neurada procumbens	4	22.8	1.0	73.0	72.0	1154.9	149.4	34.0	17.0	8.5
Panicum turgidum	5	3.0	1.0	5.0	4.0	2.5	52.7	1.6	0.7	3.0
Pennisetum divisum	4	4.8	1.0	9.0	8.0	12.3	73.7	3.5	1.8	4.5
Savignya parviflora	6	6.3	1.0	22.0	21.0	60.7	123.0	7.8	3.2	3.5
Stipagrostis plumosa	12	13.8	2.0	36.0	34.0	113.1	76.9	10.6	3.1	12.5
Tetraena spp.	14	293.6	29.0	610.0	581.0	36141.5	64.8	190.1	50.8	299.5
Tribulus spp.	11	15.9	1.0	106.0	105.0	958.7	194.6	31.0	9.3	5.0

*Number of quadrats; [a] coefficient of variation; [b] standard deviation; [c] standard error; [d] median

Table 4-38. Descriptive statistics for plant species recorded in Wadi Al Safa for substrate type gravel.

Species	#*	Mean	Min	Max	Range	Variance	[a]COV	[b]SD	[c]SE	[d]Med
Arnebia hispidissima	6	18.2	1.0	37.0	36.0	235.0	84.4	15.3	6.3	19.0
Atractylis carduus	1	1.0	1.0	1.0	0.0					1.0
Coelachyrum piercii	1	2.0	2.0	2.0	0.0					2.0
Fagonia bruguieri	6	30.0	12.0	76.0	64.0	621.2	83.1	24.9	10.2	19.5
Helianthemum lippii	6	35.3	1.0	81.0	80.0	1248.3	100.0	35.3	14.4	27.5
Heliotropium kotschyi	2	3.0	1.0	5.0	4.0	8.0	94.3	2.8	2.0	3.0
Monsonia nivea	6	94.8	1.0	242.0	241.0	11305.4	112.1	106.3	43.4	71.0
Neurada procumbens	1	1.0	1.0	1.0	0.0					1.0
Panicum turgidum	1	1.0	1.0	1.0	0.0					1.0
Pennisetum divisum	1	2.0	2.0	2.0	0.0					2.0
Plantago ciliata	1	5.0	5.0	5.0	0.0					5.0
Plantago ovata	3	17.7	15.0	21.0	6.0	9.3	17.3	3.1	1.8	17.0
Polycarpaea repens	2	38.5	1.0	76.0	75.0	2812.5	137.7	53.0	37.5	38.5
Prosopis cineraria	1	1.0	1.0	1.0	0.0					1.0
Savignya parviflora	2	7.5	2.0	13.0	11.0	60.5	103.7	7.8	5.5	7.5
Stipagrostis plumosa	5	5.8	1.0	18.0	17.0	52.7	125.2	7.3	3.2	2.0
Tetraena spp.	7	332.6	91.0	599.0	508.0	38772.6	59.2	196.9	74.4	302.0
Tribulus spp.	4	50.3	17.0	133.0	116.0	3067.6	110.2	55.4	27.7	25.5

*Number of quadrats; [a] coefficient of variation; [b] standard deviation; [c] standard error; [d] median

Table 4-39. Descriptive statistics for plant species recorded in Mugatrah for substrate type sand.

Species	#*	Mean	Min	Max	Range	Variance	[a]COV	[b]SD	[c]SE	[d]Med
Arnebia hispidissima	4	32.0	1.0	122.0	121.0	3602.0	187.6	60.0	30.0	2.5
Cornulaca monacantha	3	1.3	1.0	2.0	1.0	0.3	43.3	0.6	0.3	1.0
Cyperus conglomeratus	2	2.5	2.0	3.0	1.0	0.5	28.3	0.7	0.5	2.5
Dipterygium glaucum	12	5.0	1.0	22.0	21.0	41.1	128.2	6.4	1.9	2.0
Eragrostis barrelieri	18	14.3	1.0	75.0	74.0	424.6	143.8	20.6	4.9	5.5
Fagonia bruguieri	10	11.6	1.0	36.0	35.0	151.8	106.2	12.3	3.9	6.5
Gisekia pharnaceoides	5	2.2	1.0	6.0	5.0	4.7	98.5	2.2	1.0	1.0
Helianthemum lippii	3	4.7	1.0	12.0	11.0	40.3	136.1	6.4	3.7	1.0
Heliotropium digynum	8	3.4	1.0	10.0	9.0	14.8	114.1	3.9	1.4	1.0
Heliotropium kotschyi	19	12.7	1.0	47.0	46.0	222.7	117.6	14.9	3.4	6.0
Indigofera intricata	6	3.0	1.0	12.0	11.0	19.6	147.6	4.4	1.8	1.0
Launaea capitata	1	1.0	1.0	1.0	0.0					1.0
Launaea mucronata	3	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0
Limeum arabicum	11	2.1	1.0	5.0	4.0	1.3	54.3	1.1	0.3	2.0
Moltkiopsis ciliata	6	3.7	1.0	7.0	6.0	3.9	53.6	2.0	0.8	3.5
Monsonia nivea	9	64.6	1.0	446.0	445.0	20786.3	223.3	144.2	48.1	11.0
Neurada procumbens	4	2.8	1.0	8.0	7.0	12.3	127.3	3.5	1.8	1.0
Panicum turgidum	23	16.8	2.0	56.0	54.0	146.5	71.9	12.1	2.5	15.0
Pennisetum divisum	22	18.5	1.0	72.0	71.0	283.5	91.2	16.8	3.6	15.0
Stipagrostis plumosa	22	28.9	1.0	228.0	227.0	3245.9	197.4	57.0	12.1	5.0
Tetraena spp.	4	67.5	2.0	256.0	254.0	15801.7	186.2	125.7	62.9	6.0
Tribulus spp.	26	50.2	4.0	239.0	235.0	2704.6	103.7	52.0	10.2	36.5

*Number of quadrats; [a] coefficient of variation; [b] standard deviation; [c] standard error; [d] median

Table 4-40. Descriptive statistics for plant species recorded in Wadi Al Safa for substrate type sand.

Species	#*	Mean	Min	Max	Range	Variance	[a]COV	[b]SD	[c]SE	[d]Med
Aerva javanica	4	2.0	1.0	3.0	2.0	1.3	57.7	1.2	0.6	2.0
Arnebia hispidissima	14	6.1	1.0	38.0	37.0	89.4	153.9	9.5	2.5	4.0
Atractylis carduus	2	2.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0	2.0
Calligonum comosum	2	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0
Calotropis procera	2	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0
Chrozophora oblongifolia	5	2.8	1.0	9.0	8.0	12.2	124.7	3.5	1.6	1.0
Coelachyrum piercii	2	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0
Dipterygium glaucum	1	1.0	1.0	1.0	0.0					1.0
Eragrostis barrelieri	22	12.5	1.0	61.0	60.0	274.5	132.1	16.6	3.5	5.5
Fagonia bruguieri	10	13.1	1.0	62.0	61.0	480.3	167.3	21.9	6.9	2.5
Gisekia pharnaceoides	4	5.3	1.0	18.0	17.0	72.3	161.9	8.5	4.3	1.0
Helianthemum lippii	4	17.0	2.0	56.0	54.0	678.7	153.2	26.1	13.0	5.0
Heliotropium digynum	2	1.5	1.0	2.0	1.0	0.5	47.1	0.7	0.5	1.5
Heliotropium kotschyi	16	8.4	1.0	44.0	43.0	136.4	138.4	11.7	2.9	3.5
Indigofera colutea	2	41.0	5.0	77.0	72.0	2592.0	124.2	50.9	36.0	41.0
Indigofera intricata	13	4.4	1.0	20.0	19.0	33.1	131.2	5.8	1.6	2.0
Launaea mucronata	1	1.0	1.0	1.0	0.0					1.0
Limeum arabicum	1	2.0	2.0	2.0	0.0					2.0
Moltkiopsis ciliata	1	2.0	2.0	2.0	0.0					2.0
Monsonia nivea	10	92.0	1.0	367.0	366.0	17759.8	144.9	133.3	42.1	13.0
Neurada procumbens	14	12.4	1.0	77.0	76.0	482.6	176.8	22.0	5.9	2.5
Panicum turgidum	16	3.1	1.0	22.0	21.0	26.1	166.7	5.1	1.3	2.0
Pennisetum divisum	5	3.4	1.0	6.0	5.0	5.3	67.7	2.3	1.0	4.0
Plantago ciliata	4	1.3	1.0	2.0	1.0	0.3	40.0	0.5	0.3	1.0
Plantago ovata	9	4.7	1.0	23.0	22.0	49.3	150.4	7.0	2.3	2.0
Polycarpaea repens	26	55.1	1.0	758.0	757.0	21332.5	265.0	146.1	28.6	20.0
Stipagrostis plumosa	31	94.6	3.0	390.0	387.0	13288.8	121.8	115.3	20.7	26.0
Tetraena spp.	22	117.5	1.0	355.0	354.0	10292.8	86.3	101.5	21.6	103.5
Tragus racemosus	6	1.8	1.0	4.0	3.0	1.8	72.5	1.3	0.5	1.0
Tribulus spp.	32	39.8	1.0	408.0	407.0	6935.4	209.5	83.3	14.7	12.0

*Number of quadrats; [a] coefficient of variation; [b] standard deviation; [c] standard error; [d] median

Table 4-41. Descriptive statistics for plant species recorded in Mugatrah for substrate type sand/gravel.

Species	#*	Mean	Min	Max	Range	Variance	[a]COV	[b]SD	[c]SE	[d]Med
Aristida abnormis	1	24.0	24.0	24.0	0.0					24.0
Arnebia hispidissima	7	60.4	11.0	138.0	127.0	3214.3	93.8	56.7	21.4	24.0
Atractylis carduus	1	17.0	17.0	17.0	0.0					17.0
Calligonum comosum	2	2.0	1.0	3.0	2.0	2.0	70.7	1.4	1.0	2.0
Cornulaca monacantha	3	15.0	1.0	39.0	38.0	436.0	139.2	20.9	12.1	5.0
Dipterygium glaucum	5	3.8	1.0	8.0	7.0	7.2	70.6	2.7	1.2	4.0
Eragrostis barrelieri	6	13.5	1.0	67.0	66.0	690.7	194.7	26.3	10.7	3.0
Fagonia bruguieri	8	200.4	5.0	527.0	522.0	30864.6	87.7	175.7	62.1	163.0
Gisekia pharnaceoides	4	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0
Helianthemum lippii	5	12.8	2.0	51.0	49.0	458.7	167.3	21.4	9.6	3.0
Heliotropium digynum	1	1.0	1.0	1.0	0.0					1.0
Heliotropium kotschyi	3	11.7	6.0	15.0	9.0	24.3	42.3	4.9	2.8	14.0
Indigofera colutea	1	3.0	3.0	3.0	0.0					3.0
Indigofera intricata	1	102.0	102.0	102.0	0.0					102.0
Launaea capitata	1	1.0	1.0	1.0	0.0					1.0
Launaea mucronata	3	2.7	1.0	4.0	3.0	2.3	57.3	1.5	0.9	3.0
Leptadenia pyrotechnica	1	1.0	1.0	1.0	0.0					1.0
Limeum arabicum	1	1.0	1.0	1.0	0.0					1.0
Moltkiopsis ciliata	1	2.0	2.0	2.0	0.0					2.0
Monsonia nivea	8	97.8	2.0	219.0	217.0	7903.6	90.9	88.9	31.4	92.0
Panicum turgidum	7	11.3	1.0	30.0	29.0	137.2	103.8	11.7	4.4	6.0
Pennisetum divisum	6	5.7	2.0	12.0	10.0	12.3	61.8	3.5	1.4	5.5
Savignya parviflora	1	3.0	3.0	3.0	0.0					3.0
Stipagrostis plumosa	6	46.5	4.0	171.0	167.0	3937.1	134.9	62.7	25.6	25.5
Tetraena spp.	7	106.9	6.0	312.0	306.0	15527.5	116.6	124.6	47.1	39.0
Tribulus spp.	8	47.6	16.0	119.0	103.0	1786.3	88.7	42.3	14.9	22.5

*Number of quadrats; [a] coefficient of variation; [b] standard deviation; [c] standard error; [d] median

Table 4-42. Descriptive statistics for plant species recorded in Wadi Al Safa for substrate type sand/gravel.

Species	#*	Mean	Min	Max	Range	Variance	[a]COV	[b]SD	[c]SE	[d]Med
Anabasis setifera	1	1.0	1.0	1.0	0.0					1.0
Arnebia hispidissima	5	21.0	1.0	80.0	79.0	1128.5	160.0	33.6	15.0	5.0
Fagonia bruguieri	5	25.2	2.0	95.0	93.0	1548.7	156.2	39.4	17.6	7.0
Helianthemum lippii	4	11.5	3.0	28.0	25.0	127.0	98.0	11.3	5.6	7.5
Heliotropium kotschyi	4	3.3	1.0	6.0	5.0	6.9	80.9	2.6	1.3	3.0
Indigofera intricata	1	6.0	6.0	6.0	0.0					6.0
Monsonia nivea	3	142.7	3.0	313.0	310.0	24730.3	110.2	157.3	90.8	112.0
Neurada procumbens	1	1.0	1.0	1.0	0.0					1.0
Panicum turgidum	1	1.0	1.0	1.0	0.0					1.0
Pennisetum divisum	2	2.0	1.0	3.0	2.0	2.0	70.7	1.4	1.0	2.0
Plantago ovata	2	8.5	7.0	10.0	3.0	4.5	25.0	2.1	1.5	8.5
Polycarpaea repens	1	53.0	53.0	53.0	0.0					53.0
Stipagrostis plumosa	4	81.5	17.0	227.0	210.0	9537.0	119.8	97.7	48.8	41.0
Tetraena spp.	5	465.6	29.0	875.0	846.0	136866.8	79.5	370.0	165.4	422.0
Tragus racemosus	1	2.0	2.0	2.0	0.0					2.0
Tribulus spp.	4	40.0	3.0	79.0	76.0	1690.0	102.8	41.1	20.6	39.0

*Number of quadrats; [a] coefficient of variation; [b] standard deviation; [c] standard error; [d] median

Table 4-43. Descriptive statistics for plant species recorded in Wadi Al Safa for substrate type sand/Cemented Sand.

Species	#*	Mean	Min	Max	Range	Variance	[a]COV	[b]SD	[c]SE	[d]Med
Aerva javanica	1	4.0	4.0	4.0	0.0					4.0
Anabasis setifera	1	2.0	2.0	2.0	0.0					2.0
Arnebia hispidissima	3	10.7	3.0	22.0	19.0	100.3	93.9	10.0	5.8	7.0
Cleome sp.	1	2.0	2.0	2.0	0.0					2.0
Eragrostis barrelieri	1	5.0	5.0	5.0	0.0					5.0
Fagonia bruguieri	4	4.0	1.0	10.0	9.0	16.7	102.1	4.1	2.0	2.5
Haloxylon salicornicum	1	1.0	1.0	1.0	0.0					1.0
Helianthemum lippii	2	4.0	3.0	5.0	2.0	2.0	35.4	1.4	1.0	4.0
Heliotropium digynum	1	1.0	1.0	1.0	0.0					1.0
Heliotropium kotschyi	4	7.0	1.0	22.0	21.0	100.7	143.3	10.0	5.0	2.5
Indigofera intricata	1	1.0	1.0	1.0	0.0					1.0
Launaea mucronata	1	4.0	4.0	4.0	0.0					4.0
Monsonia nivea	3	43.7	3.0	73.0	70.0	1321.3	83.2	36.4	21.0	55.0
Panicum turgidum	3	1.7	1.0	3.0	2.0	1.3	69.3	1.2	0.7	1.0
Pennisetum divisum	2	1.5	1.0	2.0	1.0	0.5	47.1	0.7	0.5	1.5
Plantago ciliata	2	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0
Plantago ovata	1	12.0	12.0	12.0	0.0					12.0
Polycarpaea repens	5	79.8	3.0	352.0	349.0	23237.7	191.0	152.4	68.2	10.0
Stipagrostis plumosa	6	62.7	1.0	197.0	196.0	5731.9	120.8	75.7	30.9	36.0
Tetraena spp.	4	190.8	64.0	254.0	190.0	7434.3	45.2	86.2	43.1	222.5
Tragus racemosus	1	1.0	1.0	1.0	0.0					1.0
Tribulus spp.	6	49.7	2.0	193.0	191.0	5857.5	154.1	76.5	31.2	9.5

*Number of quadrats; [a] coefficient of variation; [b] standard deviation; [c] standard error; [d] median

Table 4-44. Mean number of plants for each substrate type for Mugatrah (M) and Wadi Al Safa (W).

Species	G		G/S		S		S/G		S/G/R		S/G/S		S/S	
	M	W	M	W	M	W	M	W	M	W	M	W	M	W
A. javanica	2.0			3.0		2.0								4.0
A. setifera				1.0										2.0
A. abnormis							24.0							
A. hispidissima	180.7	18.2		2.0	32.0	6.1	60.4	21.0	17.0			2.0	3.0	10.7
A. carduus	2.0	1.0				2.0	17.0							
C. comosum						1.0	2.0							
C. procera						1.0								
C. oblongifolia						2.8								
Cleome sp.														2.0
C. monacantha	11.5	2.0			1.3	1.0	15.0							
C. conglomeratus					2.5									
D. glaucum	2.5				5.0	1.0	3.8		3.0					
E. barrelieri	2.5				14.3	12.5	13.5							5.0
F. bruguieri	140.8	30.0		2.0	11.6	13.1	200.4	25.2	106.0			4.0	28.0	4.0
G. pharnaceoides	3.5				2.2	5.3	1.0							
H. salicornicum														1.0
H. lippii	47.5	35.3		1.0	4.7	17.0	12.8	11.5				10.0	7.0	4.0
H. digynum	16.0				3.4	1.5	1.0							1.0
H. kotschyi	3.0	3.0			12.7	8.4	11.7	3.3	62.0			1.0	10.0	7.0
I. colutea						41.0	3.0							
I. intricata	3.7				3.0	4.4	102.0	6.0					1.0	1.0
L. capitata					1.0		1.0							
L. mucronata					1.0	1.0	2.7							4.0
L. pyrotechnica							1.0							
L. arabicum					2.1	2.0	1.0		1.0					
M. ciliata				1.0	3.7	2.0	2.0							
M. nivea	227.6	94.8		69.0	64.6	92.0	97.8	142.7	56.0			3.0		43.7
N. procumbens	22.8	1.0			2.8	12.4		1.0				2.0	2.0	
P. turgidum	3.0	1.0		2.0	16.8	3.1	11.3	1.0	1.0					1.7
P. divisum	4.8	2.0			18.5	3.4	5.7	2.0	5.0					1.5
P. ciliata		5.0				1.3								1.0
P. ovata		17.7		11.0		4.7		8.5						12.0
P. repens		38.5		4.0		55.1		53.0						79.8
P. cineraria		1.0												
S. parviflora	6.3	7.5					3.0							
S. verrucosum													3.0	
S. plumosa	13.8	5.8		354.0	28.9	94.6	46.5	81.5	5.0				1.0	62.7
T. racemosus						1.8		2.0						1.0
Tetraena spp.	293.6	332.6		506.0	67.5	117.5	106.9	465.6	5.0			277.0	414.0	190.8
Tribulus spp.	15.9	50.3		182.0	50.2	39.8	47.6	40.0	8.0				1.0	49.7

G=Gravel, G/S=Gravel/Sand, S=Sand, S/G=Sand/Gravel, S/G/R=Sand/Gravel/Rock, S/G/S=Sand/Gravel/Cemented Sand, S/S=Sand/Cemented Sand

APPENDIX 4-5 – SPECIES STATISTICAL TEST

Table 4-45. Species found on the sand substrate which were either tested (Kruskal-Wallis non-parametric statistical test), not tested due to either there been not enough data or only found on one substrate type with links to the results.

Species	KW Test	Not enough data	Only one substrate	H	DF	P
Aerva javanica	✓			2.2	1	0.136
Anabasis setifera		✓				
Aristida abnormis		✓				
Arnebia hispidissima	✓			6.54	6	0.366
Atractylis carduus		✓				
Calligonum comosum		✓				
Calotropis procera		✓				
Chrozophora oblongifolia			✓			
Cleome sp.		✓				
Coelachyrum piercii		✓				
Cornulaca monacantha		✓				
Cyperus conglomeratus		✓				
Dipterygium glaucum	✓			2.29	3	0.514
Eragrostis barrelieri	✓			1.02	3	0.797
Fagonia bruguieri	✓			7.95	6	0.242
Gisekia pharnaceoides	✓			1.25	2	0.535
Haloxylon salicornicum		✓				
Helianthemum lippii	✓			2.42	5	0.788
Heliotropium digynum		✓				
Heliotropium kotschyi	✓			4.78	5	0.443
Indigofera colutea		✓				
Indigofera intricata	✓			3.27	4	0.513
Launaea capitata		✓				
Launaea mucronata	✓			5.00	3	0.172
Limeum arabicum	✓			1.80	2	0.406
Moltkiopsis ciliata			✓			
Monsonia nivea	✓			2.72	5	0.743
Neurada procumbens			✓			
Panicum turgidum	✓			23.97	4	0.000
Pennisetum divisum	✓			10.54	5	0.061
Plantago ciliata		✓				
Plantago ovata	✓			2.83	2	0.243
Stipagrostis plumosa	✓			17.37	6	0.008
Tetraena spp.	✓			9.37	6	0.154
Tribulus spp.	✓			12.48	6	0.052

Aerva javanica

Location	N	Median	Ave Rank	Z
WS	4	2	2.5	-1.41
WS/S	1	4	5.0	1.41

WS= Wadi Al Safa Sand; WS/S= Wadi Al Safa Sand/Cemented Sand

Overall 5 3.0

H	DF	P	
2.00	1	0.157	
2.22	1	0.136	Adjusted for ties

Arnebia hispidissima

Location	N	Median	Ave Rank	Z
MS	4	2.5	12.0	-0.66
MS/G	2	79.0	25.5	1.96
MS/G/R	1	17.0	22.0	0.93
MS/S	1	3.0	10.0	-0.56
WS	14	4.0	12.5	-1.26
WS/G	3	5.0	15.3	0.19
WS/S	3	7.0	17.8	0.74

MS=Mugatrah Sand; MS/G=Mugatrah Sand/Gravel; MS/G/R=Mugatrah Sand/Gravel/Rock; MS/S=Mugatrah Sand/Cemented Sand; WS= Wadi Al Safa Sand; WS/G= Wadi Al Safa Sand/Gravel; WS/S= Wadi Al Safa Sand/Cemented Sand

Overall 28 14.5

H	DF	P	
6.40	6	0.380	
6.54	6	0.366	Adjusted for ties

Dipterygium glaucum

Location	N	Median	Ave Rank	Z
MS	12	2	8.7	0.30
MS/G	2	3	9.5	0.32
MS/G/R	1	3	10.5	0.43
WS	1	1	2.0	-1.41

MS=Mugatrah Sand; MS/G=Mugatrah Sand/Gravel; MS/G/R= Mugatrah Sand/Gravel/Rock, WS= Wadi Al Safa Sand;

Overall 16 8.5

H	DF	P	
2.15	3	0.542	
2.29	3	0.514	Adjusted for ties

Eragrostis barrelieri

Location	N	Median	Ave Rank	Z
MS	18	5.5	23.4	0.64
MS/G	2	34.5	27.5	0.63
WS	22	5.5	20.4	-0.87
WS/S	1	5.0	21.0	-0.08

MS=Mugatrah Sand; MS/G=Mugatrah Sand/Gravel; WS= Wadi Al Safa Sand; WS/S= Wadi Al Safa Sand/Cemented Sand

Overall 43 22

H	DF	P	
1.00	3	0.801	
1.02	3	0.797	Adjusted for ties

Fagonia bruguieri

Location	N	Median	Ave Rank	Z
MS	10	6.5	16.9	0.18
MS/G	3	22.0	24.3	1.52
MS/G/R	1	106.0	31.0	1.57
MS/S	1	28.0	26.0	1.03
WS	10	2.5	13.2	-1.34
WS/G	3	6.0	16.7	0.03
WS/S	4	2.5	11.6	-1.11

MS=Mugatrah Sand; MS/G=Mugatrah Sand/Gravel; MS/G/R=Mugatrah Sand/Gravel/Rock; MS/S=Mugatrah Sand/Cemented Sand; WS= Wadi Al Safa Sand; WS/G= Wadi Al Safa Sand/Gravel; WS/S= Wadi Al Safa Sand/Cemented Sand

Overall 32 16.5

H	DF	P	
7.85	6	0.249	
7.95	6	0.242	Adjusted for ties

Gisekia pharnaceoides

Location	N	Median	Ave Rank	Z
MS	5	1	7.2	0.57
MS/G	3	1	5.0	-0.83
WS	4	1	6.8	0.17

MS=Mugatrah Sand; MS/G=Mugatrah Sand/Gravel; WS= Wadi Al Safa Sand;

Overall 12 6.5

H	DF	P	
0.73	2	0.695	
1.25	2	0.535	Adjusted for ties

Helianthemum lippii

Location	N	Median	Ave Rank	Z
MS	3	1.0	5.3	-1.01
MS/G	2	4.0	6.8	-0.27
MS/S	1	7.0	12.0	1.12
WS	4	5.0	8.6	0.64
WS/G	2	4.5	7.8	0.09
WS/S	2	4.0	6.8	-0.27

MS=Mugatrah Sand; MS/G=Mugatrah Sand/Gravel; MS/S=Mugatrah Sand/Cemented Sand; WS= Wadi Al Safa Sand; WS/G= Wadi Al Safa Sand/Gravel; WS/S= Wadi Al Safa Sand/Cemented Sand

Overall 14 7.5

H	DF	P	
2.39	5	0.793	
2.42	5	0.788	Adjusted for ties

Heliotropium kotschyi

Location	N	Median	Ave Rank	Z
MS	19	6.0	23.4	0.67
MS/G/R	1	62.0	43.0	1.69
MS/S	1	10.0	30.0	0.64
WS	16	3.5	19.5	-1.01
WS/G	2	5.5	23.5	0.17
WS/S	4	2.5	17.1	-0.82

MS=Mugatrah Sand; MS/G/R=Mugatrah Sand/Gravel/Rock; MS/S=Mugatrah Sand/Cemented Sand; WS= Wadi Al Safa Sand; WS/G= Wadi Al Safa Sand/Gravel; WS/S= Wadi Al Safa Sand/Cemented Sand

Overall 42 22.0

H	DF	P	
4.72	5	0.451	
4.78	5	0.443	Adjusted for ties

Indigofera intricata

Location	N	Median	Ave Rank	Z
MS	6	1	10.1	-0.63
MS/S	1	1	6.5	-0.79
WS	13	2	12.4	0.80
WS/G	1	6	18.0	1.02
WS/S	1	1	6.5	-0.79

MS=Mugatrah Sand; MS/S=Mugatrah Sand/Cemented Sand; WS= Wadi Al Safa Sand; WS/G= Wadi Al Safa Sand/Gravel; WS/S= Wadi Al Safa Sand/Cemented Sand

Overall 22 11.5

H	DF	P	
2.74	4	0.603	
3.27	4	0.513	Adjusted for ties

Launaea mucronata

Location	N	Median	Ave Rank	Z
MS	3	1	3	-0.65
MS/G	1	1	3	-0.29
WS	1	1	3	-0.29
WS/S	1	4	6	1.46

MS=Mugatrah Sand; MS/G=Mugatrah Sand/Gravel; WS= Wadi Al Safa Sand; WS/S= Wadi Al Safa Sand/Cemented Sand

Overall 6 3.5

H	DF	P	
2.14	3	0.543	
5.00	3	0.172	Adjusted for ties

Limeum arabicum

Location	N	Median	Ave Rank	Z
MS	11	2	7.3	0.69
MS/G/R	1	1	2.5	-1.20
WS	1	2	8.0	0.27

MS=Mugatrah Sand; MS/G/R=Mugatrah Sand/Gravel/Rock; WS= Wadi Al Safa Sand

Overall 13 7.0

H	DF	P	
1.47	2	0.478	
1.80	2	0.406	Adjusted for ties

Monsonia nivea

Location	N	Median	Ave Rank	Z
MS	9	11	11.6	-1.11
MS/G	3	43	15.8	0.42
MS/G/R	1	56	19.0	0.64
WS	10	13	13.6	-0.20
WS/G	1	112	22.0	1.03
WS/S	3	55	16.3	0.54

MS=Mugatrah Sand; MS/G=Mugatrah Sand/Gravel; WS= Wadi Al Safa Sand; WS/G= Wadi Al Safa Sand/Gravel; WS/S= Wadi Al Safa Sand/Cemented Sand

Overall 27 14

H	DF	P	
2.67	5	0.750	
2.72	5	0.743	Adjusted for ties

Panicum turgidum

Location	N	Median	Ave Rank	Z
MS	23	15.0	31.9	4.65
MS/G	2	9.5	24.0	0.11
MS/G/R	1	1.0	5.0	-1.39
WS	16	2.0	13.5	-3.59
WS/S	3	1.0	10.5	-1.71

MS=Mugatrah Sand; MS/G=Mugatrah Sand/Gravel; MS/G/R=Mugatrah Sand/Gravel/Rock; WS= Wadi Al Safa Sand; WS/S= Wadi Al Safa Sand/Cemented Sand

Overall 45 23.0

H	DF	P	
23.52	4	0.000	
23.97	4	0.000	Adjusted for ties

Pennisetum divisum

Location	N	Median	Ave Rank	Z
MS	22	15.0	20.6	3.02
MS/G	2	4.5	13.8	-0.49
MS/G/R	1	5.0	14.5	-0.26
WS	5	4.0	10.2	-1.71
WS/G	1	1.0	3.5	-1.42
WS/S	2	1.5	5.8	-1.70

MS=Mugatrah Sand; MS/G=Mugatrah Sand/Gravel; MS/G/R=Mugatrah Sand/Gravel/Rock; WS= Wadi Al Safa Sand; WS/G= Wadi Al Safa Sand/Gravel; WS/S= Wadi Al Safa Sand/Cemented Sand

Overall 33 17.0

H	DF	P	
10.46	5	0.063	
10.54	5	0.061	Adjusted for ties

Plantago ovata

Location	N	Median	Ave Rank	Z
WS	9	2	5.2	-1.65
WS/G	1	7	9.0	0.95
WS/S	1	12	10.0	1.26

WS= Wadi Al Safa Sand; WS/G= Wadi Al Safa Sand/Gravel; WS/S= Wadi Al Safa Sand/Cemented Sand

Overall 11 6.0

H	DF	P	
2.77	2	0.251	
2.83	2	0.243	Adjusted for ties

Polycarpaea repens

Location	N	Median	Ave Rank	Z
WS	26	20	16.3	-0.19
WS/G	1	53	27.0	1.14
WS/S	5	10	15.2	-0.34

WS= Wadi Al Safa Sand; WS/G= Wadi Al Safa Sand/Gravel; WS/S= Wadi Al Safa Sand/Cemented Sand

Overall 32 16.5

H	DF	P	
1.36	2	0.508	
1.36	2	0.507	Adjusted for ties

Stipagrostis plumosa

Location	N	Median	Ave Rank	Z
MS	22	5	22.3	-3.28
MS/G	1	28	39.5	0.35
MS/G/R	1	5	15.0	-0.96
MS/S	1	1	2.5	-1.63
WS	31	26	40.2	2.94
WS/G	3	41	48.7	1.47
WS/S	6	36	34.3	0.17

MS=Mugatrah Sand; MS/G=Mugatrah Sand/Gravel; MS/G/R=Mugatrah Sand/Gravel/Rock; MS/S=Mugatrah Sand/Cemented Sand; WS= Wadi Al Safa Sand; WS/G= Wadi Al Safa Sand/Gravel; WS/S= Wadi Al Safa Sand/Cemented Sand

Overall 62 33

H	DF	P	
17.35	6	0.008	
17.37	6	0.008	Adjusted for ties

Tetraena spp.

Location	N	Median	Ave Rank	Z
MS	4	6.0	10.9	-1.59
MS/G	2	163.0	20.3	0.17
MS/G/R	1	5.0	5.5	-1.26
MS/S	1	414.0	35.0	1.50
WS	22	103.5	18.0	-0.70
WS/G	3	805.0	27.7	1.45
WS/S	4	222.5	25.0	1.17

MS=Mugatrah Sand; MS/G=Mugatrah Sand/Gravel; MS/G/R=Mugatrah Sand/Gravel/Rock; MS/S=Mugatrah Sand/Cemented Sand; WS= Wadi Al Safa Sand; WS/G= Wadi Al Safa Sand/Gravel; WS/S= Wadi Al Safa Sand/Cemented Sand

Overall 37 19

H	DF	P	
9.37	6	0.154	
9.37	6	0.154	Adjusted for ties

Tribulus spp.

Location	N	Median	Ave Rank	Z
MS	26	36.5	46.3	3.00
MS/G	3	25.0	45.5	0.76
MS/G/R	1	8.0	23.5	-0.63
MS/S	1	1.0	3.0	-1.61
WS	32	12.0	30.3	-2.26
WS/G	3	6.0	31.0	-0.46
WS/S	6	9.5	33.1	-0.42

Overall 72 36.5

H	DF	P	
12.46	6	0.052	
12.48	6	0.052	Adjusted for ties

Kruskal-Wallis test for each species against site and substrate type of gravel.

Table 4-46. Species found on the gravel substrate which were either tested (Kruskal-Wallis non-parametric statistical test), not tested due to either there been not enough data or only found on one substrate type with links to the results.

Species	KW Test	Not enough data	Only one substrate
Aerva javanica		✓	
Anabasis setifera		✓	
Arnebia hispidissima	✓		
Atractylis carduus		✓	
Calligonum comosum		✓	
Coelachyrum piercii		✓	
Cornulaca monacantha	✓		
Dipterygium glaucum	✓		
Eragrostis barrelieri	✓		
Fagonia bruguieri	✓		
Gisekia pharnaceoides		✓	
Helianthemum lippii	✓		
Heliotropium digynum		✓	
Heliotropium kotschyi	✓		
Indigofera colutea		✓	
Indigofera intricata		✓	
Launaea capitata		✓	
Launaea mucronata		✓	
Leptadenia pyrotechnica		✓	
Limeum arabicum		✓	
Moltkiopsis ciliata		✓	
Monsonia nivea	✓		
Neurada procumbens	✓		
Panicum turgidum	✓		
Pennisetum divisum	✓		
Plantago ciliata		✓	
Plantago ovata		✓	
Polycarpaea repens		✓	
Prosopis cineraria		✓	
Savignya parviflora	✓		
Stipagrostis plumosa	✓		
Tetraena spp.	✓		
Tribulus spp.	✓		

Arnebia hispidissima

Location	N	Median	Ave Rank	Z
MG	14	127	21.6	4.06
MG/S	5	24	12.9	-0.61
WG	6	19	8.0	-2.26
WG/S	3	2	5.3	-2.08
WG/Sab	1	2	3.5	-1.37

MG=Mugatrah Gravel; MG/S=Mugatrah Gravel/Sand; WG= Wadi Al Safa Gravel; WG/S= Wadi Al Safa Gravel/Sand; WG/Sab= Wadi Al Safa Gravel/Cemented Sand

Overall 29 15

H	DF	P	
18.54	3	0.000	
18.59	3	0.000	Adjusted for ties

Cornulaca monacantha

Location	N	Median	Ave Rank	Z
MG	4	1.5	3.8	-0.35
MG/S	3	5.0	4.3	0.35

MG=Mugatrah Gravel; MG/S=Mugatrah Gravel/ Sand;

Overall 7 4

H	DF	P	
0.12	1	0.724	
0.13	1	0.714	Adjusted for ties

Dipterygium glaucum

Location	N	Median	Ave Rank	Z
MG	4	2.5	3.5	-0.71
MG/S	3	4.0	4.7	0.71

MG=Mugatrah Gravel; MG/S=Mugatrah Gravel/ Sand;

Overall 7 4

H	DF	P	
0.50	1	0.480	
0.58	1	0.445	Adjusted for ties

Eragrostis barrelieri

Location	N	Median	Ave Rank	Z
MG	2	2.5	3.3	-0.23
MG/S	4	2.5	3.6	0.23

MG=Mugatrah Gravel; MG/S=Mugatrah Gravel/ Sand;

Overall 6 3.5

H	DF	P	
0.05	1	0.817	
0.06	1	0.803	Adjusted for ties

Fagonia bruguieri

Location	N	Median	Ave Rank	Z
MG	13	103.0	16.8	1.36
MG/S	5	163.0	23.0	2.55
WG	6	19.5	8.5	-2.02
WG/S	3	7.0	7.0	-1.67
WG/Sab	1	2.0	1.0	-1.67

MG=Mugatrah Gravel; MG/S=Mugatrah Gravel/Sand; WG= Wadi Al Safa Gravel; WG/S= Wadi Al Safa Gravel/Sand; WG/Sab=Wadi Al Safa Gravel/Cemented Sand

Overall 28 14.5

H	DF	P	
14.71	4	0.005	
14.72	4	0.005	Adjusted for ties

Helianthemum lippii

Location	N	Median	Ave Rank	Z
MG	11	16.0	13.0	0.35
MG/S	3	3.0	10.8	-0.44
WG	6	27.5	13.8	0.53
WG/S	4	9.5	10.3	-0.70

MG=Mugatrah Gravel; MG/S=Mugatrah Gravel/Sand; WG= Wadi Al Safa Gravel; WG/S= Wadi Al Safa Gravel/Sand;

Overall 24 12.5

H	DF	P	
0.85	3	0.837	
0.85	3	0.836	Adjusted for ties

Heliotropium kotschyi

Location	N	Median	Ave Rank	Z
MG	3	3	6.0	0.00
MG/S	3	14	10.0	2.45
WG	2	3	5.3	-0.35
WG/S	3	1	2.5	-2.14

MG=Mugatrah Gravel; MG/S=Mugatrah Gravel/Sand; WG= Wadi Al Safa Gravel; WG/S= Wadi Al Safa Gravel/Sand;

Overall 11 6

H	DF	P	
7.81	3	0.050	
8.18	3	0.042	Adjusted for ties

Monsonia nivea

Location	N	Median	Ave Rank	Z
MG	14	152	17.9	1.77
MG/S	5	170	14.2	-0.23
WG	6	71	11.3	-1.21
WG/S	3	3	11.0	-0.86
WG/Sab	1	69	13.0	-0.24

MG=Mugatrah Gravel; MG/S=Mugatrah Gravel/Sand; WG= Wadi Al Safa Gravel; WG/S= Wadi Al Safa Gravel/Sand; WG/Sab=Wadi Al Safa Gravel/Cemented Sand

Overall 29 15.0

H	DF	P	
3.54	4	0.472	
3.54	4	0.471	Adjusted for ties

Neurada procumbens

Location	N	Median	Ave Rank	Z
MG	4	8.5	5	1.41
WG	1	1.0	2	-1.00
WG/S	2	1.5	3	-0.77

MG=Mugatrah Gravel; WG= Wadi Al Safa Gravel; WG/S= Wadi Al Safa Gravel/Sand;

Overall 7 4.0

H	DF	P	
2.14	2	0.343	
2.31	2	0.315	Adjusted for ties

Panicum turgidum

Location	N	Median	Ave Rank	Z
MG	5	3	7.3	0.22
MG/S	5	6	8.4	1.02
WG	1	1	3.0	-1.07
WG/S	1	1	3.0	-1.07
WG/Sab	1	2	6.5	-0.13

MG=Mugatrah Gravel; MG/S=Mugatrah Gravel/Sand; WG= Wadi Al Safa Gravel; WG/S= Wadi Al Safa Gravel/Sand; WG/Sab=Wadi Al Safa Gravel/Cemented Sand

Overall 13 7.0

H	DF	P	
2.80	4	0.591	
2.97	4	0.562	Adjusted for ties

Pennisetum divisum

Location	N	Median	Ave Rank	Z
MG	4	4.5	5.5	0.00
MG/S	4	5.5	6.5	0.85
WG	1	2.0	2.5	-1.04
WG/S	1	3.0	4.5	-0.35

Overall 10 5.5

H	DF	P	
1.53	3	0.676	
1.56	3	0.670	Adjusted for ties

Savignya parviflora

Location	N	Median	Ave Rank	Z
MG	6	3.5	5.2	0.26
MG/S	1	3.0	4.0	-0.39
WG	2	7.5	5.0	0.00

MG=Mugatrah Gravel; MG/S=Mugatrah Gravel/Sand; WG= Wadi Al Safa Gravel

Overall 9 5.0

H	DF	P	
0.16	2	0.925	
0.16	2	0.923	Adjusted for ties

Stipagrostis plumosa

Location	N	Median	Ave Rank	Z
MG	12	12.5	12.3	-0.14
MG/S	5	23.0	16.0	1.24
WG	5	2.0	6.6	-2.10
WG/S	1	17.0	15.5	0.43
WG/Sab	1	354.0	24.0	1.66

MG=Mugatrah Gravel; MG/S=Mugatrah Gravel/Sand; WG= Wadi Al Safa Gravel; WG/S= Wadi Al Safa Gravel/Sand; WG/Sab=Wadi Al Safa Gravel/Cemented Sand

Overall 24 12.5

H	DF	P	
7.54	4	0.110	
7.57	4	0.109	Adjusted for ties

Tetraena spp.

Location	N	Median	Ave Rank	Z
MG	14	299.5	16.6	0.62
MG/S	5	39.0	6.0	-2.64
WG	7	302.0	18.0	0.86
WG/S	3	277.0	17.0	0.31
WG/Sab	1	506.0	26.0	1.21

MG=Mugatrah Gravel; MG/S=Mugatrah Gravel/Sand; WG= Wadi Al Safa Gravel; WG/S= Wadi Al Safa Gravel/Sand; WG/Sab=Wadi Al Safa Gravel/Cemented Sand

Overall 30 15.5

H	DF	P	
8.10	4	0.088	

Tribulus spp.

Location	N	Median	Ave Rank	Z
MG	11	5.0	7.2	-3.09
MG/S	5	20.0	14.6	1.21
WG	4	25.5	15.4	1.32
WG/S	1	72.0	17.0	0.87
WG/Sab	1	182.0	22.0	1.66

MG=Mugatrah Gravel; MG/S=Mugatrah Gravel/Sand; WG= Wadi Al Safa Gravel; WG/S= Wadi Al Safa Gravel/Sand; WG/Sab=Wadi Al Safa Gravel/Cemented Sand

Overall 22 11.5

H	DF	P	
10.66	4	0.031	
10.72	4	0.030	Adjusted for ties

APPENDIX 4-6 – SPECIES DESCRIPTIONS

Table 4-47. List of species identified during the study. Details from Jongbloed et al. (2003) and Karim, F. M. & Dakheel, A. J. (2006)

Family	Species	Common Name	Description	Habitat	Distribution	Height
Aizoaceae	*Sesuvium verrucosum*	Sea-purslane	Perennial, spreading stems from base, up to 30 cm	Saline sand	Coastal in the Northern Emirates	30 cm
Amaranthaceae	*Aerva javanica*	Desert cotton	Perennial straggly bush up to 100 cm	Sand on roadsides, disturbed sites silt on alluvial plains	Common and widespread	100 cm
	Anabasis setifera	Hamd al arnab	Perennial, stems much branched, up to 50 cm	Coastal sand	Common on coastal areas	50 cm
	Cornulaca monacantha	Had	Perennial, erect, much branched up to 80 cm	Coastal and inland saline sand	Common in coastal areas.	80 cm
	Haloxylon salicornicum	Remith, hamd	Perennial, woody up to 100 cm in height	Gravel and Sand plains	Common and widespread	100 cm
Apocynaceae	*Calotropis procera*	Sodom's Apple	Perennial, shrub or small tree up to 250-500 cm	Sandy plains and low dunes. Gravel lower wadis	Common and widespread	250-500 cm
	Leptadenia pyrotechnica	Marakh	Perennial, stems branching, erect up to 250-300 cm.	Sandy plains and low dunes.	Common and widespread in the Northern Emirates	250-300 cm
Asteraceae	*Atractylis carduus*	White Thistle	Perennial or annual, stems erect up to 15 cm	Sand and gravel plains, limestone hills	Locally common and widespread.	15 cm
	Launaea capitata	Huwa, hazan	Annual or biennial, very flat on the ground	Stable sand between low dunes	Common and widespread in the Northern Emirates	1-5 cm
	Launaea mucronata	Huwa ghazal	Perennial, stems branching, erect up to 80 cm	Sand., disturbed roadsides	Common and widespread in the Northern Emirates	80 cm

Table 4-47. List of species identified during the study (*Continued*)

Family	Species	Common Name	Description	Habitat	Distribution	Height
Boraginaceae	*Arnebia hispidissima*	Arabian primrose	Annual, sometimes biennial. Stem stiff, erect up to 20 cm	Sand plains between low dunes	Common and widespread	20 cm
	Heliotropium digynum		Perennial, woody up to 40-60 cm in height	Sand between dunes, sandy plains	Common and widespread	40-60 cm
	Heliotropium kotschyi	Ramram	Perennial, woody up to 60 cm in height	Sand and gravel	Common and widespread along coasts	60 cm
	Moltkiopsis ciliata	Ghabshah, halam	Perennial, woody base, stems much branched, erect up to 25 cm	Sand, tolerates saline conditions	Common and widespread	25 cm
Brassicaceae	*Savignya parviflora*	Jaljalan	Annual, stems slender branched from base, erect up to 20-35 cm	Sand and gravel plains	Common after rains	20-35 cm
Caryophyllaceae	*Polycarpaea repens*	Kameela	Perennial, woody base or spreading, up to 30 cm	Stable sand between dunes, gravel	Locally common.	30 cm
Cistaceae	*Helianthemum lippii*	Ragroug	Perennial, woody up to 30 cm in height	Sand, silt of inland gravel plains	Common along the Arabian Gulf coast	30 cm
Cleomaceae	*Cleome sp.*		Annual to perennial erect and up to 50 cm	Sand, gravel plains		50 cm
	Dipterygium glaucum	Alqa	Perennial. Slender stems up to 80 cm	Sand	Common and widespread in the sandy desert.	80 cm
Cyperaceae	*Cyperus conglomeratus*	Thanda	Perennial. Stem and leaves up to 50 cm	Sand. Quickly colonises disturbed ground. Drought resistant	Common and widespread.	50 cm
Euphorbiaceae	*Chrozophora oblongifolia*	Tannoon	Perennial, woody base stems much branched erect, up to 80 cm	Gravel plains	Common and widespread in Hajar Mountains	80 m

APPENDIX 4-7

Table 4-47. List of species identified during the study (*Continued*).

Family	Species	Common Name	Description	Habitat	Distribution	Height
Fabaceae	*Indigofera colutea*		Perennial, woody, spreading, up to 50 cm in height	Sand plains	Locally common	50 cm
	Indigofera intricata	Humeira	Perennial, woody, spreading, up to 70 cm in height	Sand plains	Common and widespread between Abu Dhabi, Al Ain and Sharjah	70 cm
	Prosopis cineraria	Ghaf	tree up to 10-25 m	Sand plains, dunes and wadi banks	Common and widespread	10-25 m
Geraniaceae	*Monsonia nivea*	Dahma	Perennial, silver-grey, woody base, erect or spreading up to 30 cm	Sand plains between dunes	Common and widespread	30 cm
Molluginaceae	*Gisekia pharnaceoides*	Dedam	Annual with slender stems up to 20 cm	Sand plains between low dunes	Not common. Recorded in sandy deserts of Northern Emirates	20 cm
	Limeum arabicum		Perennial, stems intricately tangled, erect up to 80 cm	Low sand dunes	Locally common	80 cm
Neuradaceae	*Neurada procumbens*	Creeping-thorn Rose	Annual stems, prostrate or spreading up to 20 cm	Sand plains	Common and widespread	20 cm
Plantaginaceae	*Plantago ciliata*	Rabla	Annual, virtually no stem up to 5 cm high	Stable sand, low hills	Locally common and widespread.	5 cm
	Plantago ovata	Rubla	Annual, virtually no stem up to 10 cm high	Sand, mountains	Locally common on sandy plains	10 cm
Poaceae	*Aristida abnormis*		Annual, erect up to 40 cm	Sand, salt flats along the Arabian Gulf coast	Not common, but widespread in coastal areas.	40 cm
	Coelachyrum piercii	Deqana	Perennial erect up to 45 cm forming tussocks	Sand	Locally common and widespread.	45 cm
	Eragrostis barrelieri	Annual lovegrass	Annual, up to 5-50 cm	Sand, plantations, gardens	Common and widespread along the Arabian Gulf coast	5-50 cm

Table 4-47. List of species identified during the study (*Continued*).

Family	Species	Common Name	Description	Habitat	Distribution	Height
Poaceae	*Panicum turgidum*	Thumam	Perennial, woody rooting parts, erect up to 100 cm or more	Sand, gravel	Common and widespread	100 cm
	Pennisetum divisum	Sabth	Perennial, woody rooting parts, erect up to 150 cm, much branched at angles at nodes	Sand	Common and widespread	150 cm
	Stipagrostis plumosa	Nassi	Perennial, tufted, tubular roots	up to 40-60 cm	Sand, gravel	20 cm
	Tragus racemosus		Annual, tufted and spreading, up to 30 cm	Plantations, gardens	Not common but widespread along Arabian Gulf coast	30 cm
Polygonaceae	*Calligonum comosum*	Arta	Perennial, woody base, stems branched and erect up to 150 - 200 cm	Sand plains between, roadsides	Common and widespread in sand dunes and plains.	150-200 cm
Zygophyllaceae	*Fagonia bruguieri*	Dereima	Perennial woody base up to 40 cm	Sand, gravel plains	Common in the Hajar Mountains and adjacent plains	40 cm
	Tetraena spp.	Zygophyllum	Perennial, up to 80 cm	Sandy plains between low dunes	Common and widespread	80 cm
	Tribulus spp.	Tribulus	Annual to biennial, prostrate to spreading up to 40 cm	Sand, compacted sand	Locally common	40 cm

APPENDIX 4-8 – VEGETATION SURVEY LOG

Appendix VII

Vegetation Survey Log (Rev 3)

Date _____ Location _____ _____

Burrow # _____ Heading _____ GPS _____

Tracks @ Burrow YES / NO Tracks @ Survey YES / NO

Notes _____

_____

Substrate

Sand (S)		Gravel (G)		Sabkha (Sk)		Other		Mix	
	%		%		%		%		%

	Species	Count (A/D)	% Cover	Pic #
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

If mixed substrate include the % of each type and tick mix; Count (A/D) A = Alive and D = Dead
Prec/Est = Precise or estimated count?

Appendix VII

Vegetation Survey Log (Rev 3)

Notes and Tallies

1		11	
2		12	
3		13	
4		14	
5		15	
6		16	
7		17	
8		18	
9		19	
10		20	

If mixed substrate include the % of each type and tick mix; Count (A/D) A = Alive and D = Dead
Prec/Est = Precise or estimated count?

CHAPTER 5: VITAMIN D

5.1 INTRODUCTION

Vitamin D (also referred to as calciferol) is a fat-soluble vitamin that is naturally present in very few foods. There are two main forms, vitamin D_2 and vitamin D_3. Most of the Vitamin D metabolism pathways have been developed through rat/chick models as there is a paucity of data on the normal circulating levels of vitamin D metabolites in birds, mammals, and reptiles under normal conditions (Horst et al, 2005).

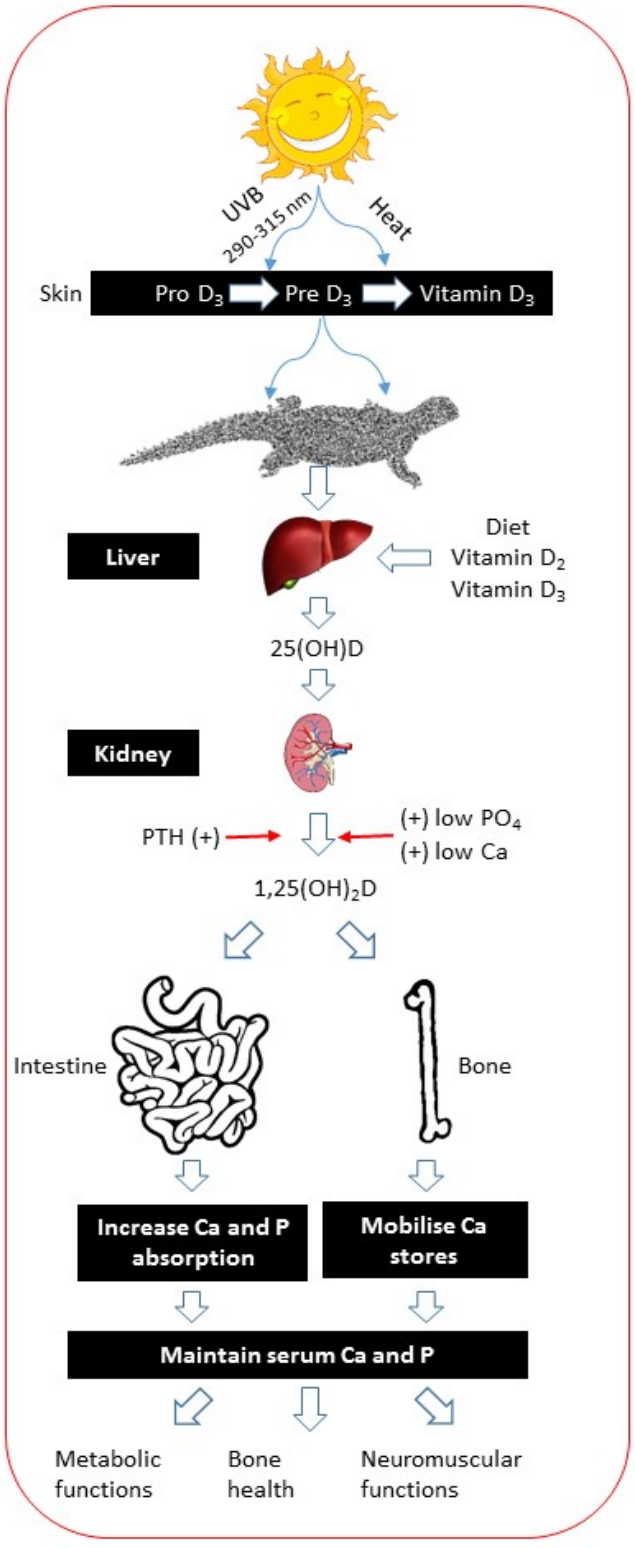


Figure 5-1. Vitamin D synthesis and metabolic pathway.

For humans, vitamin D is mainly produced endogenously when UVB (290-315 nm) from the sun hits the skin and triggers the thermal isomerisation of 7-dehydrocholesterol (7-DHC) (Chen *et al*, 2007; National Institue of Health, 2016). The resultant previtamin D_3 requires heat to convert it to vitamin D_3, with the whole process being a function of the amount of UVB exposure and temperature availability (see Figure 5-1 for dhub vitamin D metabolism). Exogenous sources are also available from

items such as oily fish, fish liver oil, egg yolk and through supplementation. In humans, toxic levels of vitamin D_3 are avoided due to the production of many non-vitamin D forms such as lumisterol, tachysterol, suprasterol etc. (Hollis, 2005) together with the associated feedback loops.

The biologically inert form of vitamin D undergoes two hydroxylations, firstly in the liver where vitamin D is converted to 25-hydroxyvitamin D [25(OH)D] also known as calcidiol (Lips, 2007; National Institue of Health, 2016) and secondly in the kidney where 25(OH)D is converted to the physiologically active form 1,25-dihydroxyvitamin D [$1,25(OH)_2D$] (calcitriol) (Institute of Medicine, 2011; Holick, 2012). Calcitriol is generally believed to enter target cells by diffusion and then to interact with a cytoplasmic/nuclear vitamin D receptor (VDR) protein where it modifies the transcriptional activity of the target genes. Laing & Fraser (1999) suggest that iguanian lizards possess a vitamin D endocrine system that is physiologically similar to that of birds and mammals, with the Vitamin D binding protein (DBP) closer aligned to that of birds than mammals.

The major circulating metabolite is 25(OH)D, which refers to both 25-hydroxyergocalciferol (25-OH-D_2) and 25-hydroxycholecalciferol (25-0H-D_3) components, and is usually bound to vitamin D binding protein (DBP) (Zella *et al*, 2008). This reflects the sum of vitamin D from diet and photobiogenesis over a period of several weeks or months. When the circulating 25(OH)D is required for the production of calcitriol (in the event of reduced calcium [Ca] or phosphorous [P] levels), the active metabolite, $1,25(OH)_2D$, which is responsible for most actions of vitamin D (Lips, 2007) is produced in the kidney and is closely controlled by serum Ca and P levels through the parathyroid hormone (PTH). However, the hydroxylation to $1,25(OH)_2D$ is often restricted by kidney disease or a decrease of renal function, as occurs with aging. The serum concentration of 25(OH)D is almost 100 times that of $1,25(OH)_2D$ and has a much longer half-life (15 days). 25(OH)D also represents all vitamin D produced cutaneously and from food and supplements. As such the serum concentration of 25(OH)D is used in the measurement of reference intervals for vitamin D (Bouillon *et al*, 1998; Lips, 2007; National Institue of Health, 2016) and is a combination of $25(OH)D_2$ and $25(OH)D_3$. However, it does not give an indication of vitamin D stored in body tissues.

5.1.1 VITAMIN D AND CALCIUM

While the actions of vitamin D are now recognised as being wide and varied (Institute of Medicine, 2011), it is primarily linked to calcium absorption and in the maintenance of serum Ca and P levels, ensuring the correct mineralisation of bone and bone growth. More recently, vitamin D has been linked to other roles within the body such as the control of cell growth, neuromuscular and immune function and some cells have also been found to have vitamin D receptors (VDR) allowing them convert the circulating 25(OH)D to $1,25(OH)_2D$ (Holick, 2007; Holick & Chen, 2008; 2012; National Institue of

Health, 2016).



Figure 5-2. Uromastyx shortly after emerging from burrow. Note the dark colour which could be a method designed to increase heat absorption.

Heaney *et al* (2003) suggest that the exact level of vitamin D required to normalise absorption of Ca is not known. Low levels of 25(OH)D have led to a number of ways to describe vitamin D status and include "vitamin D insufficiency," "vitamin D inadequacy," or "hypovitaminosis D" (Binkley *et al*, 2007). Low vitamin D status has been linked to a number of conditions in humans (Binkley *et al*, 2004; Lips, 2007; Melamed *et al*, 2008; Roizen *et al*, 2013; National Institue of Health, 2016) usually causing impairment of skeletal mineralisation, resulting in rickets and osteomalacia in children or osteomalacia alone in adults. However, less severe degrees of vitamin D insufficiency contribute to bone loss without necessarily impairing bone mineralisation. Specifically, vitamin D inadequacy leads to Ca malabsorption with can result in secondary hyperparathyroidism leading, over time, to bone loss and osteoporosis (Binkley *et al*, 2004). Similar descriptions exist with reptiles and in non-human animals 25(OH)D insufficiency is primarily associated with metabolic bone disease (MBD) (Raphael *et al*, 1999; Ferguson *et al*, 2003; Hetenyi *et al*, 2015) but also reproduction and immune function (Burger *et al*, 2007; Acierno *et al*, 2008; Hetenyi *et al*, 2015; Holick, 2016). In the quest to determine the correct level of 25(OH)D, little emphasis has been put on the upper limit or vitamin D intoxication (Institute of Medicine, 2011) which invariably has been based on short term studies. National Institue of Health (2016) suggest that, based on the works that they have studied, serum 25(OH)D from 125 to 150 nmol/L should be avoided. Yet, some authors have documented limits exceeding this for reptiles (Nijboer *et al*, 2001) while others give values of 243 nmol/L vitamin D_3 (Gillespie *et al*, 2000) for Komodo dragons (*Varanus komodoensis*) and 211 nmol/L for chuckwalla (*Sauromalus obesus*) (Aucone *et al*, 2003).

5.1.2 BLOOD REFERENCE INTERVALS (RI) FOR VITAMIN D

As with blood reference intervals (RI), the RI for vitamin D varies between laboratories and with other extrinsic variables (Hollis, 2005; Lips, 2007; Heijboer et al, 2012; Cashman et al, 2016) and there is a risk of over supplementation of vitamin D to achieve the "correct" serum 25(OH)D level. In their

studies van der Mei et al (2007) and Kull et al (2009) put their lower limits signifying insufficiency at ≤ 50 nmol/L. However, Hollis (2005) report the level of vitamin D insufficiency at ≤ 80nmol/L while Roizen et al (2013) suggest the lower limit for humans to be at 75 nmol/L. Cashman et al (2016) state the insufficiency band at between <25 to <75 nmol/L. Some authors suggest that the optimum level for humans be set at 125 nmol/l in the US (Binkley et al, 2007), while Melamed et al (2008) suggest the optimal level should be 75 nmol/L. Interestingly, Luxwolda et al (2012) found that Masai herders who had continuous exposure to the sun had mean circulating levels of 25(OH)D of 115 nmol/L. These various cut off points suggest that there is little consensus on optimal levels of 25(OH)D (Holick 2007; Hansen et al, 2008) in humans, let alone non-human animals. This has led to the question: How much is too much? (Institute of Medicine, 2011). National Institue of Health (2016) suggest that, with respect to humans, hypervitaminosis D can lead to hypercalcemia and eventually to soft tissue calcification and resultant renal and cardiovascular damage. The same debate has not occurred in the veterinary literature, with regards upper and lower limits of vitamin D in reptiles, as equivalent research has not yet been undertaken. As such, in the current study the values for human medicine will be tentatively used to assess sufficiency and insufficiency.

5.1.3 HEALTH PROBLEMS ASSOCIATED WITH VITAMIN D

A common health problem with captive reptiles is metabolic bone disease (MBD). This complex of diseases which includes, nutritional secondary hyperparathyroidism (NSHP) (reported as a problem in captive held tuatara, *Sphenodon* sp. (Burgess *et al*, 2009)) as a result of hypocalcaemia which can lead to hypotension, dysrhythmias, gastrointestinal dysfunction, seizures, tetany, dystocia (difficulty giving birth for viviparous species), and egg-binding.

5.1.4 ABSORPTION OF VITAMIN D IN REPTILES

The ability of different reptiles to absorb dietary vitamin D is highly variable, with herbivorous and omnivorous reptiles typically having a poor ability to do so (Mitchell & Tully Jr, 2008). In captive environments UV is boosted through the use of specialised lights (see Figure 5-3).

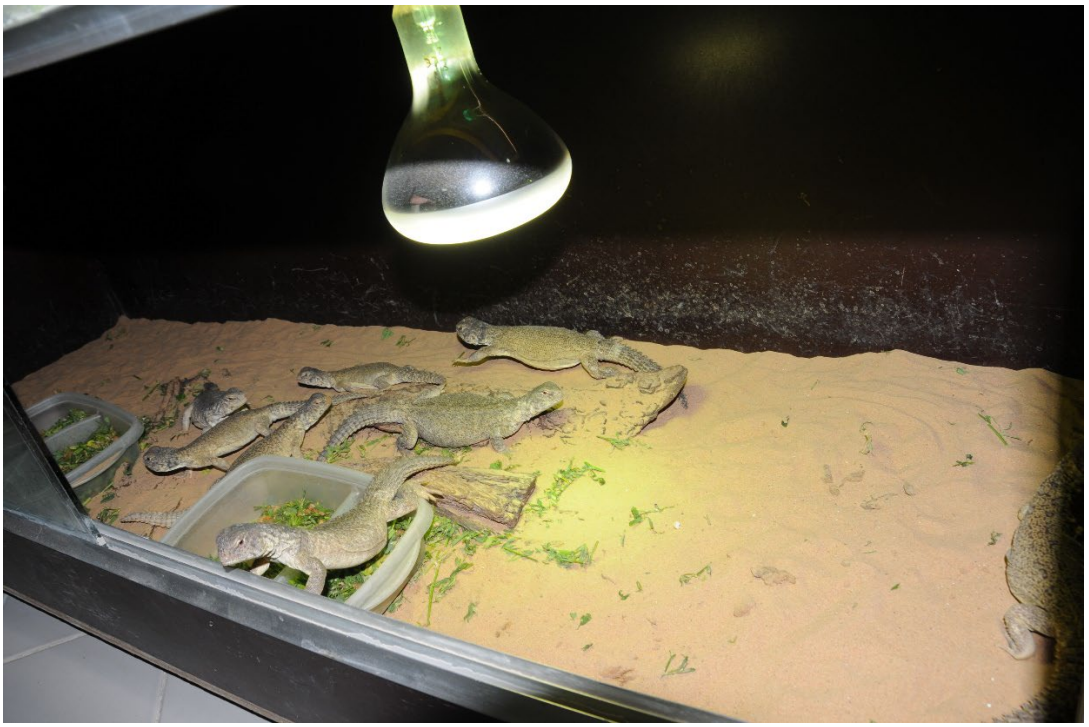


Figure 5-3. Captive juvenile *Uromastyx aegyptia leptieni* demonstrating the proximity of the UV bulb to the animals.

The importance of dietary and UVB mediated endogenous synthesis of vitamin D, and as such vitamin D metabolism, appears to differ between reptile species (Oonincx *et al*, 2013) (see Figure 5-2). It is generally argued that diurnal desert species, such as *Uromastyx*, would have a competitive advantage over other reptile species with regard to the vitamin D production (see Figure 5-4).

Carman *et al* (2000) showed that a species of house gecko had a much greater capacity to produce vitamin D_3 than the Texas spiny lizard. They argued that this may be an adaptation allowing the gecko maximise its limited exposure to UVB. Raphael *et al* (1999) are the only authors found in the literature to have looked at the vitamin D status in two *Uromastyx* species, *Uromastyx aegyptia* (dhub) (n=14) and *Uromastyx ornata* (ornate mastigure) (n=8) where they found that concentrations of 25(OH)D (12.5 – 107.3 nmol/L) were lower than other herbivorous lizards.

5.1.5 THE UV INDEX (UVI)

Miyauchi & Nakajima (2016) have shown how the UV Index (UVI) is widely used as a measure of UV risk and suggest that knowledge of harmful UV levels that pose a risk to health can be used to provide immediate estimates of the amount of beneficial UV exposure needed to produce vitamin D in humans. Similarly, the UVI is also used as an indicator of the 4 Ferguson Zones (Baines *et al*, 2016) which are based upon UVB measurement. These are the mean voluntary UVI exposures for a particular species of reptile based on recordings in their natural habitat. While outside the scope of this particular part of the study, they are introduced here for reference purposes (APPENDIX 5-3, Table

5-30).



Figure 5-4. Juvenile *Uromastyx* basking on rock (left) slightly darker and adult (right) with mouth open and body slightly raised from rock to aid cooling.

According to the IUCN guidelines for reintroduction and translocations, (IUCN/SSC, 2013) a necessary prerequisite for any translocation will include a comprehensive health check. Part of the translocation or management of the translocation animals will more often than not require them to be housed/kept in a captive situation for some time prior to their release as Barcello & Tourenq (2005) reported. While in captivity it is paramount that the animals are held under optimum conditions, and this will include measures to maintain the animals' vitamin D status at a condition similar to its wild state. As part of this health study, a collaborative research project was started with the School of Food & Nutritional Sciences in UCC to look at Vitamin D_3 levels in dhub. These results are presented within the report.

As the "normal" vitamin D state is not known for dhub and many other squamate species, related to the potential translocation of the species from anthropogenically threatened locations, the objective of the current study was to determine the circulating levels of 25(OH)D_3 in wild dhub. The influence of the time of the year was investigated to determine any seasonality ("season") as well as differences between males and females. From these data, RIs for the species which would act as the "standard" for *U. a. leptieni* would be reported. Other metabolites such as calcium, ionised calcium and phosphorous are reported here in a general form as well. Reference intervals for these are available in APPENDIX 5-1, while comparisons to other authors, where found in the literature, are presented in APPENDIX 5-2.

5.2 MATERIAL AND METHODS

5.2.1 UV INDEX

Data relating to ultraviolet radiation was recorded in the form of a UV (see Chapter 3 Appendix 3.2) (Solarmeter 6.2 Sensitive UVB Meter in μWcm^2, Solartech, Inc., Harrison Township, MI). These data were collected every hour from 05:30 through to 19:30 on a daily basis from September 2015 through to November 2016 with extra data collected in February and March 2017 to determine if the direction the meter was held towards the sun affected the UVB values recorded. As these were handheld units, two assistants were renumerated for the data collection and funding did not allow for the continual data collection.

5.2.2 DETERMINATION OF SEASON

Although there is no data to suggest definitive seasons within the UAE, the current study took seasons to be as per Table 5-1.

Table 5-1. Seasonal breakdown used throughout the study.

Survey Period	Dates
Spring	1st Feb to 30th Apr
Summer	1st May to 31st Jul
Autumn	1st Aug to 31st Oct
Winter	1st Nov to 31st Jan

5.2.3 UV MEASUREMENT

Environmental data were collected using a Vantage Pro2 weather station (Davis Instruments, US) with the recording interval set to 30 minutes (Table 5-2). These weather station data were collected from January 2013 through to December 2018.

Table 5-2. Davis Instruments declared accuracy for the Vantage Pro2 weather station.

Data Collected	Company accuracy
Temperature (°C)	± 0.3 °C
Humidity (%)	± 2%
Solar Radiation (W/m^2)	± 5% of full scale (0 to 1800 W/m^2)
*Ultra Violet Index	± 5% of full scale
Wind Direction (1 – 360°)	± 3°
Wind Speed (Km/h)	± 3.2 Km/h
Rainfall (0.2 mm)	For rain rates up to 100 mm/hr ±4% of total

**UV Index has been defined by Canadian scientists in 1992 and subsequently adopted by the World Health Organisation which measures the UV levels at the surface of the Earth. This gives a more easily remembered set of units, ranging from 1 to 15 and the potential of skin damage from the sun.*

Spectral irradiances for ultraviolet B light ($\mu W/cm^2$) were measured using a Solarmeter Model 6.2

ultraviolet B light meter (Solartech Inc, Harrison Township MI, USA), which has a wavelength band of 280–320 nm for ultraviolet B light at one site, WAS.

5.2.4 SAMPLES FOR VITAMIN D3 ANALYSIS

All sample collection and processing were completed as per the blood sampling protocol in APPENDIX 5-6. All animals were captured as per the capture and translocation part of this study (see Chapter 6).

Samples were collected from 185 adult *Uromastyx aegyptia leptieni* in the UAE in two seasons during the period of September and October 2015 and March (Autumn) and April 2016 (Spring) (Figure 5-5). Samples from six unknown sexed captive animals (three each from two different facilities) were also collected for comparative purposes. Of these dhub, Shj (Figure 5-3), and AA were housed under artificial lights and fed a captive diet of green vegetable matter and seeds.

Table 5-3. Number of individuals (not including repeat animals) per sex, season, and site where dhub were sampled.

		2015		2016	
Site	Sex	# of Samples	Mean Weight	# of Samples	Mean Weight
MUG	Female	13	702.00	15	705.73
WAS		18	805.31	37	786.52
AA		Not Sampled		1	176.0
Shj				2	502.5
MUG	Male	11	1333.82	15	1450.79
WAS		29	1219.86	27	1296.04
AA		Not Sampled		2	NR
Shj				1	300

The weight (g) and length (cm) (snout to end of tail) were recorded for each animal prior to blood draw. 3 to 4 ml of blood (Figure 5-5) were collected from the ventral coccygeal vein, depending on the weight of the animal, using a 5 ml disposable plastic syringe and a 23 G needle. A safe volume would



Figure 5-5. Procedures involved in the blood draw from the ventral coccygeal vein, preparation of the blood smear to decanting the plasma post centrifugation into the 0.5 ml cryovials prior to freezing.

be 10% of total blood volume in a healthy reptile with blood volume equating to around 5–8% of body weight. Taking the smallest animal would be at least 450gr, it was safe to remove up to 4 ml of blood. 0.75 ml was transferred into a 1 ml paediatric lithium heparin tube and the rest was transferred into a 4 ml lithium heparin tube (Mini collect, Greiner, Austria). Fresh blood smears were directly prepared to study the morphology of blood parasites and differential WBC as per Dubai Falcon Hospital procedures.

All blood samples were processed as soon after collection as possible and no longer than five hours post collection. For the Vit D_3 study, cells were removed from plasma by centrifugation for 7 minutes at 5,000 rpm using a NF 200 Santrifuj (Nuve Sanayi, Turkey) bench top centrifuge. The plasma, if it had not been analysed immediately, was transferred as 0.5 ml aliquots into 1.0 ml cryovial tubes using a Pasteur pipette. These were stored and transported at –20 °C or lower. The remaining plasma which was used for the biochemical analysis was kept refrigerated at 4 °C. Haemoglobin and haematocrit values were determined on site as soon after collection as possible with an EKF Diagnostics Hemo Vet Blood Analyser, EKF Diagnostic, GmbH, Germany.

As most errors in a clinical chemistry laboratory are due to preanalytical errors, controlling these variables is fundamental to reducing errors in later analyses (Simundic & Lippi, 2012; Ellervik &

Vaught, 2015). As such, the blood slide and 0.75 ml of whole blood was transferred to the Dubai Falcon Hospital for processing within 18 hours post collection thereby avoiding freeze-thaw cycles which could cause detrimental effect to many plasma components (Lippi *et al*, 2019).

See APPENDIX 5-6, APPENDIX 5-7and APPENDIX 5-8 for the detailed procedures employed during blood collection.

On arrival at Dubai Falcon Hospital, the haematology samples were processed on the same day of blood collection. These tubes were placed in a blood roller mixture for 10 mins. Lithium heparin samples were analysed for ionised calcium, Na+ and K + using I stat analyser and CG8+ catridges (Abaxis) and were centrifuged at 5000 rpm for 5 mins. Plasma was separated using a micropipette. Blood chemistry was done using ABX Mira Plus (France) wet chemistry analyzer with plasma samples. The blood chemistry parameters included were Total Protein (TP), Albumin (ALB), Globulin(GLOB), Gamma Glutamyl Transferase (GGT), Aspartate Amino Transferase (AST), Lactate dehydrogenase (LDH), Uric acid (UA), creatine kinase (CK), Cholesterol (CHOL), Alanine aminotransaminase (ALT), UREA, Alkaline Phosphatase (ALP) and Glucose (GLU).

During analysis, the considered value of iCa^{++} concentration was that measured at the actual pH of the animal and not the calculated value, corrected for pH 7.4 (Evenepoel *et al*, 2010).
Packed cell volume (PCV), Total leucocyte count, and differential WBC count were completed as per the methods for haematology procedures described by Hawkey & Samour (1988).

It was vitally important that these samples were handled consistently throughout the study. 300 µl of plasma was required to run the Vit D_3 analysis (LC-MS/MS which is a combination of liquid chromatography (LC) with mass spectrometry (MS)). In case of loss, two samples were taken, one was held as backup. The samples were taken immediately after centrifugation as per instructions above and stored at -40 °C until analysis. The A samples were submitted for analysis at the Cork Centre for Vitamin D and Nutrition Research, School of Food and Nutritional Sciences, University College, Cork, Ireland and imported subject to licences below. The B samples were held in the freezers of Dubai Falcon Hospital, Dubai, UAE.

The current study looks only at $25(OH)D_3$. The reason for this is twofold. Firstly, *Uromastyx aegyptia leptieni* is considered to be solely herbivorous with no access to external sources of vitamin D (Cunningham, 2000; Wilms *et al*, 2010; Wilms *et al*, 2011; Wilms *et al*, 2012). Secondly, a pilot run of the analysis revealed that there was no $25(OH)D_2$ in the plasma samples analysed. To ensure that $25(OH)D_2$ would be recorded if it were in the sample, spiking trials were carried out which proved that

if it were there it would have been identified during the analysis.

As a safeguard and for any future studies that might have a processing delay using frozen samples, a number of samples were re-tested a year after initial testing to determine the stability of the reptile plasma and these returned very similar values to the initial test. (APPENDIX 5-3)

A total of 178 individual animals were caught and identified with the use of 11 mm generic ISO 11785 compliant Radio-Frequency Identification (RFID) transponders. Of these, some were caught a number of times for resampling. This allowed the collection of 216 blood samples for analysis together with various morphometric details. One animal was also used to design a harness (Figure 5-6) to allow the attachment of an iButton, temperature and humidity logger as well as an ATS (Advanced Telemetry Systems, USA) gps logger and VHF transmitter. These were fitted in September 2014 and used to trial the use of gps technology and the radio tracking equipment that was subsequently used.



Figure 5-6. Harness design for attaching data loggers.

Following a number of issues with the GPS data loggers and the need to frequently recapture animals, these were not used for most of the survey. Instead, larger VHF transmitters were utilised to give further range and longer battery life (Figure 5-7).



Figure 5-7. Recapture of dhub using the net method showing how worn the saddle with VHF receiver and iButton get from the burrow.

5.2.5 PERMITS AND PERMISSIONS

Haematology, biochemistry and blood parasites analysis were completed at Dubai Falcon Hospital, Dubai, UAE. Since Vit D_3 analysis of the samples were carried out at the Cork Centre for Vitamin D and Nutrition Research, School of Food and Nutritional Sciences, University College, Cork, Ireland, all samples were exported as per UAE Ministry of Climate Change and Environment export permit: MOCCAE/EA/966/2017 and UAE Ministry of Climate Change and Environment issued CITES Export certificate 17MEW1848 and imported into Ireland with National Parks and Wildlife Service, CITES Cert IE-17-000102 and UCC ABP CAT 3 Certificate 2017/69.

5.2.6 SOFTWARE AND STATISTICS

Statistical analysis was completed using MedCalc Statistics v 17.4 MedCalc Software bvba, Ostend, Belgium; http://www.medcalc.org; 2017 and Minitab v 17.

As outliers (data points that lie at a distance from other data points which might be the result of inaccuracies) usually exert disproportionate influence on substantive conclusions (Aguinis *et al*, 2013) these were removed. These potential error outliers were identified as observations 1.5 times the interquartile range (Q3 – Q1) (Minitab Inc, 2021).

5.3 RESULTS

5.3.1 UVI

Data presented in Chapter 3 details the UV analysis in more detail. However, before examining the Vitamin D results below, it is interesting to note that there was no statistical difference between the months and either site except for September 2015 $t(1669) = 4.01$, $p = <0.001$. The data in Table 5-4 and Figure 5-8 and Figure 5-9 show that the highest UVI values were at 12:00. These data also demonstrate that there was a higher UVI in MUG when compared to WAS for each of the months. Behavioural data (Chapter 2) suggests that animals have different thermal requirements and tolerances based on the time of year and time of day. Using the Ferguson Zones as a guide, the study animals would be classed in Zone 4 (APPENDIX 5-3) throughout the data collection (UVI between 2.6 to 3.5) reaching this threshold shortly after 10.00 in the morning for all months except October where the threshold was passed after 11:00 (Figure 5-8 and Figure 5-9 black line).

Table 5-4. UV Index at hourly intervals measured on the Davis Weather station at ground level during the vitamin D portion of the study for WAS and MUG in September and October 2015 and March and April 2016.

			07	08	09	10	11	12	13	14	15	16	17
WAS	Sep	2015	0.00	0.37	1.21	2.38	3.46	3.85	3.58	2.73	1.64	0.64	0.00
MUG			0.00	0.50	1.61	2.97	4.21	4.80	4.46	3.30	1.90	0.81	0.00
WAS	Oct		0.00	0.46	1.31	2.38	3.21	3.34	2.84	1.91	0.86	0.16	0.00
MUG			0.00	0.24	1.23	2.22	3.16	3.59	3.24	2.30	1.25	0.32	0.00
WAS	Mar	2016	0.10	0.45	1.38	2.85	3.93	4.32	4.28	3.16	1.73	0.58	0.00
MUG			0.00	0.15	1.25	2.73	3.96	4.54	4.41	3.40	2.00	0.63	0.00
WAS	Apr		0.00	0.49	1.74	3.47	4.59	4.95	4.84	3.40	1.85	0.55	0.00
MUG			0.00	0.40	1.70	3.24	4.76	5.27	5.15	3.83	2.06	0.61	0.00

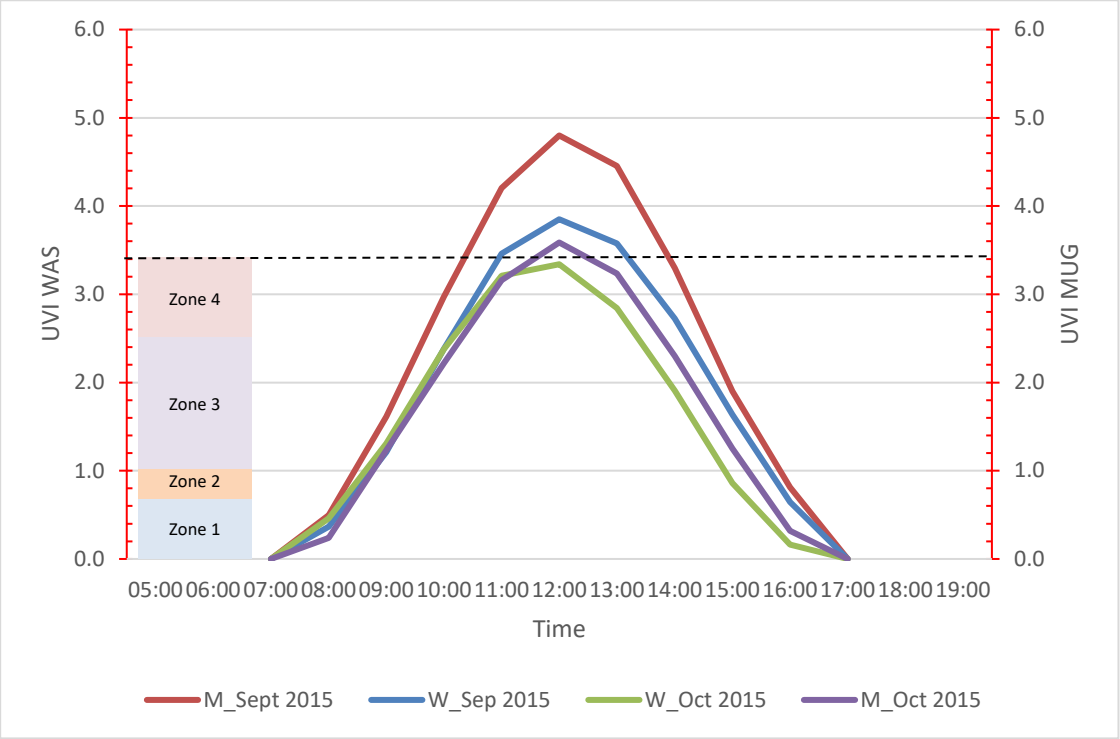


Figure 5-8. The mean monthly UV index (from the Davis Weatherstation) for MUG and WAS in September and October 2015 measured at ground level during the vitamin D portion of the study at hourly intervals reported as per the UV Index scale. Ferguson Zones (1 to 4) shown for reference with the black broken line showing the division between Zones 3 and 4 and the time this was reached.

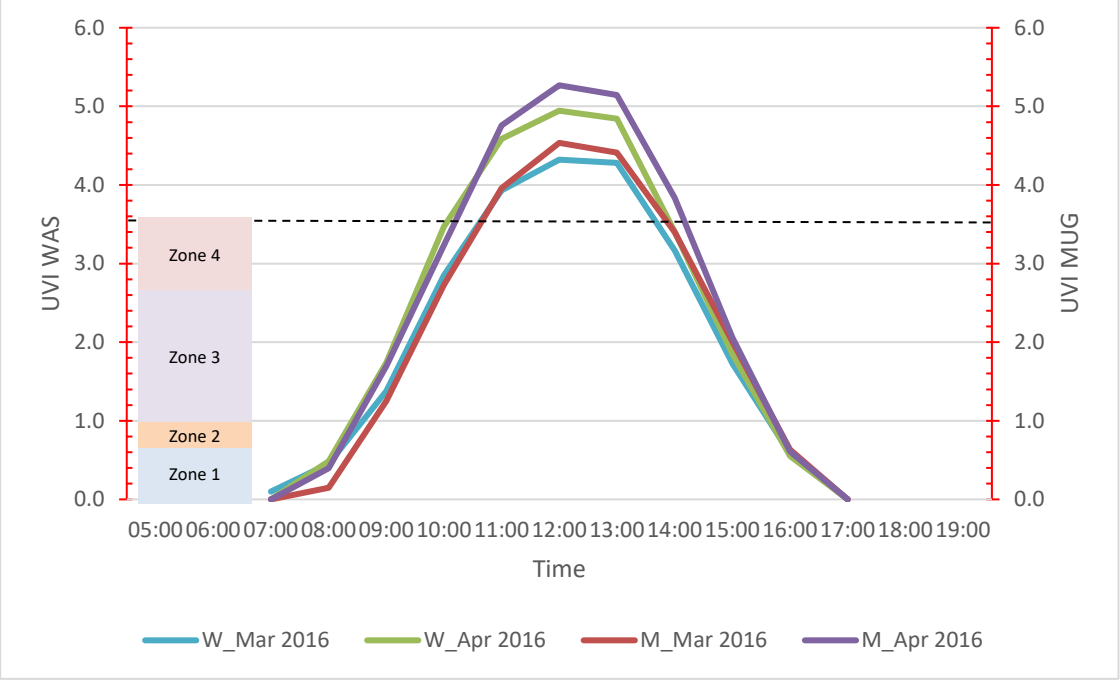


Figure 5-9. The mean monthly UV index (from the Davis Weather station) for MUG and WAS in March and April 2016 measured at ground level during the vitamin D portion of the study at hourly intervals reported as per the UV Index scale. Ferguson Zones (1 to 4) shown for reference with the black broken line showing the division between Zones 3 and 4 and the time this was reached.

5.3.2 VITAMIN D3 ANALYSIS

The results from the vitamin D_3 analysis are presented in the form of box plots which represent the

mean level of circulating 25(OH)D_3. Outliers were checked using Grubbs – double sided test (α=0.05). One sample was removed from the data set as a result of this analysis (APPENDIX 5-1 and APPENDIX 5-3). All data were tested for normal distribution and found to be normally distributed (apart from male animals in 2015 (MUG 2015 P<0.0001) allowing the use of parametric analysis.

There is a lower mean level of 25(OH)D in 2015 when compared to 2016 for both sites (Table 5-5). There is not the same immediately obvious difference between sexes within the same site for 2015 but males in MUG had slightly lower mean values (-6.12 nmol/L) than females and similarly in WAS males had on average lower mean 25(OH)D than females (-11.2). In 2016, this is reversed with males in MUG (13.7 nmol/L) and WAS (10.32 nmol/L) having higher mean 25(OH)D. However, when one compares the same sex between MUG and WAS for 2015 there is a large difference in mean 25(OH)D for females (38.28 nmol/L), males (33.25 nmol/L) and a similar pattern is visible for 2016 for females (31.65 nmol/L) and males (28.26 nmol/L) (Figure 5-10).

Table 5-5. Mean, SE Mean, St Deviation, Minimum, Quartile 1, Median, Quartile 3 and Maximum for 25(OH)D results for each year, site and sex (N=173*). These data do not include the results from the 6 captive dhub sampled.

Year	Site	Sex	N	Mean	SEM	StDev	Min	Q1	Median	Q3	Max
2015	M	F	13	34.66	4.68	16.88	9.17	22.8	32.87	42.07	77.89
	W		18	72.94	7.18	30.47	31.61	41.85	74.39	91.54	141.61
	M	M	11	28.54	4.85	16.1	8.75	16.24	23.48	38.95	64.29
	W		29	61.79	4.1	22.06	15.11	48.74	59.09	76.25	117.9
2016	M	F	15	66.31	6.41	24.83	33	45.78	67.95	71.85	116.08
	W		41	97.96	6.76	43.3	15.54	71.66	90.92	123.17	206.77
	M	M	14	80.02	7.86	29.42	44.7	52.42	75.72	101.61	143.81
	W		32	108.28	5.98	33.82	48.13	85.3	115.55	132.3	191.41

Site: M=MUG, W=WAS; Sex: F=Female, M=Male

**To be truly representative of the wild state, these data did not include any values for the captive reared animals and are only for those animals caught in the wild.*

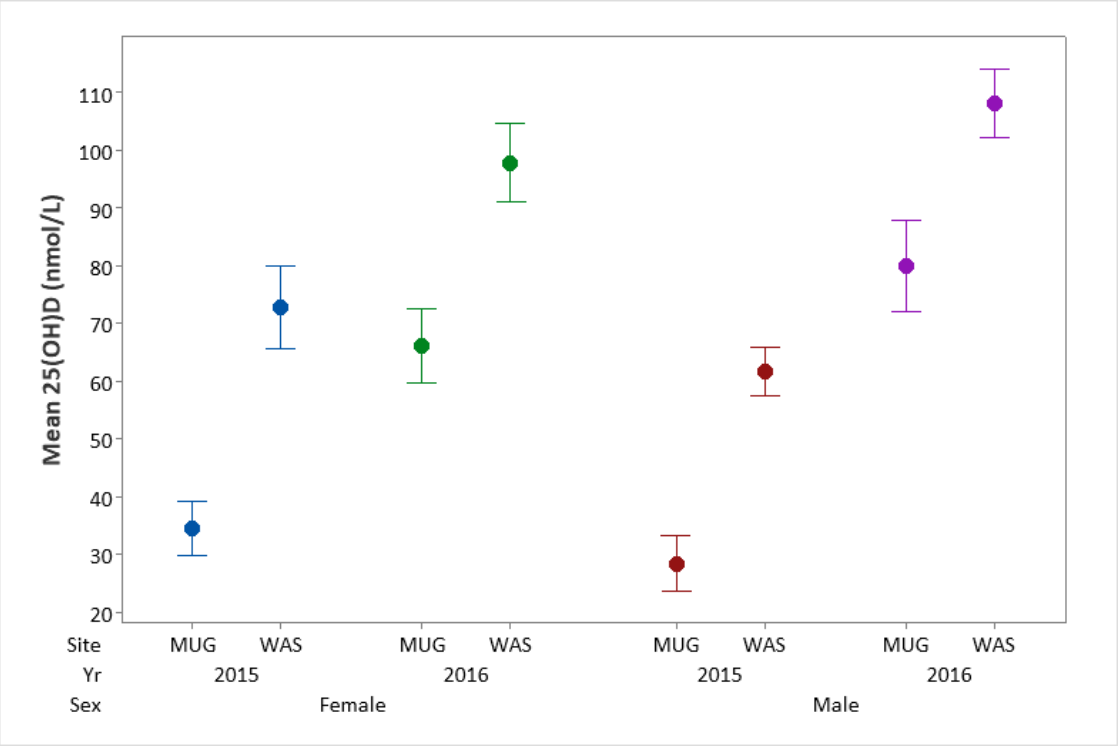


Figure 5-10. The mean circulating 25(OH)D (nmol/l) recorded for males and females in WAS and MUG sites during September and October (2015) and March and April (2016). Bars are one Standard Error from the Mean for (*N*=173 for all years, sites and sexes).

The lowest mean values recorded were in 2015 for both females (34.66 ± 4.7) and males (28.5 ± 4.9) in MUG.

5.3.3 Repeat Samples

For both sites and sexes combined, a total of 41 animals were caught both in 2015 and 2016. The paired *t* test suggested that there was a significant difference between animals sampled in 2015 and 2016, for 25(OH)D as well as the other analytes, calcium (Ca), ionised calcium (iCa^{++}) and phosphorus (Phos). Based on Figure 5-10, for all the wild samples, one would expect the difference between samples taken in 2015 and 2016. Table 5-6 demonstrates that there was a significant difference between the 25(OH)D levels for each year. The interesting observation from these data is the significantly different levels for Ca, iCa^{++} and Phos before the summer (2016) and after the summer (2015) which is suggestive of a seasonal bias in the circulating levels of these analytes, with levels being higher for Ca and iCa^{++}, but lower for Phos.

Table 5-6. Paired *t* test for N= 41 for 25(OH)D and N=41 for other analytes in animals comparing the different analytes between September and October 2015 and March and April 2016.

	2015		**2016**		**t**	**N**	**P**
Analyte	$\bar{x}$	SD	$\bar{x}$	SD			
25(OH)D	51.71	28.69	90.26	36.43	-9.62	41	<0.001
Ca	9.6	0.28	10.46	0.39	-10.45	41	<0.001*
iCa^{++}	1.27	0.10	1.38	0.10	-4.73	41	<0.001*
Phos	3.99	2.07	3.19	0.95	2.36	41	0.023*

*Ca, iCa^{++} and Phos are included here as they are all relevant to the levels of 25(OH)D.

To attempt to determine what variables were influencing these results most, the data were put into a general linear model (GLM) to look at the interactions between, site, year, sex, site*year, site*sex, sex*year, site*sex*year (Table 5-7).

Table 5-7. ANOVA looking at the interaction between Site, Sex and Year for 25(OH)D

Source	**DF**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**
Site	1	31583	31583.3	34.63	< 0.001*
Year	1	31474	31474.3	34.51	< 0.001*
Sex	1	171	171.3	0.19	0.666
Site* Year	1	25	24.8	0.03	0.869
Site*Sex	1	1531	1531.5	1.68	0.198
Sex* Year	1	2113	2113.0	2.32	0.131
Site*Sex* Year	1	16	15.5	0.02	0.897
Error	117	106717	912.1		
Total	124	179284			

*Significantly different (*p< 0.05*) statistics in bold and asterisk

The adjusted R-sq suggests that only 37% of the variability in the results are due to the difference between site and year sampled. When one looks in greater detail, by completing a post hoc test using the Tukey pairwise comparison of site, one finds that sex can be omitted from future models (Table 5-8) as males and females do not show a major impact on the variation observed (both grouped together in A). However, both the year (group A and B) and site (group A and B) do show a significant influence on the variation observed.

Table 5-8. Tukey pairwise comparison with (95% confidence) of sex, site and year.

		N	$\bar{X}$	Group	N	$\bar{X}$	Group	N	$\bar{X}$	Group
Sex	Male	56	70.118	A						
	Female	69	67.551	A						
Site	WAS				84	86.264	A			
	MUG				41	51.406	B			
Year	2015							74	86.234	A
	2016							51	51.436	B

When sex is omitted from the model and site*year (Table 5-9) is looked at, one can see that there is still a highly significant difference between these.

Table 5-9. ANOVA looking at the interaction between Site and Year for 25(OH)D

Source	DF Adj	SS	Adj MS	F-Value	P-Value
Site	1	30928	30928.1	33.80	< 0.001*
Year	1	33085	33085.1	36.15	< 0.001*
Site* Year	1	55	55.2	0.06	0.806
Error	121	110733	915.1		
Total	124	179284			

*Significantly different (*p< 0.05*) statistics in bold and asterisk

The combined site*year does not have a significant influence (*P=0.806*), but site on its own and year on its own do. This is reflected in the adjusted R-sq which suggests that these factors contribute to just 37% of the variation.

When the test for equal variance was carried out it showed that most of the variance could be accounted for by the data from MUG 2015 and WAS 2016 (Figure 5-11)

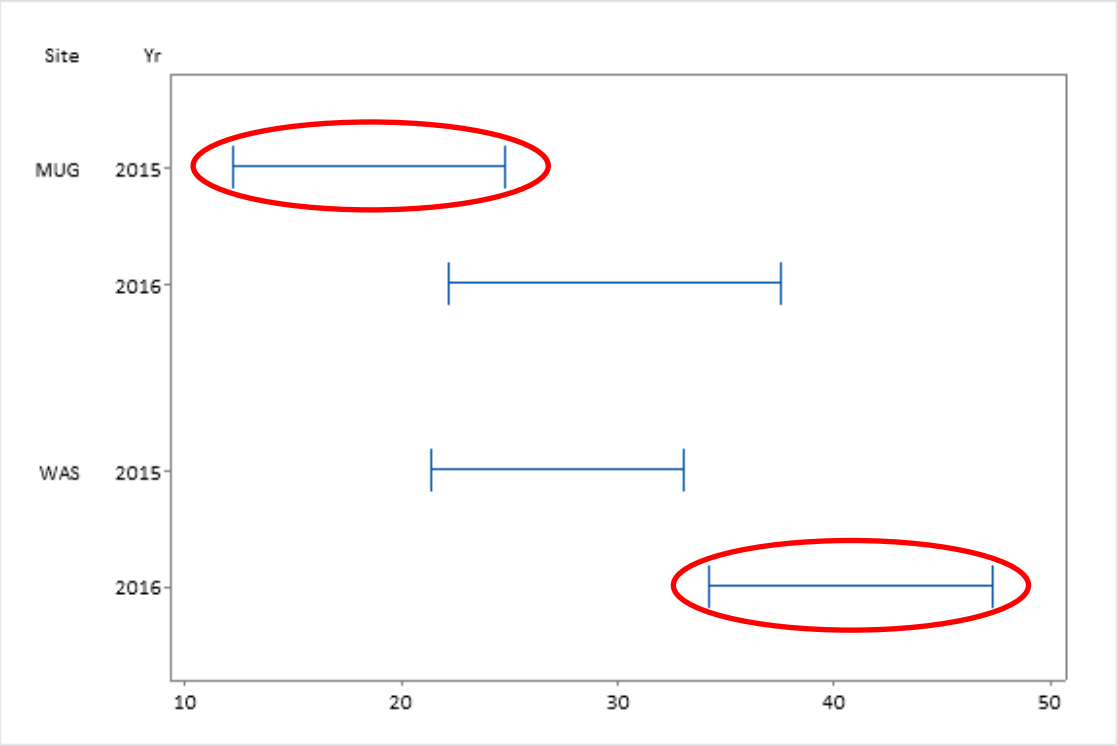


Figure 5-11. Test of equal variance Site and Year for 25(OH)D. If intervals do not overlap, the corresponding standard deviations are significantly different.

As there was a definite difference between samples collected in WAS and MUG as well as between 2015 and 2016 (Table 5-5), the proportion of animals to fall into the sufficiency bands for 25 (OH) D_3 was looked at.

For the purpose of this study and due to the lack of any formalisation of sufficiency intervals for reptiles, it was decided to differentiate these as follows based on those for humans:

Based on the bands described for humans in Table 5-10 about 30% of MUG animals showed levels which would be classed as having severe vitamin D deficiency (25(OH)D) in 2015 (Figure 5-12). However, the animals did not show any obvious signs of rickets or MBD on examination.

Table 5-10. 25(OH)D level of sufficiency bands as described for humans*.

Condition	**Range (nmol/L)**
Deficient	< 25
Insufficiency	> 26 < 75
Sufficient	> 76 < 150
Excessive	> 151 < 375
Intoxication	> 376

*Adapted from Cashman *et al* (2016).

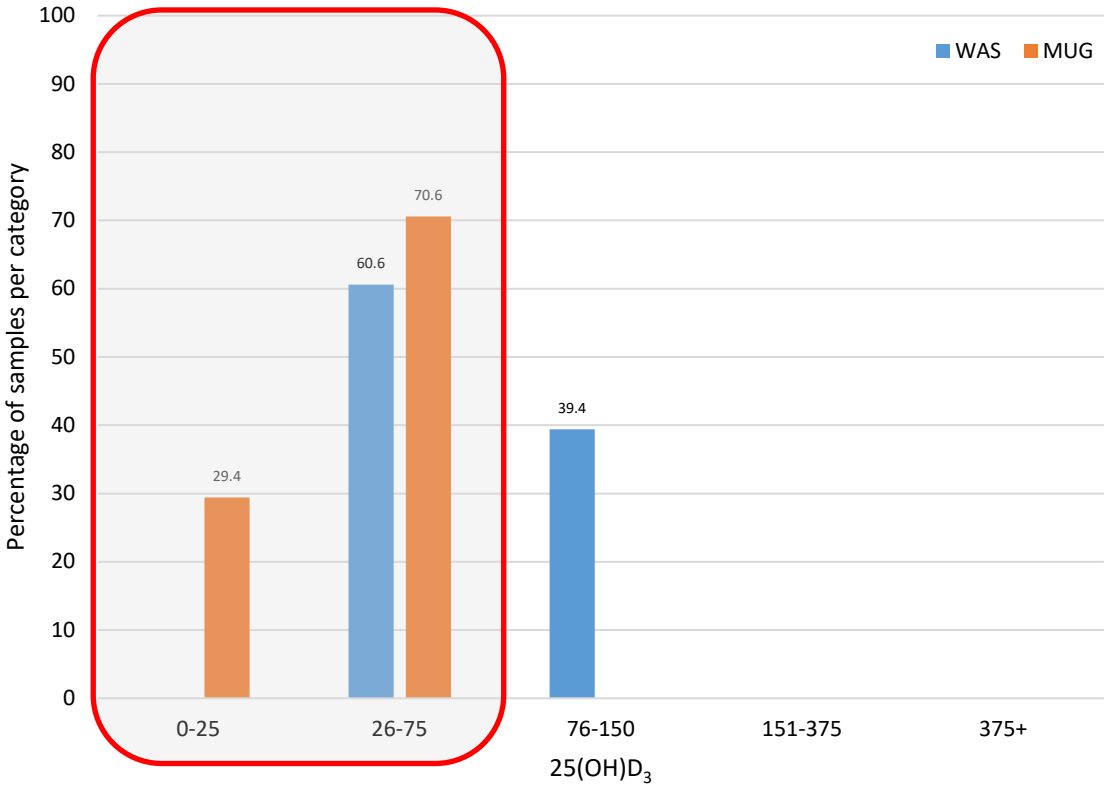


Figure 5-12. The percentage of samples of $25(OH)D_3$ that were recorded for each limit band (as per Table 5-10) for September and October 2015 for males and females combined for the two sites. Circled area represents what would be deficient in human reference intervals.

The remaining 70% of animals would have been considered to have insufficient vitamin D levels. The situation for the WAS animals was slightly better, but, depending on what reference intervals (RI) one looks at, slightly more than 60% of those sampled were deficient in 25(OH)D. In 2016, using the sufficiency guidelines for humans the number of deficient animals fell to 4% while 70% and 30% were considered to have sufficient circulating 25(OH)D in WAS and MUG respectively.

Figure 5-12 and Figure 5-13 clearly illustrate the difference both in season and in site for the recorded 25(OH)D levels in the dhub.

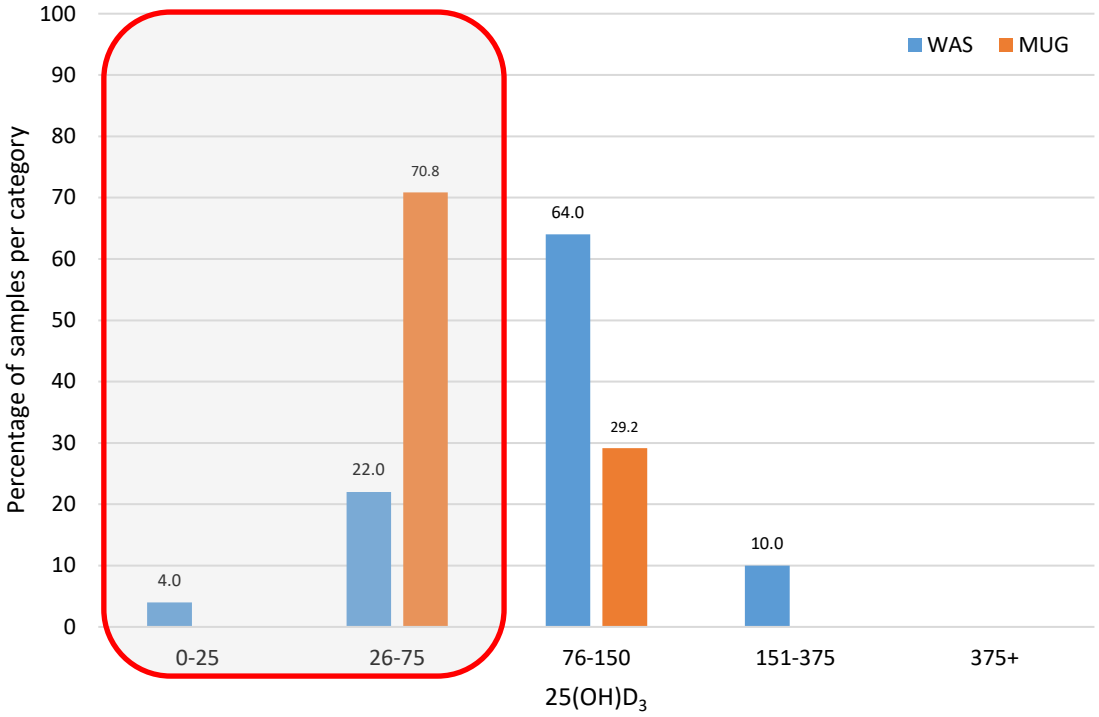


Figure 5-13. The percentage of samples of $25(OH)D_3$ that were recorded for each limit band (as per Table 5-10) for March and April 2016 for males and females combined for the two sites. Circled area represents what would be deficient in human reference intervals.

As mentioned at the start of the Results, the data demonstrate that the UVI was similar for 2015 and 2016, however, there was an apparent difference in the proportion of samples which had higher values in either month for each site and year (Appendix 3). MUG had in excess of 70% of all animals sampled in 2015 and 2016 with levels lower than 75 nmol/L. WAS had more than 70% lower than 75 nmol/L in September 2015 (N=28) and more than 75% greater than 75 nmol/L in October 2015 (N=8).

5.3.4 CALCIUM

Mean Ca levels (mmol/L) did not appear to differ between the sexes within their own site and during the same year (Figure 5-14). In September and October 2015, mean levels were similar between females (9.69 ± 0.06) and males (9.66 ± 0.09) in MUG. WAS females (9.51 ± 0.12) and males (9.62 ± 0.05) were very similar to MUG animals for the same period. In 2016, however, there was a slight increase in mean Ca levels. In that year, females in MUG had the lowest mean levels (10.14 ± 0.08) with males having slightly higher levels (10.49 ± 0.16) for the 2016 samples. Females (10.77 ± 0.07) and males (10.63 ± 0.08) in WAS were higher again.

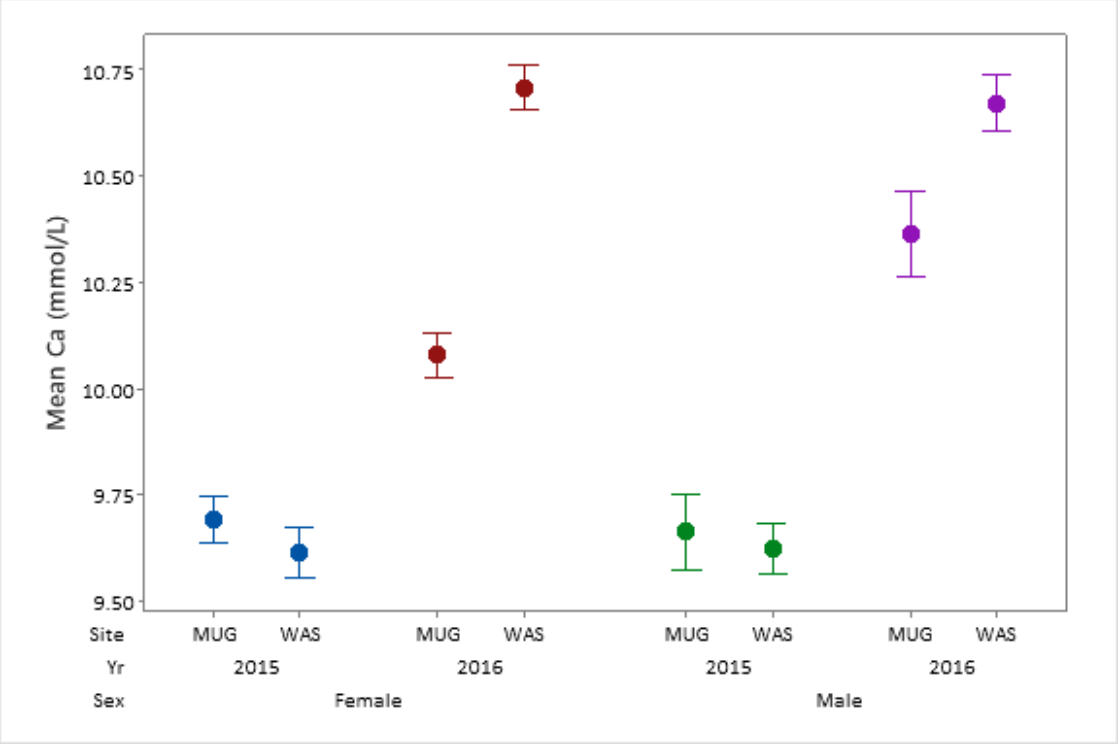


Figure 5-14. The mean and SEM circulating Ca (mmol/L) recorded for males and females in WAS and MUG sites during September and October 2015 and March and April 2016. Bars are one Standard Error from the Mean for (*N*=170 for all years, sites and sexes).

When the paired samples were examined, there was a statistical difference between the animals from 2015 and 2016. Looking at the GLM (Table 5-11) both Site, Year and Site*Year have a statistical effect on the mean Ca levels whereas sex has little overall effect. The adjusted R-sq also shows that 74.5% of the variability in the results are due to the difference between site and year sampled.

Table 5-11 ANOVA looking at the interaction between Site, Sex and Year for Ca.

Source	DF	AdjSS	AdjMS	F-Value	P-Value
Site	1	1.4703	1.4703	15.00	**< 0.001***
Year	1	22.6581	22.6581	231.15	**< 0.001***
Sex	1	0.1144	0.1144	1.17	0.282
Site*Year	1	2.4027	2.4027	24.51	**< 0.001***
Site*Sex	1	0.1772	0.1772	1.81	0.181
Year*Sex	1	0.1586	0.1586	1.62	0.205
Site*Year*Sex	1	0.2811	0.2811	2.87	0.092
Error	162	15.8796	0.0980		
Total	169				

*Significantly different ($p < 0.05$) statistics in bold.

When looking in greater detail by completing a post hoc test using the Tukey pairwise comparison of the three factors, sex can be omitted from future models while site and year appear to be the main contributory factors (Table 5-12).

Table 5-12. Tukey pairwise comparison with (95% confidence) of sex, site and year

		N	$\bar{X}$	**Group**	**N**	$\bar{X}$	**Group**	**N**	$\bar{X}$	**Group**
Sex	Male	84	10.081	A						
	Female	86	10.024	A						
Site	WAS				118	10.155	A			
	MUG				52	9.950	B			
Year	2015							100	10.455	A
	2016							70	9.649	B

As with the 25(OH)D results, this suggests that again, the sex of the dhub does not have a significant impact on the variation observed.

When the ANOVA is run again (Table 5-13) with only site and year included, the adjusted R-sq does not improve, further highlighting the significance between site and year.

Table 5-13 ANOVA looking at the interaction between Site and Year for Ca

Source	**DF**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**
Site	1	1.508	1.5080	15.19	**< 0.001***
Year	1	23.000	22.9995	231.67	**< 0.001***
Site*Year	1	2.464	2.4638	24.82	**< 0.001***
Error	166	16.480	0.0993		
Total	169				

Significantly different (*p< 0.05*) statistics in bold and asterisk

Although the test for equal variance does not indicate any significant difference (*P=0.286*) the values for MUG 2016 do show the largest variation (Figure 5-15).

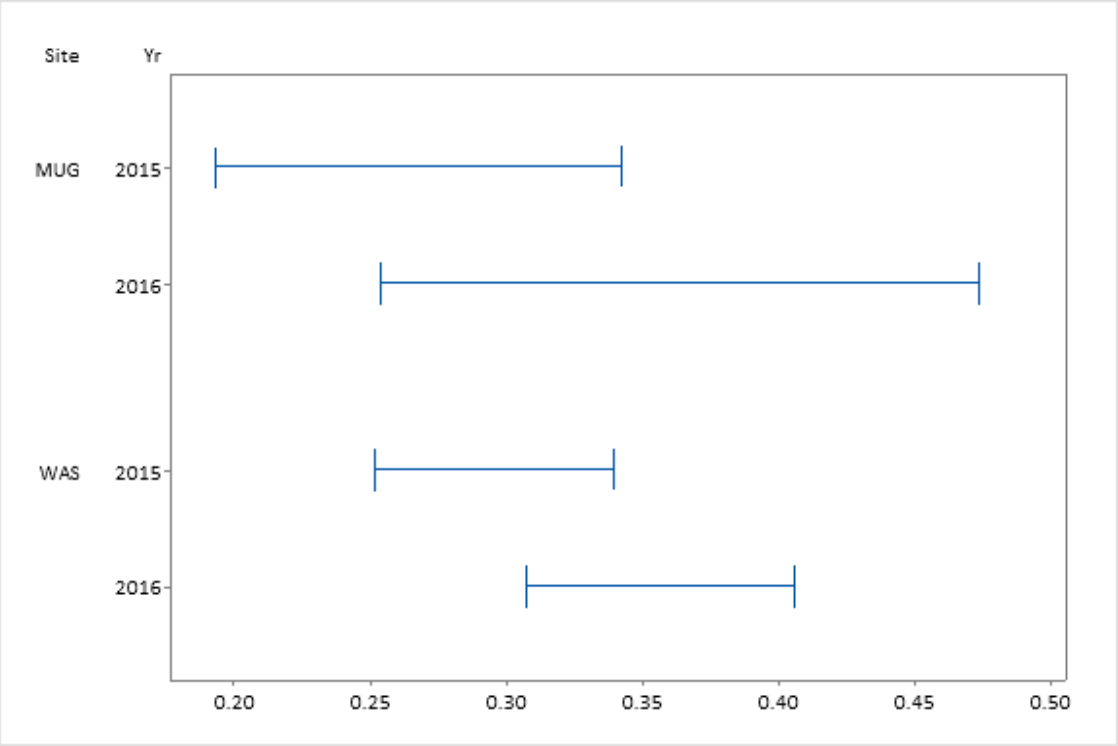


Figure 5-15. Test of equal variance Site and Year for calcium. If intervals do not overlap, the corresponding standard deviations are significantly different.

5.3.5 IONISED CALCIUM (iCa^{++})

Mean iCa^{++} levels (mmol/L) were lowest for MUG females in 2015 (1.23 ± 0.02) when compared to the other sites and sexes (1.29 ± 0.03). In 2016, MUG females again had slightly lower iCa^{++} (1.3 ± 0.03) levels than the other sites and sexes for that year (MUG males 1.4 ± 0.04 and WAS females and males 1.4 ± 0.01) (Figure 5-16).

The ANOVA (Table 5-14) suggests that there are a lot more interacting factors for iCa^{++} than for either Ca or 25(OH)D. Almost all factors were responsible for the significant differences observed. Apart from site and year, sex and site*year also have an influence of the variation observed. The adjusted R-sq shows that 31.5% of the variability in the results are due to the difference between these variables.

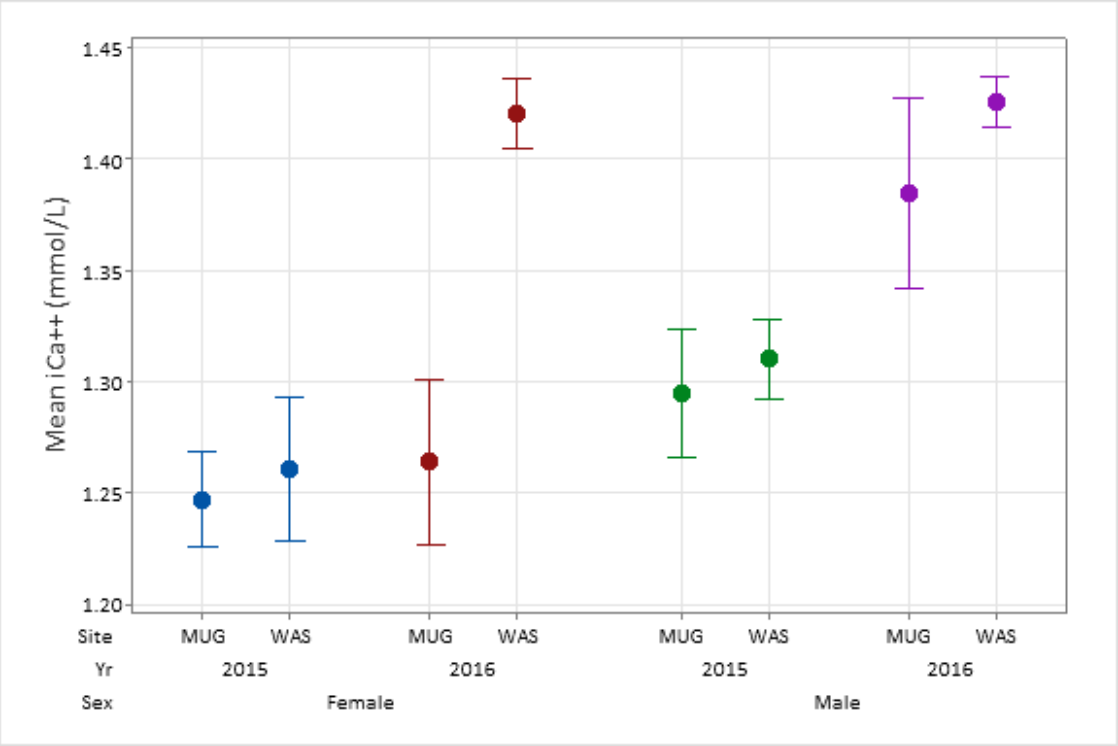


Figure 5-16. The mean circulating iCa^{++} (mmol/L) recorded for males and females in WAS and MUG sites during September and October 2015 and March and April 2016. Bars are one Standard Error from the Mean for (*N*=176 for all years, sites and sexes).

Table 5-14. ANOVA looking at the interaction for between Site, Sex and Year for iCa^{++} (mmol/L).

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Site	1	0.11643	0.116425	10.80	0.002*
Year	1	0.32844	0.328436	24.99	< 0.001*
Sex	1	0.11175	0.111750	5.63	0.003*
Site* Year	1	0.06317	0.063174	5.95	0.023*
Site*Sex	1	0.02918	0.029179	0.30	0.120
Year *Sex	1	0.00188	0.001881	0.09	0.692
Site* Year *Sex	1	0.03093	0.030930	0.59	0.109
Error	168	2.00534	0.011937		
Total	175				

*Significantly different (*p< 0.05*) statistics in bold and asterisk

Looking in greater detail by completing a post hoc test using the Tukey pairwise comparison of site, for iCa^{++}, sex cannot be omitted from future models (Table 5-15).

Table 5-15. Tukey pairwise comparison with (95% confidence) of sex, site and year for iCa^{++} (mmol/L).

		N	$\bar{X}$	Group	N	$\bar{X}$	Group	N	$\bar{X}$	Group
Sex	Male	86	1.354	A						
	Female	90	1.298	B						
Site	WAS				122	1.354	A			
	MUG				54	1.298	B			
Year	2015							105	1.374	A
	2016							71	1.278	B

iCa^{++} does show significant differences between all of the pairs in the pairwise comparison. Table 5-16 would suggest that there are similarities between all of the pairs apart from WAS 2016. This differs from the observed summary stats where WAS animals had similar mean levels to MUG males.

Table 5-16. Tukey pairwise comparison with (95% confidence) of site*year

Site*Yr	N	Mean	Grouping	
WAS 2016	75	1.42305	A	
MUG 2016	30	1.32433		B
WAS 2015	47	1.28570		B
MUG 2015	24	1.27073		B

5.3.6 PHOSPHOROUS

Mean Phos levels (mmol/L) were highest in 2016 with WAS females (4.421 ± 0.745) while WAS males had the lowest levels (3.181 ± 0.198) in 2016. Mean levels for 2015 were very similar across both sites and sexes (Figure 5-17).

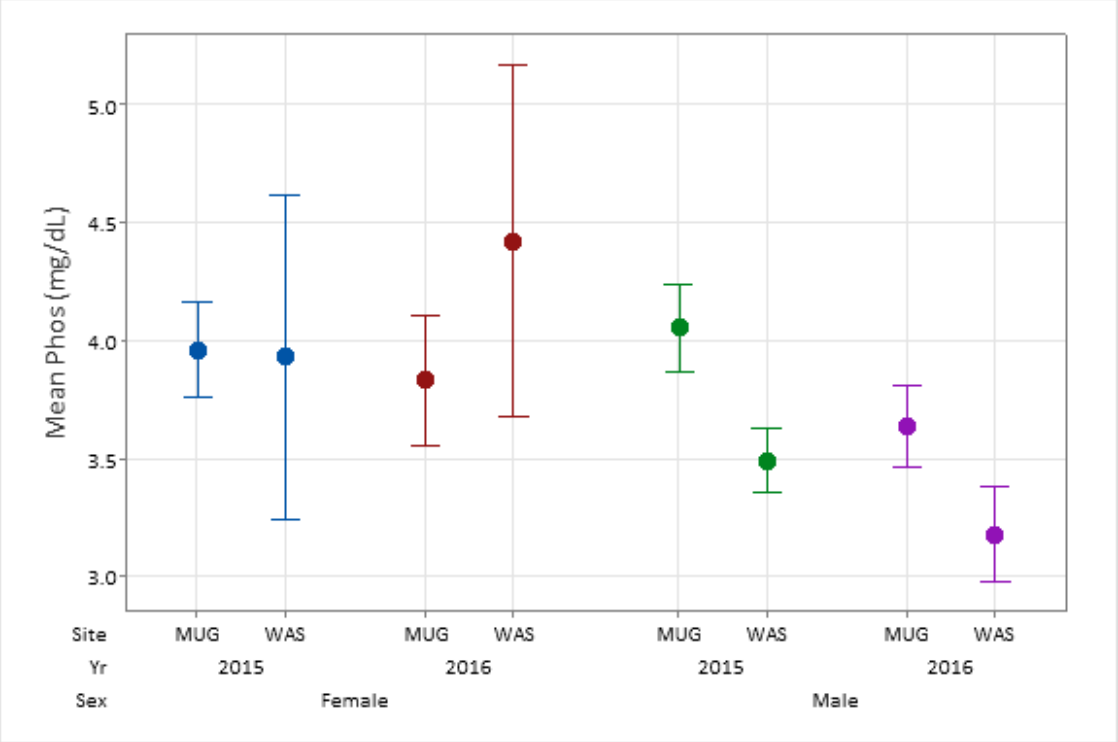


Figure 5-17. The mean circulating Phos (mg/dL) recorded for males and females in WAS and MUG sites during September and October 2015 and March and April 2016.

When the relationship was looked at through a GLM (Table 5-17) it suggests that statistically there are no differences between site, year or sex for mean Phos levels.

Table 5-17. ANOVA looking at the interaction between Site, Sex and Year for Phos (mg/dL).

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Site	1	0.47	0.4669	0.06	0.800
Yr	1	0.30	0.3027	0.04	0.838
Sex	1	7.08	7.0792	0.98	0.324
Site*Yr	1	1.17	1.1707	0.16	0.688
Site*Sex	1	5.52	5.5157	0.76	0.384
Yr*Sex	1	2.65	2.6543	0.37	0.546
Site*Yr*Sex	1	0.58	0.5807	0.08	0.777
Error	166	1201.66	7.2389		
Total	173				

*Significantly different ($p< 0.05$) statistics in bold and asterisk

When one looks at the mean Ca:P ratio for the different sites and years, MUG animals appear to have lower ratio levels in males and females (2.4:1.3) in 2015 compared to WAS animals (2.4:1.1). In 2016, WAS animals had significantly higher ratios (2.7:1.0) than MUG females (2.5:1.2) and males (2.6:1.2).

5.3.7 Weight and Length

The weight and length (snout to end of tail) were recorded for each animal prior to blood draw. There

was no statistical difference between the mean body lengths for any of the animals between 2015 (M=557.3, SD=65.3) and 2016 (M=555.1, SD=70.6); t(36)=0.72, *p*=0.474 . However, there was a statistical difference between the mean body weights of the animals in 2015 (M=1044.9, SD=412.2) and 2016 (M=1116.8, SD=451.2); t(40)-3.97, *p*=<0.000. To rule out any potential site difference a GLM was run (Table 5-18) looking at the difference between, Site, Year and Sex, it was clear that the sex of the animal had a major influence on the results. Interestingly, Site*Sex (only marginally not significant), was not relevant when the Tukey pairwise comparison was run on the data (Table 5-19).

Table 5-18. ANOVA looking at the interaction between Site, Sex and Year for the mean animal weights.

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Site	1	682.0	682.0	0.010	0.932
Year	1	131481.0	131481.0	1.390	0.240
Sex	1	12437914.0	12437914.0	131.260	**0.000***
Site*Year	1	3.0	3.0	0.000	0.995
Site*Sex	1	347539.0	347539.0	3.670	0.057
Sex*Year	1	161994.0	161994.0	1.710	0.193
Site*Sex*Year	1	4091.0	4091.0	0.040	0.836
Error	168	15919890.0	94761.0		
Total	175				

*Significantly different (*p< 0.05*) statistics in bold and asterisk

Table 5-19. Tukey pairwise comparison with (95% confidence) of site*sex*year for males and females indicating the different grouping.

Site*Sex*Year	N	Mean	Grouping	
MUG Male 2016	14	1450.79	A	
WAS Male 2016	32	1358.81	A	
MUG Male 2015	11	1333.82	A	
WAS Male 2015	29	1219.86	A	
WAS Female 2015	19	806.63		B
WAS Female 2016	43	789.56		B
MUG Female 2016	15	705.73		B
MUG Female 2015	13	702.00		B

5.3.8 PARASITOLOGY

During the study, only blood parasitology was completed on the samples submitted for haematology and biochemistry (*N*=175). Three different genera of haemoparasite were identified, *Aegyptianella* sp., *Babesia* sp. And a species of Hemogregarine. The results (Table 5-20) show that 70 % showed no signs of infection, while 30% were positive for one of the three haemoparasite groups.

Table 5-20. Blood parasite list identified with the number of dhub confirmed positive for each species or negative.

Parasite	Female	Male	Total
Aegyptianella sp.	14	14	28
Babesia sp.	3	2	5
Hemogregarine sp.	10	10	20
Negative	64	58	122

Eight of the 175 samples were positive for more than one parasite (Figure 5-18).

There did not appear to be any difference between male or female infection levels but there was a difference in incidence of infection with only once confirmed positive sample for *Babesia* sp and Hemogregarines in WAS compared to four *Babesia* sp and 17 Hemogregarines in MUG.

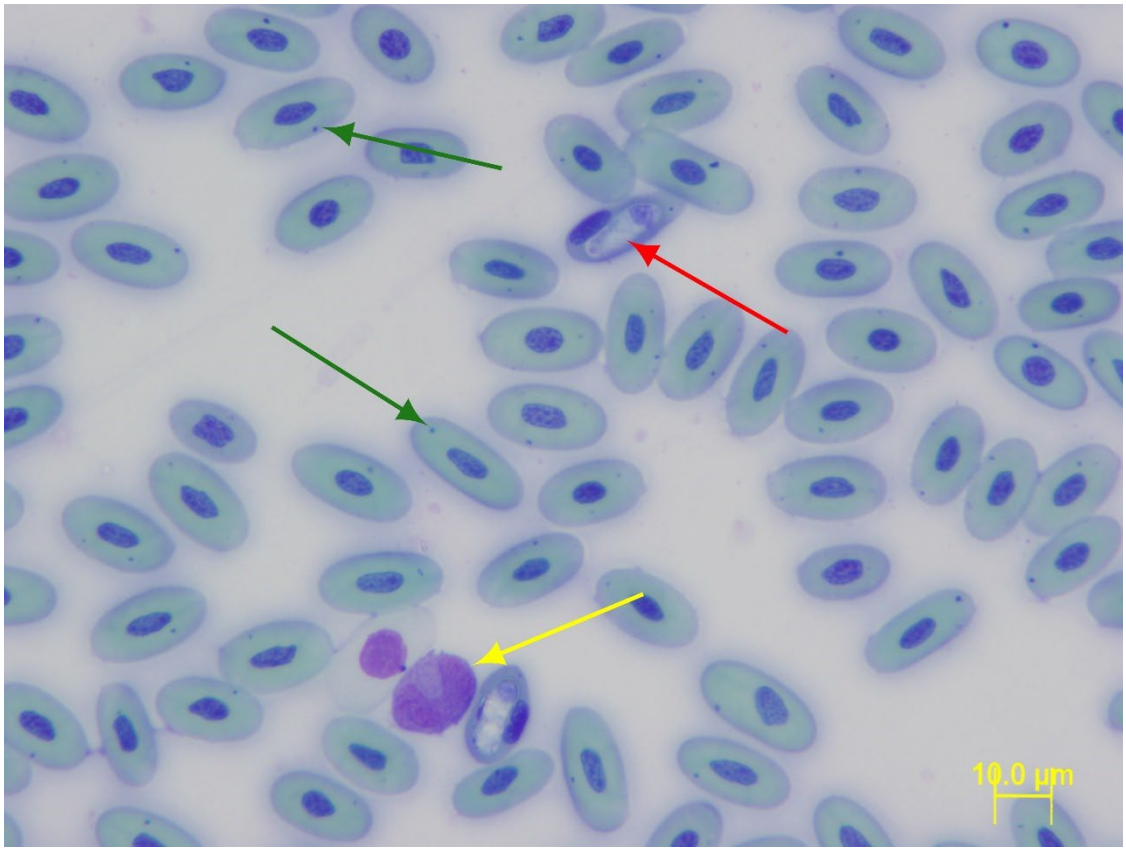


Figure 5-18. Blood smear from AQ01 showing a monocyte (yellow arrow), *Aegyptianella* sp (green arrow) and Hemogregarine (red arrow). (*Photo C. Silvanose*)

5.4 DISCUSSION

Nutritionally related problems are regularly seen in captive reptiles with many predominantly related to disorders of vitamin D and calcium metabolism (Eatwell, 2009; Rendle & Calvert, 2019). The current study therefore affords one a unique opportunity to determine accurate levels of many metabolites which have been suggested from captive animals.

Vitamin D analysis and reference ranges are at present an imperfect science in relation to human medicine (Jenkinson, 2019). The situation when it comes to non-human animals, and reptiles in particular, is even more confusing. While UV radiation (UVA and UVB) is a documented human carcinogen where over exposure can lead to increased risk of skin cancer, it is also responsible for cutaneous synthesis of vitamin D_3 (Wolpowitz & Gilchrest, 2006; Chang & Lee, 2019). Due to the ectothermic nature of reptiles, body temperature is essential to facilitate the isomerisation of pre D_3 to vitamin D_3 in the skin, where possible restrictions to this process would include skin thickness and pigmentation (Bikle *et al*, 2013), however, research and knowledge on UV tolerance in reptiles is quite limited (Chang & Zheng, 2003). In humans, multiple factors affect the level of biosynthesis of vitamin D_3, including UV intensity, duration of exposure, angle of incidence, as well as skin pigmentation (Bikle *et al*, 2013). In Caucasians with skin type II, 20–30% of the radiation of 295 nm is transmitted through the epidermis. In Blacks with skin type V only about 2–5% of the UVB photons penetrate through the epidermis (Chen *et al*, 2010). Reference values for many vitamins such as 25(OH)D remain by and large unknown or very limited and the dietary and ultraviolet light requirements are unknown for most species; however, establishing normal values under certain conditions will start to provide some initial reference ranges (Miller *et al*, 2009). It is hoped that this study will contribute valuable additional information to the management and husbandry of lizards in general, but dhub lizards in particular.

In vitamin D production simulations, Alamri *et al* (2015) have shown (using ampoules containing 7-dehydrocholesterol in ethanol exposed to sunlight every hour) that the time of day that vitamin D_3 production started at ambient temperature was around 8.00 am in Dammam, Saudi Arabia (which is 1° further north than Dubai, where the present research was carried out) with a peak production at 11.30 am during June 2013. This ties in with Bikle *et al* (2013) who suggest that the formation of pre-D_3 is relatively rapid. However, Alamri *et al* (2015) have also shown that the vitamin D_3 production was almost 50% less in Dammam than the other cities that they investigated, suggesting that this could be as a result of pollution. Lessan *et al* (2015) conducted a similar study in Abu Dhabi, UAE and suggested that their results were consistent with other studies. They estimated that the percentage conversion versus time of day, varied throughout the year, with the conversion rate in January only 34% of the

July peak. Work from Olds *et al* (2008) suggested a curvilinear relationship between sun exposure and serum 25(OH)D levels, as well as variation depending upon initial concentrations of 7-DHC (broken down to produce the pre-D isomers upon exposure to UVB) levels. At lower levels, vitamin D_3 production rises immediately in response to UV exposure, whereas at higher levels, the rate of production is lower and reaches an earlier plateau.

The current study shows a definite seasonal shift, which could be attributed to some of the above factors, but the most interesting aspect is the difference between sites. While only 29 Km apart, the statistical difference in vitamin D levels between site locations was very dramatic. The reason for the site difference is not fully understood, but it is postulated that perhaps skin pigmentation (although, no immediately obvious differences in colouration were observed between sites) or, most likely, time spent foraging might be a deciding factor. If, as Alamri *et al* (2015) found, there was a negative impact on 25(OH)D production with pollution, one would expect there to be a negative effect on the WAS population and therefore reduced 25(OH)D, as these were closer to Dubai city which does have a pollution issue (see Figure 5-19).

One would expect that if serum 25(OH)D was regulated by UVI, then levels should show a similar pattern to that of UVI with higher levels in September and April and slightly lower levels in October when the UVI does not exceed a mean value of 7.8. The higher proportion of 25(OH)D in the WAS animals in October might be due to them basking more or foraging more than those in MUG. Indeed, the higher mean recorded levels of 25(OH)D in 2016 was most likely due to two factors, the breeding season and the extreme rain which led to a flush of fresh and varied vegetation for the animals to forage on (see Chapter 4). Conversely, the lower recorded levels in 2015 was most likely due to the reduced vegetation therefore less time spent foraging. Reduced temperatures would also mean more time in the burrow. However, the reverse appears to be the case in relation to the 25(OH)D levels with consistently higher mean levels of 25(OH)D between sex and years.



Figure 5-19. Air pollution over Dubai city from the WAS site.

5.4.1 CA AND ICA++

One would expect that there would be a higher demand for Ca and therefore 25(OH)D in particular in April leading up to the breeding season as suggested by Carman *et al* (2000) and Ferguson *et al* (2002) for other species. Ionised calcium is often used as the definitive indication of circulating calcium in the body (Eatwell, 2009; Eatwell *et al*, 2014). A decrease in plasma proteins can also result in a decreased total calcium value, while the ionized calcium level usually remains normal. Therefore, the measured ionized calcium value can more precisely characterize the physiologically active calcium state in patients with potentially altered protein levels.

As serum 25(OH)D concentration is a useful biomarker of the supply of vitamin D available to target tissues in most situations, it is relevant as a stand-in for overall vitamin D status. However, what is not clearly established is the extent to which 25(OH)D levels serve as a biomarker of effect. That is, there is some question as to whether levels of 25(OH)D relate to health outcomes via a causal pathway and can serve as predictors of such outcomes (Institute of Medicine, 2011). Taken with the current results, are the particularly low levels of 25(OH)D in wild dhub a predictor of possible health issues? Because 25(OH)D deficiency <50 nmol/L and insufficiency < 75 nmol/L in humans can reduce calcium absorption and cause hypocalcemia, Roizen *et al* (2013) hypothesized that the high prevalence of vitamin D

deficiency would also lead to Ca deficiency. Many authors have stated that, low levels of total 25(OH)D are associated with negative health outcomes in subjects (Holick 2007; Holick & Chen, 2008; Melamed *et al*, 2008; Pilz *et al*, 2008; Adams & Hewison, 2010; Jenkinson, 2019) with the risk of skeletal issues being one of the most significant discussed. In a study of the levels of 25(OH)D in black Americans (non-white) and white Americans, Powe *et al* (2013) found that non-whites had consistently lower levels of 25(OH)D than whites and were often diagnosed as vitamin D deficient, yet the non-whites had higher bone mineral density than whites. There have been a number of reports, such as this, detailing the effect of pigmentation on circulating 25(OH)D levels (Holick & Chen, 2008; Chen *et al*, 2010; Mitchell *et al*, 2019).

Fan *et al* (2014) have suggested that the ability to modify skin coloration allows animals to accommodate the different demands of inter- or intra-specific communication, camouflage, thermoregulation, and protection from the damaging effects of UV radiation (Figure 5-20 and Figure 5-21). Clusella-Trullas *et al* (2008) have described the thermal melanism hypothesis (TMH) which predicts that dark (low skin reflectance) individuals are at an advantage in cool climates, as they heat faster and reach higher equilibrium temperatures than lighter (higher reflectance) coloured animals. In other species there is a circadian pigmentation rhythm, as is evident with dhub when they bask.



Figure 5-20. Different colouration in two animals taken on 26th April 2017 at 15:00. Animals were approximately 60m apart. (Mean UVI 4.7 for April).

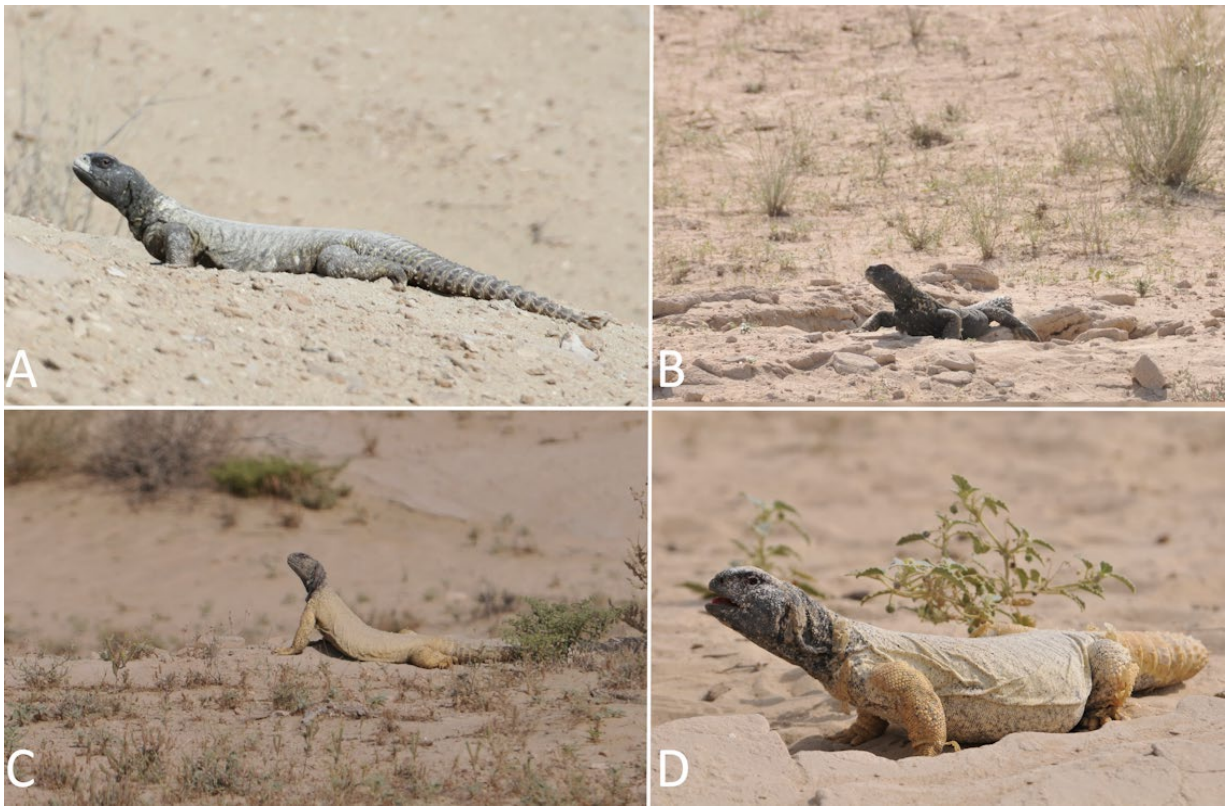


Figure 5-21. Various colours throughout the year (not the same animal) A. 13th Dec 2013 at 13:45 (MUG); B. 27th Mar 2008 at 09:25 (WAS); C. 13th May 2008 at 8:24 (MUG); D. 29th Jun 2008 at 9:11 (WAS).

The functional significance of this has not been extensively studied but one would postulate that it is a primary response to UV and thermal radiation levels. It could act, for example as a reflectance aid and changes in colour could help in regulating body temperature. Other species have been shown to change colour during the day to increase the amount of heat absorbed and help the body warm up (Fan *et al*, 2014). Similar conditions are seen with the dhub where they change from slate grey/black when they emerge from their burrows to almost a yellow colour during the day (Figure 5-22). This change is very quick during the summer and slower, and at times less pronounced, during the cooler months. The change in reflectance could most likely assist in reducing the effects of excessive UV exposure, as well as in their own body temperature regulation, which in turn will regulate 25(OH)D. Vergneau-Grosset & Péron (2020) suggest that a consequence of low UVB exposure includes low plasma or hepatic vitamin D concentration and metabolic bone disease. This does not appear to be the case with the wild dhub in this study where the mean Ca:P ratio was of 2.6-2.7:1 irrespective of the recorded 25(OH)D levels.

Kull *et al* (2009) have demonstrated seasonal variation in the studies of humans that they examined, which averaged approximately 25 nmol/L 25(OH)D between summer and winter.

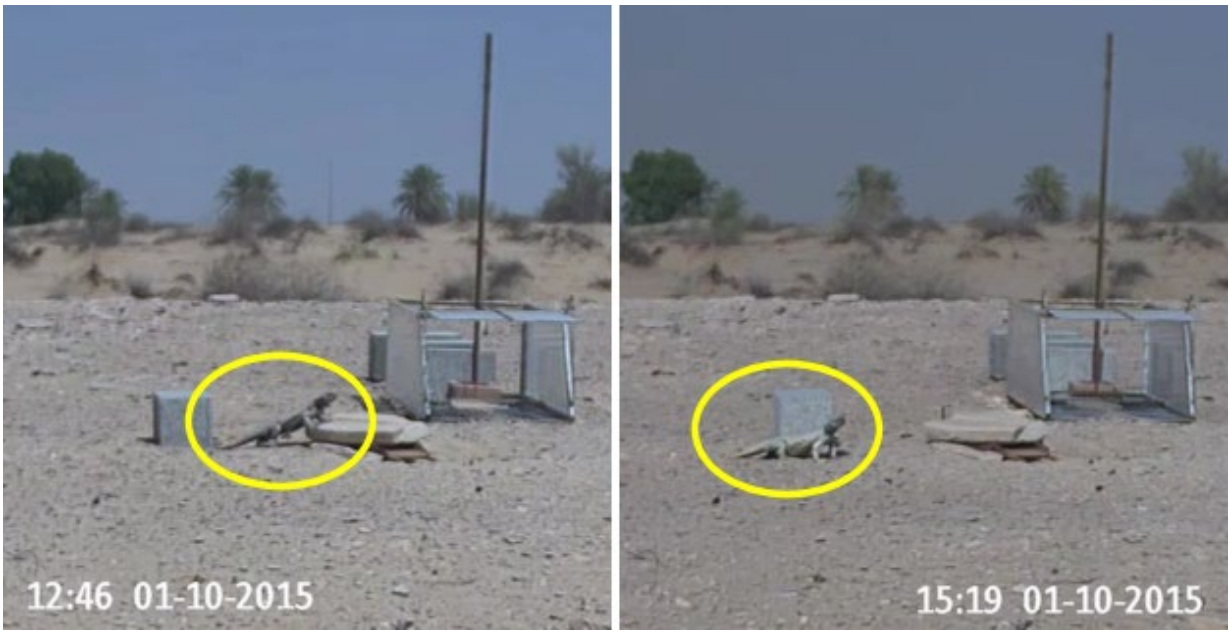


Figure 5-22. Screen grab highlighting the rate of thermal melanism in dhub. It took this animal no more than 2½ hours to change from slate grey having emerged from its burrow to yellow.

In other studies, free-living individuals in the lower latitudes appear to experience an approximately one-third seasonal increase in their circulating serum 25(OH)D levels as they moved from the winter months to the summer months (Institute of Medicine, 2011). Results from behavioural analysis in MUG (for daylight hours between 05:30 and 19:30) of a number of dhubs during August 2014 suggest that of the 1,332 hours analysed at that time, only 383 hours were spent outside exposed to the sun. The remaining time was spent inside the burrow. While there is a lot more data to analyse and different time periods to look at, if approximately 28% of the available time of the dhub is spent in the sun and the dhub can regulate the angle of their bodies to reduce or increase exposure (specific behaviours observed) to the sun, then it is plausible that the animals can control their own UV exposure and in return vitamin D_3 synthesis. Similarly, Ferguson *et al* (2003) have suggested that panther chameleons show a positive phototaxis to greater UVA and UVB light while Bashaw *et al* (2016) found that in their study of leopard geckos, the leopard gecko also showed a positive interaction with thermal enrichment. It is certainly plausible that reptiles show a negative phototaxis and thermotaxis and use all of the above strategies to maintain a state of stasis with regards their thermal and vitamin D status.

A number of authors (Al-Hazmi, 2001; Cunningham, 2001b, a) have suggested that *U. aegyptia*, while being mostly herbivorous, has at times been seen to eat insects as part of its diet as well as identifying them from stomach contents. More recently, Castilla *et al* (2011) have suggested that insects make up a much larger portion of their diet than previously considered and as such suggested that they should be perhaps considered opportunistic scavengers. It is argued that this identification might be a little excessive and, while a photograph of a dhub eating a bird wing during the summer of 2015 has been

viewed (Figure 5-23), it would be best perhaps to identify them as incidental scavengers/consumers as it is believed that the majority of items (stones, reptile skin, insects etc) which have been recovered from stomach analysis and faecal examination, are ingested accidentally as the animal forages and are most likely not identified and sought out.



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Figure 5-23. Dhub lizard eating a bird wing during the summer of 2015 (Al Ain, UAE).

This is important when one looks at the total 25(OH)D levels. If dhub obtained larger parts of their nutrition as scavengers/omnivores, then perhaps there would be an additional portion of the total 25(OH)D which should be recorded as $25(OH)D_2$ rather than $25(OH)D_3$ on its own. As it was, analysis showed no $25(OH)D_2$ in the preliminary samples analysed. Furthermore, several authors (Ferguson *et al*, 2005; Kumar *et al*, 2018) have suggested that the absorption of $25(OH)D_2$ by reptiles is not very efficient and rates of less than 5% have been suggested. Here in the current study, it is believed that the $25(OH)D_3$ returned was equivalent to the total 25(OH)D present.

With all of this considered, there is no doubt that for the majority of dhub sampled, their circulating 25(OH)D levels would be considered either deficient or insufficient in human medicine, particularly in MUG. Work reported by National Institue of Health (2016) suggest that the main storage source of vitamin D is the adipose tissue of subjects. It also suggests that the sequestered vitamin D is not readily available. Laing & Fraser (1999) suggested that the concentration of vitamin D binding protein (DBP) in human plasma was significantly higher than that in chicken plasma and also significantly higher than that in squamate plasma. They also suggested, based on the results of their study, that there was no significant correlation between plasma 25(OH)D concentration and plasma total calcium concentration, helping to confirm their view that this vitamin D metabolite in iguanians operates not as a regulated, biologically active metabolite, but as a storage form of vitamin D. Miller *et al* (2009) also found a similar lack of correlation between calcium and 25(OH)D in the elephant population that they studied. Oonincx *et al* (2013) suggested that in times of low UVB availability, captive bearded dragons (*Pogona vitticeps*) rely on stored vitamin D and 25(OH)D to maintain an adequate vitamin D status. Gyimesi & Bums (2002) suggested that circulating levels of 25(OH)D in Komodo dragons, (*Varanus*

komodoensis), were maintained at normal levels six to eight months after continual exposure to UVB lighting was removed. Oonincx *et al* (2020) reported levels of 25(OH)D_3 in leopard geckos (*Eublepharis macularius*) which were supplemented with dietary vitamin D_3 and exposed to low level UVB radiation at 61 ± 20 nmol/L. Similar observations by Roizen *et al* (2013) did not observe a relationship between 25(OH)D and higher levels of total plasma calcium. This was consistent with the notion that within the physiological range, levels of 25(OH)D do not lead to higher concentrations of plasma Ca. Zella *et al* (2008) suggest that the primary function of DBP is not directed toward controlling the activity of 1,25(OH)D but rather at maintaining appropriate levels of 25(OH)D. These results are similar to the current study where there was no apparent relationship between increased 25(OH)D and either Ca, iCa^{++} or Phos (APPENDIX 5-3). In fact, mean Ca:P ratio was consistent for all of the sampled animals.

Although, dhub meat has a high protein and low fat content (Abu-Tarboush *et al*, 1996) it is not without probability that they can store surplus vitamin D in the reserves that they have. Perhaps there are multi-faceted interactions at play and a combination of pigmentation and vitamin D sequestering are at play resulting in the reduced 25(OH)D levels observed in the dhub. However, this does not explain the difference between animals at the two locations. From the current study, Ca and P levels were similar to those published (Elamin, 2004; Barcello & Tourenq, 2005; Naldo *et al*, 2009; Teare, 2013). However, the mean Ca:P ratio at 2.7:1 was not as per that suggested by Salmon & Griffin (2012), and Donoghue (2006).

Excessive exposure to UVB can lead to toxic levels of vitamin D. This can, however, be controlled by a photo-degradation process (Chen *et al*, 2007) amongst other factors. It has been suggested that there would be adaptive factors utilised by different reptile species to maintain their level of exposure to UV light within a certain safe range (Sakich & Tattersall, 2022) and the evidence in this study supports these assertions. The movement of vitamin D and 25(OH)D is mediated by DBP, binding 85 to 90% of total circulating 25(OH)D. The DBP fraction consists primarily of 25(OH)D bound to albumin, with less than 1% of total 25(OH)D in the free form. Due to the high affinity of 25(OH)D to DBP, the albumin and free part are referred to as the bioavailable portion (Oleröd *et al*, 2017). Powe *et al* (2013) suggests that DBP also appears to inhibit some actions of vitamin D because the bound fraction may be unavailable to act on target cells. The success of releasing 25(OH)D from DBP prior to lab analysis plays a critical role in the return of accurate results. Heijboer *et al* (2012) in their study suggested that in fully automated assays, not all 25(OH)D is extracted from the DBP in sera that have a relatively high DBP concentration. They add that such incomplete extraction leads to falsely low 25(OH)D concentration results. If, perhaps, reptile DBP acts in a different manner to human DBP then it could be argued that not all of the 25(OH)D was released during the analysis which might lead to the low results. Again, this would not however explain the differences between locations.

5.4.2 PARASITOLOGY

While the majority of the dhub captured showed no signs of illness, some were emaciated, had damaged tail tips and one had what appeared to be a form of arthritis on the front legs. A number did appear to have an ectoparasitic mite similar to chiggers (Trombiculid). As only the blood smears were examined, the genera or groups identified on examination were reported. As such, the true level of parasitosis was not determined. A 30% infection rate with haemoparasites for this study is far less than those reported by others where they had a confirmed infection rate of 65% (Naldo *et al*, 2006; Naldo *et al*, 2009). Blood parasitism is relatively frequent in animals from the wild, but the clinical significance is low and they are usually considered an incidental finding (Šlapeta *et al*, 2017; Damas-Moreira *et al*, 2022). However, long-term effects of parasites on amphibians and reptiles are relatively poorly known (Vitt & Caldwell, 2013), and new parasite species are being frequently described (Telford *et al*, 2012).

5.4.3 OVERGRAZING

It is suggested that, as WAS had an issue with overgrazing from gazelle and camels, that the available resources for dhub to acquire the required nutrition were not as readily available as those in MUG which was not subject to such severe grazing. As such, the animals in WAS would conceivably be required to spend longer time foraging than those in MUG, perhaps exposing areas which have lesser pigmentation to more UVB radiation. One can rule out the additional 25(OH)D levels in WAS as derived from scavenged material which might be a strategy in times of food shortage as suggested by Castilla *et al* (2011), as all the results looked only at 25(OH)D_3. Differences in levels in 2016 between sites were not as pronounced which would tie in with the increased vegetation, therefore reduced foraging time, which resulted from the rain early in 2016 (see Chapter 4 for additional information). This increased exposure could also potentially have a cleansing effect with regards large external ectoparasites which were absent on all captured dhub.

5.4.4 CONCLUSION

In all conservation translocation procedures, the health status of the animals being considered for translocation needs to be determined (IUCN/SSC, 2013). In many instances, animals will need to be housed for varying durations prior to any translocation or for veterinary procedures prior to the translocation (Barcello & Tourenq, 2005). While basic haematological and biochemical parameters are known about similar species it is essential to get as much specific data as possible on the animals concerned.

Raphael *et al* (1999) recorded 25(OH)D levels of 54 ± 34 nmol/L (n=14) in the animals that they studied

which is similar to the current study. These are the only two studies known to have looked at the vitamin D status in this species that has been found in the literature. The current study is the only one known to look at *Uromastyx aegyptia* vitamin D levels in the wild state. Raphael *et al* (1999) worked on captive animals with unknown husbandry or dietary status.

Reference intervals (RI) are by no means easy to determine or should not be used interchangeably unless the full details of where the samples came from, when they were collected, age of the animals, health of the animals etc. are known. For example, the results from Gillespie *et al* (2000) use a commercial radioimmunoassay kit which gave results considered extreme by National Institue of Health (2016). It is then up to the clinician to determine the value of the RI that they will be using. The current study does just this and all of the information is detailed (APPENDIX 5-1 and APPENDIX 5-2).

This study has gone a long way to determine what these RI should be. However, due to the relationship between parathyroid hormone (PTH) and circulating levels of 25(OH)D it would be advantageous for future studies to determine levels for PTH, to see whether there is an equilibrium between the two.

What is clear from these results is that there is not much agreement on what reference intervals should be in human or non-human animals. It is believed that one is at risk of anthropomorphising the requirements of reptiles in our quest for what is a normal reference interval and perhaps reptiles who in their natural environment are exposed to high levels of UV radiation do not require similar levels to humans. Dhub are diurnal and ectothermic and spend up 28% of daylight hours in direct sunlight where UVI values could reach between UVI five or six before retreating to their burrow. Perhaps, the basal rate of circulating 25(OH)D is much lower in dhub as suggested in the results. Sequestered vitamin D might be released as required and then topped up with minimum exposure. It is concluded that the RI for dhub is seasonal and actually much lower than one would expect of humans under the same conditions during the summer. Within a few days of capture there could be significant differences in the circulating 25(OH)D levels in the same animal (Appendix 3). For example, WAS 040 was captured 3 times in 2016. After the first capture and over a period of 21 days levels dropped 25.8 nmol/L but increased by 10.4 nmol/L the next day. One could suggest that perhaps dhub are regulating their vitamin D levels rather than maximising them as has been suggested by Ferguson *et al* (2015) for other iguanids. This is why we see the differences between years.

With regards to the level of parasites recorded, as it was a very basic look at the haemoparasites status of the captured dhub, it would be important to look at infection rate (and include endoparasites) during September and again in March when activity increases. Better screening would also be

required prior to holding any specimens prior to a translocation.

While we now have a better understanding of vitamin D status in non-captive dhub, there are still issues which need to be addressed when it comes to the captive environment. This was highlighted from the 3 collections where animals housed under artificial lights were sampled. Two of these collections maintained their animals in an environment where levels were considered sufficient, but the third had animals which would be considered deficient. While the current study primarily focused on wild dhub, the captive held dhub results were not presented in the results to reduce the risk of bias. Three animals (one male and two females) from a captive environment that were exposed to UV lights showed the highest levels of 25(OH)D. These had a mean 25(OH)D of 136.4 nmol/L and a Ca:P ratio of 2.3:1. The question has to be asked, are we incorrectly using values from artificial environments to guide the veterinary care of our animals? This certainly would need to be investigated further. Another very important factor to take into consideration is the method of Vitamin D elucidation. At the time of processing, liquid chromatography with tandem mass spectrometry (LC-MS-MS) was the gold standard in Vit D analysis.

Although the ultimate conservation goal is to avoid the need for animal translocation, in cases where it becomes necessary, it is crucial to prioritise the swift release of the animals. When immediate release is not possible, it becomes vitally important to meticulously manage all relevant veterinary and environmental factors in translocation programs to safeguard the well-being and health of the animals throughout the process.

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APPENDIX 5-1 - REFERENCE INTERVALS FOR DHUB

Table 5-21.Reference values for dhub in WAS and MUG for 2015 and 2016.

		N	Min	Max	Mean	Median	SD	Parametric		Non-Parametric	
								Lower	Upper	Lower	Upper
HB (g/dL)	WAS 2015	34	6.7	18.8	9.92	9.00	2.60	4.83	15.01	**6.70***	**18.80***
	MUG 2015	18	6.0	12.1	8.85	8.50	1.62	5.67	12.03	6.00	12.10
	WAS 2016	53	5.0	11.9	8.38	8.20	1.51	5.41	11.35	5.35	11.76
	MUG 2016	25	5.9	12.5	8.2	7.9	1.897	4.48	11.91	5.9	12.5
HCT (%)	WAS 2015	34	18.0	51.0	27.5	25.50	6.89	14.37	41.39	18.00	51.00
	MUG 2015	18	16.0	33.0	23.39	22.50	4.59	14.39	32.39	16.00	33.00
	WAS 2016	53	15.0	35.0	24.58	24.00	4.44	15.88	33.29	16.05	34.65
	MUG 2016	25	17.0	35.0	24.0	23.0	5.400	13.37	34.55	17.00	35.00
WBC (103/µl)	WAS 2015	34	1.1	3.8	2.07	2.00	0.68	0.73	3.40	**1.10***	**3.80***
	MUG 2015	18	1.1	3.0	1.66	1.60	0.43	0.81	2.50	**1.10***	**3.00***
	WAS 2016	53	1.7	6.0	2.64	2.40	0.81	1.05	4.23	**1.74***	**5.41***
	MUG 2016	25	1.8	5.6	3.15	2.9	1.09	1.01	5.28	1.8	5.6
Azuro (%)	WAS 2015	35	1.0	13.0	5.09	5.00	2.15	0.88	9.29	**1.00***	**13.00***
	MUG 2015	18	3.0	9.0	5.17	4.00	1.82	1.59	8.73	3.00	9.00
	WAS 2016	53	2.0	10.0	6.11	6.00	2.17	1.86	10.37	2.00	10.00
	MUG 2016	25	3.0	11.0	7.76	8.00	1.71	4.40	11.12	3.00	11.00
Lymph (%)	WAS 2015	35	8.0	16.0	12.00	12.00	1.73	8.61	15.39	8.00	16.00
	MUG 2015	18	7.0	16.0	11.67	12.00	2.63	6.50	16.83	7.00	16.00
	WAS 2016	53	7.0	18.0	11.72	12.00	2.03	7.73	17.70	**7.35***	**18.00***
	MUG 2016	25	7.0	17.0	10.28	9.00	2.65	5.08	15.48	7.00	17.00
Hetero (%)	WAS 2015	35	74.0	87.0	81.74	82.00	2.77	76.32	87.17	74.00	87.00
	MUG 2015	18	76.0	88.0	81.50	81.00	3.13	75.37	87.63	76.00	88.00
	WAS 2016	53	76.0	86.0	80.36	80.00	2.57	75.33	85.39	76.00	85.65
	MUG 2016	25	70.0	84.0	80.08	81.00	3.41	73.39	86.77	**70.00***	**84.00***
Baso (%)	WAS 2015	35	0.0	1.0	0.06	0.00	0.24	-0.40	0.52	**0.00***	**1.00***
	MUG 2015	18	0.00	1.00	0.06	0.00	0.24	-0.41	0.52	**0.00***	**1.00***
	WAS 2016	53	0.0	1.0	0.08	0.00	0.27	-0.45	0.60	**0.00***	**1.00***
	MUG 2016										

Table 5-21. Reference values for dhub in WAS and MUG for 2015 and 2016. (*Continued*)

		N	Min	Max	Mean	Median	SD	Parametric		Non-Parametric	
								Lower	Upper	Lower	Upper
Mono (%)	WAS 2015	35	0.0	3.0	1.1	1.0	0.68	-0.21	2.44	**0.00***	**3.00***
	MUG 2015	18	1.0	3.0	1.56	1.00	0.71	0.17	2.94	1.00	3.00
	WAS 2016	53	1.0	5.0	1.75	2.00	0.88	0.04	3.47	**1.00***	**4.30***
	MUG 2016	25	1.0	3.0	1.60	2.00	0.65	0.33	2.87	1.00	3.00
Ca (mg/dL)	WAS 2015	35	9.1	10.0	9.60	9.60	0.24	9.12	10.08	9.10	10.00
	MUG 2015	18	9.2	9.9	9.63	9.65	0.24	9.17	10.09	9.20	9.90
	WAS 2016	25	9.7	11.0	10.26	10.20	0.38	9.522	11.01	9.70	11.00
	MUG 2016	25	9.7	11.0	10.26	10.20	0.38	9.522	11.01	9.70	11.00
iCa^{++} (mmol/L)	WAS 2015	35	0.92	1.59	14.28	1.28	0.12	1.05	1.53	0.92	1.59
	MUG 2015	18	1.13	1.39	1.27	1.27	0.09	1.10	1.43	1.13	1.39
	WAS 2016	25	1.04	1.55	1.32	1.37	0.14	1.04	1.60	1.04	1.60
	MUG 2016	25	1.04	1.55	1.32	1.37	0.14	1.04	1.60	1.04	1.60
CHOL (mg/dL)	WAS 2015	35	94.0	540.0	259.89	236.00	106.33	51.48	468.29	94.00	540.00
	MUG 2015	18	82.0	433.0	185.89	177.00	82.00	25.18	346.60	82.00*	433.0*
	WAS 2016	25	56.0	214.0	121.84	119.00	35.54	52.19	191.49	56.00	214.00
	MUG 2016	25	56.0	214.0	121.84	119.00	35.54	52.19	191.49	56.00	214.00
Phos (mg/dL)	WAS 2015	35	2.2	15.9	3.72	3.30	2.24	-0.68	8.12	2.20*	15.90*
	MUG 2015	18	2.5	5.0	4.01	4.00	0.60	2.83	5.19	2.50	5.00
	WAS 2016	25	2.4	5.6	3.66	3.50	0.84	2.03	5.30	2.40	5.60
	MUG 2016	25	2.4	5.6	3.66	3.50	0.84	2.03	5.30	2.40	5.60
TP (g/dL)	WAS 2015	35	2.0	7.8	3.51	3.30	0.96	1.62	5.40	2.00	7.80
	MUG 2015	18	3.0	4.6	3.57	3.55	0.40	2.80	4.35	3.00	4.60
	WAS 2016	25	2.1	4.5	3.30	3.30	0.49	2.34	4.26	2.10	4.50
	MUG 2016	25	2.1	4.5	3.30	3.30	0.49	2.34	4.26	2.10	4.50
VitD3 (nmol/L)	WAS 2015	34	31.6	141.6	68.96	65.31	25.70	18.60	119.32	31.62	141.60
	MUG 2015	18	9.2	77.9	35.95	32.67	16.24	4.11	67.78	9.17*	77.89*
	WAS 2016	24	33.0	143.8	70.13	65.74	27.00	17.25	123.01	33.00	143.81
	MUG 2016	24	33.0	143.8	70.13	65.74	27.00	17.25	123.01	33.00	143.81

Parameters in bold were not normally distributed (D'Agostino-Pearson test for Normal distribution P<0.05) therefore the non-parametric value should be used).

Table 5-21. Reference values for dhub in WAS and MUG for 2015 and 2016. (*Continued*)

		N	Min	Max	Mean	Median	SD	Parametric		Non-Parametric	
								Lower	Upper	Lower	Upper
UA (mg/dL)	WAS 2015	35	2.7	18.2	7.35	6.90	2.89	1.69	13.01	2.70*	18.20*
	MUG 2015	18	2.9	6.9	4.66	4.70	1.01	2.68	6.63	2.90	6.90
	WAS 2016	25	2.0	8.4	4.18	4.00	1.41	1.422	6.95	2.00*	8.40*
	MUG 2016	25	2.0	8.4	4.18	4.00	1.41	1.422	6.95	2.00*	8.40*
GLU (mg/dL)	WAS 2015	35	102.0	285.0	198.80	198.00	35.95	128.34	269.26	102.00	285.00
	MUG 2015	18	101.0	224.0	161.83	165.00	31.93	99.24	224.42	101.00	224.00
	WAS 2016	25	93.0	230.0	150.96	137.00	38.41	75.67	226.25	93.00	230.00
	MUG 2016	25	93.0	230.0	150.96	137.00	38.41	75.67	226.25	93.00	230.00
AST (U/L)	WAS 2015	34	15.0	138.0	52.99	47.50	31.44	-8.64	114.61	15.00*	138.0*
	MUG 2015	18	15.0	118.0	42.06	36.50	26.55	-9.99	94.10	15.00	118.00
	WAS 2016										
	MUG 2016	25	16.0	172.0	49.36	36.00	37.00	-23.10	121.82	16.00*	172.0*
CK (U/L)	WAS 2015	33	247.0	6665.0	1835.4	1176.0	1639.7	-1378	5049.2	247.0*	6665*
	MUG 2015	18	195.0	6681.0	1824.6	1140.5	1730.2	-1566	5215.7	195.0*	6681*
	WAS 2016	24	245.0	6175.0	1480.1	938.00	1705.3	-1862	4822.5	245.0*	6175*
	MUG 2016	24	245.0	6175.0	1480.1	938.00	1705.3	-1862	4822.5	245.0*	6175*
ALT (U/L)	WAS 2015	35	3.0	68.0	10.99	8.00	12.52	-13.54	35.12	**3.00***	**68.00***
	MUG 2015	18	4.0	17.0	8.61	7.65	3.80	1.17	16.06	4.00	17.00
	WAS 2016	25	7.0	19.0	10.48	9.00	3.45	3.71	17.25	**7.00***	**19.00***
	MUG 2016	25	7.0	19.0	10.48	9.00	3.45	3.71	17.25	**7.00***	**19.00***
LDH (U/L)	WAS 2015	35	103.0	11512	771.23	249.00	1922.3	-2996	4538.9	**103.0***	**11512***
	MUG 2015	18	169.0	3324.0	708.67	461.0	810.5	-879.9	2297.2	**169.0***	**3324***
	WAS 2016	24	54.0	6856.0	602.71	233.00	1384.9	-211.7	3317.1	**54.00***	**6856***
	MUG 2016	24	54.0	6856.0	602.71	233.00	1384.9	-211.7	3317.1	**54.00***	**6856***
CREA (mg/dL)	WAS 2015	35	0.1	0.2	0.109	0.10	0.03	0.05	0.16	**0.10***	**0.20***
	MUG 2015	18	0.1	0.2	0.11	0.10	0.32	0.05	0.17	**0.10***	**0.20***
	WAS 2016	25	0.1	0.1	0.1						
	MUG 2016	25	0.1	0.1	0.1						

Parameters in bold were not normally distributed (D'Agostino-Pearson test for Normal distribution P<0.05) therefore the non-parametric value should be used)

Table 5-21. Reference values for dhub in WAS and MUG for 2015 and 2016. (*Continued*)

		N	Min	Max	Mean	Median	SD	Parametric		Non-Parametric	
								Lower	Upper	Lower	Upper
ALB (g/dL)	WAS 2015	35	1.5	3.4	2.08	1.90	0.45	1.20	2.96	**1.50***	**3.40***
	MUG 2015	18	1.4	2.8	1.95	1.80	0.36	1.24	2.66	1.40	2.80
	WAS 2016	25	1.4	2.5	1.94	1.90	0.35	1.26	2.63	1.40	2.50
	MUG 2016	25	1.4	2.5	1.94	1.90	0.35	1.26	2.63	1.40	2.50
ALP (U/L)	WAS 2015	35	15.0	57.0	32.23	30.00	10.88	10.91	53.55	15.00	57.00
	MUG 2015	18	10.0	61.0	30.06	25.00	14.58	1.47	58.64	10.00	61.00
	WAS 2016	25	14.0	43.0	24.12	21.00	8.24	7.96	40.28	14.00	43.00
	MUG 2016	25	14.0	43.0	24.12	21.00	8.24	7.96	40.28	14.00	43.00
BUN (mg/dL)	WAS 2015	35	1.4	2.0	1.60	1.50	0.17	1.26	1.94	**1.40***	**2.00***
	MUG 2015	18	1.5	2.0	1.64	1.60	0.15	1.34	1.95	1.50	2.00
	WAS 2016	25	0.7	2.0	0.90	0.90	0.25	0.41	1.39	**0.70***	**2.00***
	MUG 2016	25	0.7	2.0	0.90	0.90	0.25	0.41	1.39	**0.70***	**2.00***
Urea (mg/dL)	WAS 2015	35	3.9	5.6	4.46	4.20	0.48	3.52	5.41	**3.90***	**5.60***
	MUG 2015	18	4.2	5.6	4.59	4.50	0.42	3.77	5.41	4.20	5.60
	WAS 2016	25	1.5	4.2	1.94	1.90	0.51	0.95	2.93	**1.50***	**4.20***
	MUG 2016	25	1.5	4.2	1.94	1.90	0.51	0.95	2.93	**1.50***	**4.20***
GLOB (g/dL)	WAS 2015	35	0.5	5.1	1.45	1.40	0.79	-0.09	3.00	**0.50***	**5.10***
	MUG 2015	18	1.2	2.0	1.63	1.65	0.23	1.18	2.08	1.20	2.00
	WAS 2016	25	0.7	2.6	1.36	1.30	0.36	0.64	2.07	**0.70***	**2.60***
	MUG 2016	25	0.7	2.6	1.36	1.30	0.36	0.64	2.07	**0.70***	**2.60***
Na (mmol/L)	WAS 2015	35	143.0	180.0	165.34	165.00	6.57	152.46	178.22	**143.0***	**180.0***
	MUG 2015	18	160.0	171.0	164.50	164.50	3.29	158.04	170.96	160.00	171.00
	WAS 2016	25	160.0	177.0	164.36	163.00	3.53	157.43	171.29	**160.0***	**177.0***
	MUG 2016	25	160.0	177.0	164.36	163.00	3.53	157.43	171.29	**160.0***	**177.0***

Parameters in bold were not normally distributed (D'Agostino-Pearson test for Normal distribution P<0.05) therefore the non-parametric value should be used)

Table 5-21. Reference values for dhub in WAS and MUG for 2015 and 2016. (*Continued*)

		N	Min	Max	Mean	Median	SD	Parametric		Non-Parametric	
								Lower	Upper	Lower	Upper
K (mmol/L)	WAS 2015	35	2.0	6.0	3.23	3.20	0.83	1.59	4.86	**2.00***	**6.00***
	MUG 2015	18	2.0	5.5	3.42	3.30	0.71	2.016	4.82	**2.00***	**5.50***
	WAS 2016	25	2.0	3.7	2.86	2.70	0.53	1.80	3.90	2.00	3.70
	MUG 2016	25	2.0	3.7	2.86	2.70	0.53	1.80	3.90	2.00	3.70
Total Bil (mg/dL)	WAS 2015	35	1.0	1.4	1.16	1.10	0.12	0.94	1.38	1.00	1.40
	MUG 2015	18	0.9	1.5	1.19	1.20	0.12	0.95	1.43	**0.90***	**1.50***
	WAS 2016	25	1.7	2.3	2.04	2.00	0.16	1.74	2.34	1.70	2.30
	MUG 2016	25	1.7	2.3	2.04	2.00	0.16	1.74	2.34	1.70	2.30

Parameters in bold were not normally distributed (D'Agostino-Pearson test for Normal distribution P<0.05) therefore the non-parametric value should be used)

Table 5-22. Reference values for dhub (sexes combined) in MUG 2016 (September and October).

	N	Min	Max	Mean	Median	SD	Parametric		Non-Parametric	
							Lower	Upper	Lower	Upper
HB (g/dL)	25	5.9	12.5	8.2	7.9	1.897	4.48	11.91	5.9	12.5
HCT (%)	25	17.0	35.0	24.0	23.0	5.400	13.37	34.55	17.00	35.00
WBC (10^3/µl)	25	1.8	5.6	3.15	2.9	1.09	1.01	5.28	1.8	5.6
Azuro (%)	25	3.0	11.0	7.76	8.00	1.71	4.40	11.12	3.00	11.00
Lymph (%)	25	7.0	17.0	10.28	9.00	2.65	5.08	15.48	7.00	17.00
Hetero (%)	25	70.0	84.0	80.08	81.00	3.41	73.39	86.77	**70.00***	**84.00***
Baso (%)										
Mono (%)	25	1.0	3.0	1.60	2.00	0.65	0.33	2.87	1.00	3.00
Ca (mg/dL)	25	9.7	11.0	10.26	10.20	0.38	9.522	11.01	9.70	11.00
iCa^{++} (mmol/L)	25	1.04	1.55	1.32	1.37	0.14	1.04	1.60	1.04	1.60
CHOL (mg/dL)	25	56.0	214.0	121.84	119.00	35.54	52.19	191.49	56.00	214.00
Phos (mg/dL)	25	2.4	5.6	3.66	3.50	0.84	2.03	5.30	2.40	5.60
TP (g/dL)	25	2.1	4.5	3.30	3.30	0.49	2.34	4.26	2.10	4.50
VitD_3 (nmol/L)	24	33.0	143.8	70.13	65.74	27.00	17.25	123.01	33.00	143.81
UA (mg/dL)	25	2.0	8.4	4.18	4.00	1.41	1.422	6.95	**2.00***	**8.40***
GLU (mg/dL)	25	93.0	230.0	150.96	137.00	38.41	75.67	226.25	93.00	230.00
AST (U/L)	25	16.0	172.0	49.36	36.00	37.00	-23.10	121.82	**16.00***	**172.0***
CK (U/L)	24	245.0	6175.0	1480.1	938.00	1705.3	-1862	4822.5	**245.0***	**6175***
ALT (U/L)	25	7.0	19.0	10.48	9.00	3.45	3.71	17.25	**7.00***	**19.00***
LDH (U/L)	24	54.0	6856.0	602.71	233.00	1384.9	-211.7	3317.1	**54.00***	**6856***
CREA (mg/dL)	25	0.1	0.1	0.1						
ALB (g/dL)	25	1.4	2.5	1.94	1.90	0.35	1.26	2.63	1.40	2.50
ALP (U/L)	25	14.0	43.0	24.12	21.00	8.24	7.96	40.28	14.00	43.00
BUN (mg/dL)	25	0.7	2.0	0.90	0.90	0.25	0.41	1.39	**0.70***	**2.00***
Urea (mg/dL)	25	1.5	4.2	1.94	1.90	0.51	0.95	2.93	**1.50***	**4.20***
GLOB (g/dL)	25	0.7	2.6	1.36	1.30	0.36	0.64	2.07	**0.70***	**2.60***
Na (mmol/L)	25	160.0	177.0	164.36	163.00	3.53	157.43	171.29	**160.0***	**177.0***
K (mmol/L)	25	2.0	3.7	2.86	2.70	0.53	1.80	3.90	2.00	3.70
TotalBil (mg/dL)	25	1.7	2.3	2.04	2.00	0.16	1.74	2.34	1.70	2.30

Parameters in bold were not normally distributed (D'Agostino-Pearson test for Normal distribution P<0.05) therefore the non-parametric value should be used)

Table 5-23. Reference values for dhub (sexes combined) in WAS 2016 (September and October).

	N	Min	Max	Mean	Median	SD	Parametric		Non-Parametric	
							Lower	Upper	Lower	Upper
HB (g/dL)	53	5.0	11.9	8.38	8.20	1.51	5.41	11.35	5.35	11.76
HCT (%)	53	15.0	35.0	24.58	24.00	4.44	15.88	33.29	16.05	34.65
WBC (103/µl)	53	1.7	6.0	2.64	2.40	0.81	1.05	4.23	**1.74***	**5.41***
Azuro (%)	53	2.0	10.0	6.11	6.00	2.17	1.86	10.37	2.00	10.00
Lymph (%)	53	7.0	18.0	11.72	12.00	2.03	7.73	17.70	**7.35***	**18.00***
Hetero (%)	53	76.0	86.0	80.36	80.00	2.57	75.33	85.39	76.00	85.65
Baso (%)	53	0.0	1.0	0.08	0.00	0.27	-0.45	0.60	**0.00***	**1.00***
Mono (%)	53	1.0	5.0	1.75	2.00	0.88	0.04	3.47	**1.00***	**4.30***
Ca (mg/dL)	53	9.3	12.0	10.72	10.80	0.40	9.94	11.50	**9.58***	**11.76***
iCa++ (mmol/L)	53	1.0	1.7	1.42	1.43	0.09	1.25	1.59	**1.11***	**1.65***
CHOL (mg/dL)	53	1.9	650.0	180.26	160.00	104.20	-23.97	384.49	**26.09***	**582.8***
Phos (mg/dL)	53	1.7	9.0	3.37	3.10	1.43	0.57	6.16	**1.74***	**8.62***
TP (g/dL)	53	2.2	6.5	3.38	3.30	0.77	1.88	4.88	**2.27***	**5.84***
VitD3 (nmol/L)	51	15.5	206.8	104.78	106.89	40.05	29.28	183.27	18.31	201.49
UA (mg/dL)	53	1.8	11.3	4.33	3.80	1.78	0.85	7.81	**1.87***	**10.29***
GLU (mg/dL)	53	130.0	265.0	198.51	201.00	29.02	141.63	255.39	130.35	262.90
AST (U/L)	53	10.0	177.0	54.36	41.00	41.69	-27.32	136.07	**10.35***	**168.6***
CK (U/L)	52	140.0	7941.0	1833.2	1081.5	1859.7	-1811	5478.1	**148.8***	**7525***
ALT (U/L)	53	5.0	32.0	12.26	11.0	4.83	2.80	21.73	**5.35***	**29.20***
LDH (U/L)	53	39.0	3514.0	480.83	267.00	687.59	-866.8	1828.5	**45.65***	**3231***
CREA (mg/dL)	53	0.1	0.1	0.1						
ALB (g/dL)	53	1.2	5.8	2.22	2.10	0.69	0.85	3.58	**1.30***	**5.17***
ALP (U/L)	53	12.0	88.0	32.53	29.00	16.24	0.71	64.35	**12.35***	**88.00***
BUN (mg/dL)	53	0.8	2.0	1.10	0.90	0.38	0.35	1.85	**0.80***	**2.00***
Urea (mg/dL)	53	1.7	4.2	2.31	1.90	0.79	0.76	3.86	**1.70***	**4.20***
GLOB (g/dL)	53	0.7	2.6	1.18	1.10	0.41	0.38	2.00	**0.70***	**2.46***
Na (mmol/L)	53	151.0	174.0	161.81	162.00	4.46	153.07	170.55	152.05	172.25
K (mmol/L)	53	2.0	5.4	3.03	3.10	0.66	1.73	4.33	**2.00***	**5.12***
TotalBil (mg/dL)	53	1.3	2.4	2.03	2.00	0.18	1.67	2.39	1.44	2.40

Parameters in bold were not normally distributed (D'Agostino-Pearson test for Normal distribution P<0.05) therefore the non-parametric value should be used)

Table 5-24. Reference values for dhub (sexes combined) in MUG 2015 (March and April).

	N	Min	Max	Mean	Median	SD	Parametric		Non-Parametric	
							Lower	Upper	Lower	Upper
HB (g/dL)	18	6.0	12.1	8.85	8.50	1.62	5.67	12.03	6.00	12.10
HCT (%)	18	16.0	33.0	23.39	22.50	4.59	14.39	32.39	16.00	33.00
WBC (10^3/µl)	18	1.1	3.0	1.66	1.60	0.43	0.81	2.50	**1.10***	**3.00***
Azuro (%)	18	3.0	9.0	5.17	4.00	1.82	1.59	8.73	3.00	9.00
Lymph (%)	18	7.0	16.0	11.67	12.00	2.63	6.50	16.83	7.00	16.00
Hetero (%)	18	76.0	88.0	81.50	81.00	3.13	75.37	87.63	76.00	88.00
Baso (%)	18	0.00	1.00	0.06	0.00	0.24	-0.41	0.52	**0.00***	**1.00***
Mono (%)	18	1.0	3.0	1.56	1.00	0.71	0.17	2.94	1.00	3.00
Ca (mg/dL)	18	9.2	9.9	9.63	9.65	0.24	9.17	10.09	9.20	9.90
iCa^{++} (mmol/L)	18	1.13	1.39	1.27	1.27	0.09	1.10	1.43	1.13	1.39
CHOL (mg/dL)	18	82.0	433.0	185.89	177.00	82.00	25.18	346.60	**82.00***	**433.0***
Phos (mg/dL)	18	2.5	5.0	4.01	4.00	0.60	2.83	5.19	2.50	5.00
TP (g/dL)	18	3.0	4.6	3.57	3.55	0.40	2.80	4.35	3.00	4.60
$VitD_3$ (nmol/L)	18	9.2	77.9	35.95	32.67	16.24	4.11	67.78	**9.17***	**77.89***
UA (mg/dL)	18	2.9	6.9	4.66	4.70	1.01	2.68	6.63	2.90	6.90
GLU (mg/dL)	18	101.0	224.0	161.83	165.00	31.93	99.24	224.42	101.00	224.00
AST (U/L)	18	15.0	118.0	42.06	36.50	26.55	-9.99	94.10	15.00	118.00
CK (U/L)	18	195.0	6681.0	1824.6	1140.5	1730.2	-1566	5215.7	**195.0***	**6681***
ALT (U/L)	18	4.0	17.0	8.61	7.65	3.80	1.17	16.06	4.00	17.00
LDH (U/L)	18	169.0	3324.0	708.67	461.0	810.5	-879.9	2297.2	**169.0***	**3324***
CREA (mg/dL)	18	0.1	0.2	0.11	0.10	0.32	0.05	0.17	**0.10***	**0.20***
ALB (g/dL)	18	1.4	2.8	1.95	1.80	0.36	1.24	2.66	1.40	2.80
ALP (U/L)	18	10.0	61.0	30.06	25.00	14.58	1.47	58.64	10.00	61.00
BUN (mg/dL)	18	1.5	2.0	1.64	1.60	0.15	1.34	1.95	1.50	2.00
Urea (mg/dL)	18	4.2	5.6	4.59	4.50	0.42	3.77	5.41	4.20	5.60
GLOB (g/dL)	18	1.2	2.0	1.63	1.65	0.23	1.18	2.08	1.20	2.00
Na (mmol/L)	18	160.0	171.0	164.50	164.50	3.29	158.04	170.96	160.00	171.00
K (mmol/L)	18	2.0	5.5	3.42	3.30	0.71	2.016	4.82	**2.00***	**5.50***
TotalBil (mg/dL)	18	0.9	1.5	1.19	1.20	0.12	0.95	1.43	**0.90***	**1.50***

Parameters in bold were not normally distributed (D'Agostino-Pearson test for Normal distribution P<0.05) therefore the non-parametric value should be used)

Table 5-25. Reference values for dhub (sexes combined) in WAS 2015 (March and April).

	N	Min	Max	Mean	Median	SD	Parametric		Non-Parametric	
							Lower	Upper	Lower	Upper
HB (g/dL)	34	6.7	18.8	9.92	9.00	2.60	4.83	15.01	**6.70***	**18.80***
HCT (%)	34	18.0	51.0	27.5	25.50	6.89	14.37	41.39	18.00	51.00
WBC (10^3/µl)	34	1.1	3.8	2.07	2.00	0.68	0.73	3.40	1.10*	3.80*
Azuro (%)	35	1.0	13.0	5.09	5.00	2.15	0.88	9.29	**1.00***	**13.00***
Lymph (%)	35	8.0	16.0	12.00	12.00	1.73	8.61	15.39	8.00	16.00
Hetero (%)	35	74.0	87.0	81.74	82.00	2.77	76.32	87.17	74.00	87.00
Baso (%)	35	0.0	1.0	0.06	0.00	0.24	-0.40	0.52	**0.00***	**1.00***
Mono (%)	35	0.0	3.0	1.1	1.0	0.68	-0.21	2.44	**0.00***	**3.00***
Ca (mg/dL)	35	9.1	10.0	9.60	9.60	0.24	9.12	10.08	9.10	10.00
iCa^{++} (mmol/L)	35	0.92	1.59	14.28	1.28	0.12	1.05	1.53	0.92	1.59
CHOL (mg/dL)	35	94.0	540.0	259.89	236.00	106.33	51.48	468.29	94.00	540.00
Phos (mg/dL)	35	2.2	15.9	3.72	3.30	2.24	-0.68	8.12	**2.20***	**15.90***
TP (g/dL)	35	2.0	7.8	3.51	3.30	0.96	1.62	5.40	2.00	7.80
$VitD_3$ (nmol/L)	34	31.6	141.6	68.96	65.31	25.70	18.60	119.32	31.62	141.60
UA (mg/dL)	35	2.7	18.2	7.35	6.90	2.89	1.69	13.01	**2.70***	**18.20***
GLU (mg/dL)	35	102.0	285.0	198.80	198.00	35.95	128.34	269.26	102.00	285.00
AST (U/L)	34	15.0	138.0	52.99	47.50	31.44	-8.64	114.61	**15.00***	**138.0***
CK (U/L)	33	247.0	6665.0	1835.4	1176.0	1639.7	-1378	5049.2	**247.0***	**6665***
ALT (U/L)	35	3.0	68.0	10.99	8.00	12.52	-13.54	35.12	**3.00***	**68.00***
LDH (U/L)	35	103.0	11512	771.23	249.00	1922.3	-2996	4538.9	**103.0***	**11512***
CREA (mg/dL)	35	0.1	0.2	0.109	0.10	0.03	0.05	0.16	**0.10***	**0.20***
ALB (g/dL)	35	1.5	3.4	2.08	1.90	0.45	1.20	2.96	**1.50***	**3.40***
ALP (U/L)	35	15.0	57.0	32.23	30.00	10.88	10.91	53.55	15.00	57.00
BUN (mg/dL)	35	1.4	2.0	1.60	1.50	0.17	1.26	1.94	**1.40***	**2.00***
Urea (mg/dL)	35	3.9	5.6	4.46	4.20	0.48	3.52	5.41	**3.90***	**5.60***
GLOB (g/dL)	35	0.5	5.1	1.45	1.40	0.79	-0.09	3.00	**0.50***	**5.10***
Na (mmol/L)	35	143.0	180.0	165.34	165.00	6.57	152.46	178.22	**143.0***	**180.0***
K (mmol/L)	35	2.0	6.0	3.23	3.20	0.83	1.59	4.86	**2.00***	**6.00***
TotalBil (mg/dL)	35	1.0	1.4	1.16	1.10	0.12	0.94	1.38	1.00	1.40

Parameters in bold were not normally distributed (D'Agostino-Pearson test for Normal distribution P<0.05) therefore the non-parametric value should be used)

Table 5-26. Reference values for weight and length for males and females in 2016.

	N	Min	Max	Mean	Median	SD	Parametric		Non-Parametric	
							Lower	Upper	Lower	Upper
Weight (gr) (M)	31	1172.0	2168.0	1539.9	1470.0	268.11	1014.4	2065.4	1172.0	2168.0
Weight (gr) (F)	47	529.0	1174.0	785.5	785.0	139.2	512.6	1058.4	540.2	1150.6
Length (mm) (M)	30	558.0	693.0	625.3	627.5	35.3	556.1	694.6	558.0	693.0
Length (mm) (F)	46	431.0	556.0	502.6	498.0	26.8	450.1	555.1	434.5	555.8

Table 5-27. Reference values for weight and length for males and females in 2015.

	N	Min	Max	Mean	Median	SD	Parametric		Non-Parametric	
							Lower	Upper	Lower	Upper
Weight (gr) (M)	25	1122.0	1965.0	1464.2	1374.0	249.91	974.4	1954.0	1122.0	1965.0
Weight (gr) (F)	28	569.0	1089.0	788.80	797.50	121.32	550.9	1026.5	569.0	1089.0
Length (mm) (M)	22	567.0	687.0	626.90	626.00	33.89	560.49	693.32	567.00	687.00
Length (mm) (F)	25	480.0	559.0	514.96	515.00	20.03	475.69	554.23	480.00	559.00

Table 5-28. Reference values for weight and length for males and females in 2015 and 2016.

	N	Min	Max	Mean	Median	SD	Parametric		Non-Parametric	
							Lower	Upper	Lower	Upper
Weight (gr) (M)	56	1122.0	2168.0	1506.1	1427.5	260.6	995.4	2016.8	1140.0	2116.2
Weight (gr) (F)	75	529.0	1174.0	786.71	788.00	132.00	528.0	1045.4	565.0	1097.5
Length (mm) (M)	52	558.0	693.0	626.0	627.5	34.40	558.59	693.41	558.65	691.05
Length (mm) (F)	71	431.0	559.0	506.93	508.00	25.19	457.56	556.30	447.00	556.60

APPENDIX 5-2 - COMPARISON OF SOME COMMON BLOOD ANALYTES

Table 5-29. Comparison of common blood analytes between the current study and four other authors.

Parameter	Author	N	Mean	SEM	Min	Max
	WAS	130	↓↓8.8	0.2	5.0	18.8
	Elamin	24	9.0	--	4.5	11.6
HB (g/dL)	Naldo	76	9.9	0.3	3.3	17.4
	Species 360	--	--	--	--	--
	EAD	16	7.7	0.3	5.8	9.7
	WAS	130	↓2.5	0.1	1.1	6.0
	Elamin	24	8.8	--	6.1	11.3
WBC (10^3/µl)	Naldo	76	3.1	0.2	1.0	8.1
	Species 360	67	8.3	--	1.5	30.6
	EAD	16	4.1	0.5	1.1	9.9
	WAS	130	↓25.2	0.5	15.0	51.0
	Elamin	24	39.0	--	35.0	45.0
HCT (%)	Naldo	76	29.7	0.7	4.9	44.5
	Species 360	71	30.6	--	9.0	52.0
	EAD	16	29.3	0.9	24.0	36.0
	WAS	131	↑80.8	0.3	70.0	88.0
	Elamin	--	--	--	--	--
Hetero (%)	Naldo	76	64.4	1.4	35.0	81.0
	Species 360	--	--	--	--	--
	EAD	15	56.8	2.5	42.0	70.0
	WAS	131	↓0.1	0.0	0.0	1.0
	Elamin	24	0.0	--	--	--
Baso (%)	Naldo	76	0.8	0.1	0.0	4.0
	Species 360	--	--	--	--	--
	EAD	15	12.1	2.9	1.0	41.0
	WAS	131	↓11.5	0.2	7.0	18.0
	Elamin	24	21.0	--	--	--
Lymph (%)	Naldo	76	32.1	1.3	17.0	60.0
	Species 360	--	--	--	--	--
	EAD	15	23.2	3.2	8.0	50.0
	WAS	131	↓↓1.5	0.1	0.0	5.0
	Elamin	24	6.0	--	--	--
Mono (%)	Naldo	76	1.3	0.2	0.0	14.0
	Species 360	--	--	--	--	--
	EAD	15	8.0	2.0	0.0	27.0

↑Higher than others; ↓Lower than others

Table 5-29. Comparison of common blood analytes between the current study and four other authors. (*Continued*)

Parameter	Author	N	Mean	SEM	Min	Max
Weight Male (gr)	WAS	56	↑↑1506.1	34.8	1122.0	2168.0
	Elamin	--	--	--	--	--
	Naldo	61	1564.4	46.1	328.0	2146.0
	Species 360	--	--	--	--	--
	EAD	28	976.4	54.3	420.0	1420.0
Weight Female (gr)	WAS	75	↑↑786.7	15.2	529.0	1174.0
	Elamin	--	--	--	--	--
	Naldo	29	809.4	35.1	418.0	1082.0
	Species 360	--	--	--	--	--
	EAD	21	552.4	33.3	360.0	960.0
Length Male (mm)	WAS	52	↑626.0	4.8	558.0	693.0
	Elamin	--	--	--	--	--
	Naldo	61	621.0	0.7	362.0	710.0
	Species 360	--	--	--	--	--
	EAD	--	--	--	--	--
Length Female (mm)	WAS	71	↑506.9	3.0	431.0	559.0
	Elamin	--	--	--	--	--
	Naldo	29	494.0	0.7	397.0	548.0
	Species 360	--	--	--	--	--
	EAD	--	--	--	--	--

↑Higher than others; ↓Lower than others

Source of data for the comparisons.

WAS	Values derived from the blood samples taken during this study
Elamin	Elamin, B. (2004) Dynamics of blood biochemistry and haematology in the spiny-tailed lizard (*Uromastyx microlepis*). *Saudi Journal of Biological Sciences*, 11 (1), 55-65
Naldo	Naldo, J. L., Libanan, N. L. & Samour, J. H. (2009) Health Assessment of a Spiny-Tailed Lizard (*Uromastyx* spp.) Population in Abu Dhabi, United Arab Emirates. *Journal of Zoo and Wildlife Medicine Journal of Zoo and Wildlife Medicine*, 40 (3), 445-452
Species 360	Species 360 (2022) *ZIMS Medical Dataset*. (Online) Created online: https://zims.species360.org/Main.aspx [Created 01/06/2022]
EAD	Barcello, I. & Tourenq, C., 2005. Airport dhub (Spiny-tailed lizard - *Uromastyx* sp.) translocation operation. In: TERC, E. A. A. D. (Ed.), *Species and Habitat Conservation*. TERC, Environmental Agency Abu Dhabi, Abu Dhabi, p. 47.

Table 5-29. Comparison of common blood analytes between the current study and four other authors. (*Continued*)

Analyte	Author	N	Mean	SEM	Min	Max
AST	WAS	131	↑↑56.7	6.2	10.0	756.0
	Elamin	24	82.3	5.0	29.0	159.0
	Naldo	--	--	--	--	--
	Species 360	59	35.0	--	2.0	121.0
	EAD	13	53.5	14.8	10.3	207.6
CA	WAS	131	↑↑10.2	0.1	9.1	12.0
	Elamin	24	9.7	--	6.6	11.6
	Naldo	76	9.9	0.2	7.2	13.2
	Species 360	61	11.1	--	8.3	14.1
	EAD	13	8.8	0.0	7.2	10.0
CK	WAS	130	↑2146.9	266.6	140.0	19795.0
	Elamin	24	423.0	--	100.0	367.0
	Naldo	76	1778.4	234.8	141.1	10016.0
	Species 360	51	1681.0	--	63.0	6828.0
	EAD	13	1622.6	757.4	84.0	9762.0
GLU	WAS	131	↑↑184.5	3.4	93.0	285.0
	Elamin	--	--	--	--	--
	Naldo	76	200.4	6.0	67.7	355.6
	Species 360	54	169.0	--	46.0	266.0
	EAD	--	--	--	--	--
Phos	WAS	131	←3.8	0.2	1.7	25.0
	Elamin	24	4.3	--	1.9	11.3
	Naldo	--	--	--	--	--
	Species 360	56	3.8	--	1.3	8.5
	EAD	14	3.4	0.3	2.2	4.3
TP	WAS	131	↓↓3.4	0.1	2.0	7.8
	Elamin	24	4.8	--	3.8	6.8
	Naldo	76	4.0	0.1	2.6	7.4
	Species 360	--	--	--	--	--
	EAD	14	2.9	0.1	2.3	3.5
UA	WAS	131	↑5.2	0.2	1.8	18.2
	Elamin	24	2.7	--	0.3	67.3
	Naldo	76	2.9	0.2	0.3	7.3
	Species 360	58	4.8	--	3.0	8.0
	EAD	14	2.1	0.3	0.8	4.2

↑Higher than others; ↓Lower than others

APPENDIX 5-3 - FURTHER VITAMIN D ANALYSIS

Table 5-30. Species are grouped into four zones according to their thermoregulatory behaviour and microhabitat preferences, with the UVB reference guidelines determined from average irradiance of randomly encountered individuals in the field. (Baines *et al*, 2016)

Zone	Description	Zone Range UVI	Maximum UVI
Zone 1	Crepuscular or shade dweller, thermal conformer	0 – 0.7	0.6 – 1.4
Zone 2	Partial sun/occasional basker thermoregulator	0.7 – 1.0	1.1 – 3.0
Zone 3	Open or partial sun basker, thermoregulator	1.0 – 2.6	2.9 – 7.4
Zone 4	Mid-day sun basker, thermoregulator	2.6 – 3.5	4.5 – 9.5

The proportion of samples collected as per Table 4, for September 2015 shows that 95% of the samples collected in MUG and 74% of the samples from WAS would have been considered at minimum vitamin D insufficient. Interestingly 75% of the WAS animals would have been considered sufficient in October. Unfortunately, there were no samples collected from MUG in October 2015 to act as a comparison, with 25% of the WAS September animals, but only 5% of the MUG animals would have been considered sufficient (Figure 5-24).

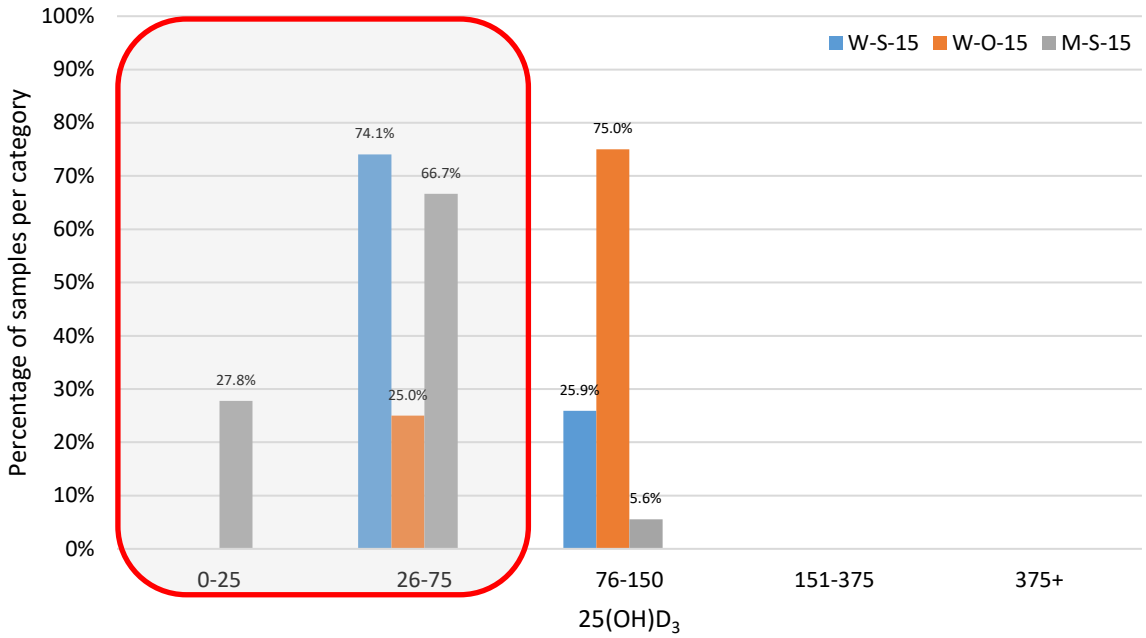


Figure 5-24. Percentage of samples per category for WAS September 2015 (W-S-15), WAS October 2015 (W-O-15) and MUG September 2015 (M-S-15). There was no data for MUG in October.

In 2016, there was still a considerably high percentage (MUG March = 70%, MUG April = 75% and WAS March = 18%, WAS April 28%) in the insufficiency and lower band (Figure 5-25). WAS again showed a higher percentage of samples in the sufficient band, but also had the highest percentage at the

extremes with the two highest values recorded in WAS for March 2016 (WAS 067 = 189.2 and WAS 003= 173.06). WAS also had the lowest value in April 2016 (WAS 083 = 15.5).

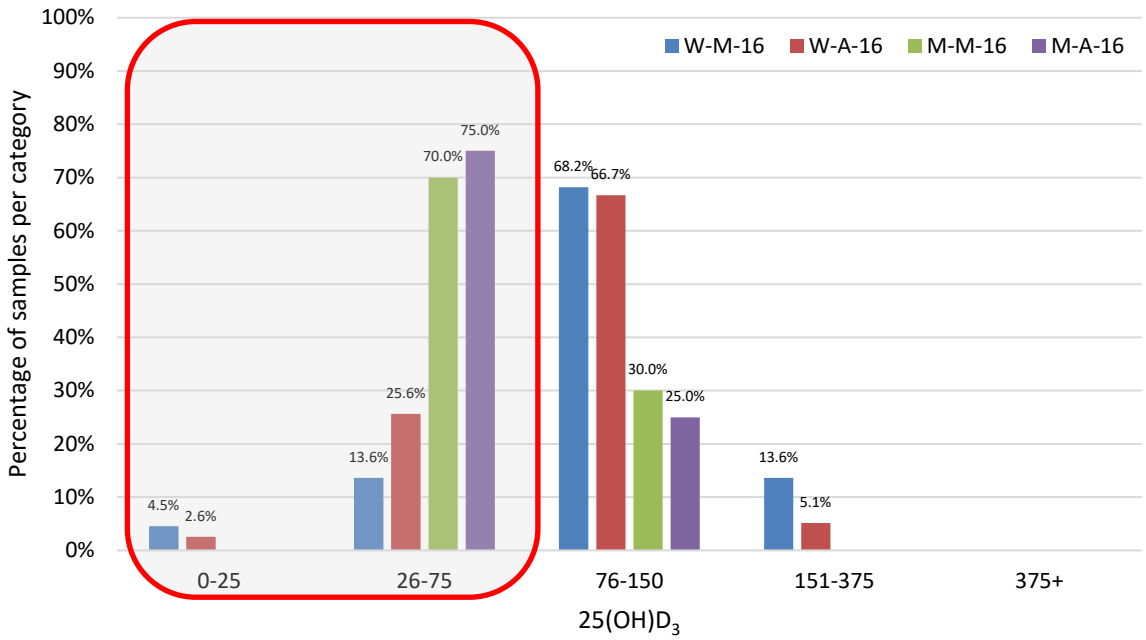


Figure 5-25. Percentage of samples per category for WAS March 2016 (W-M-16), WAS April 2016 (W-A-16), MUG March 2016 (M-M-16) and MUG April 2016 (M-A-16).

When one looks at the relationship between 25(OH)D and Ca, Ica and P one can see that there does not appear to be any linear relationship and the plots. Higher 25(OH)D does not necessarily mean higher Ca, iCa or Phos. In WAS there was a negative correlation between 25(OH)D and Ca and 25(OH)D (r = -0.413, P= 0.016); 25(OH)D and Phos (r = -0.411, P= 0.019) and positive correlations between Ca and Phos (r =0.345, P= 0.045) for 2015 and Ca and iCal (r = 0.470, P= 0.001) for 2016. In MUG there was a correlation between Ca and iCa (r =0.629, P= 0.001) in 2016 and iCa and Phos (r =-0.525, P= 0.025) in 2015. These correlations are not immediately obvious in the Scatter plots Figure 5-26, Figure 5-27 and Figure 5-28.

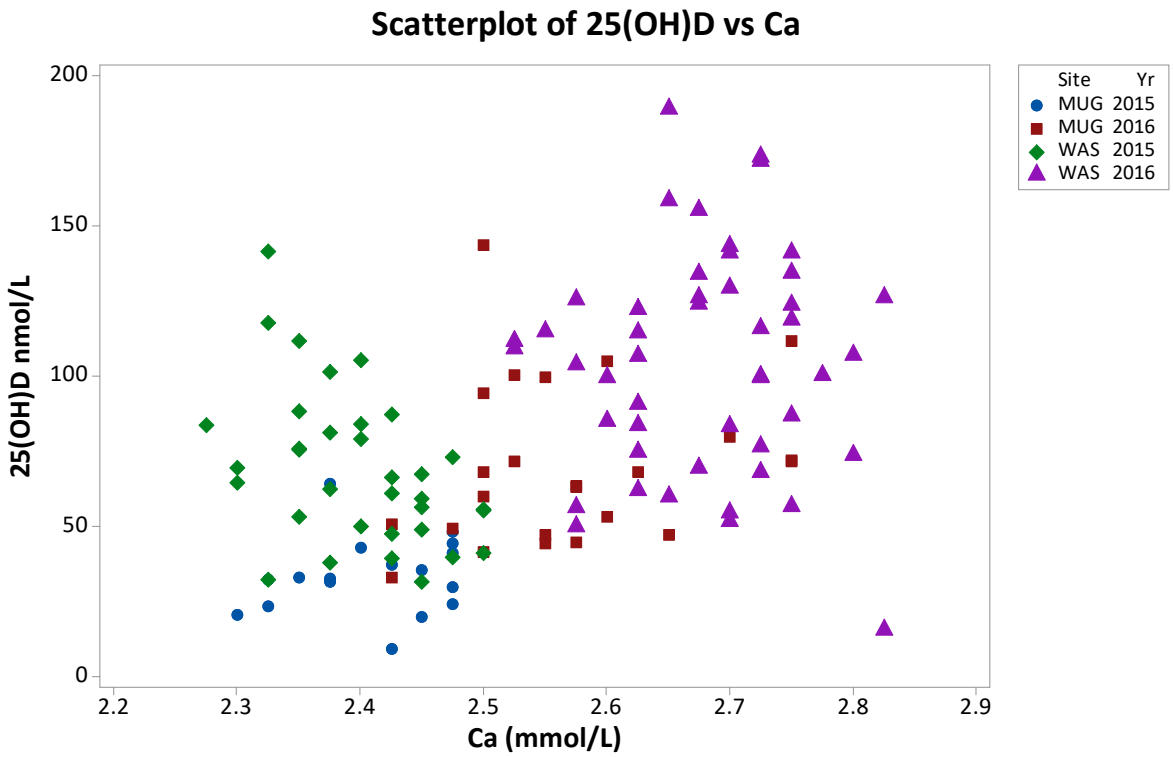


Figure 5-26. Scatter plot showing the relationship between 25(OH)D and Ca for each site and year. Males and females were merged.

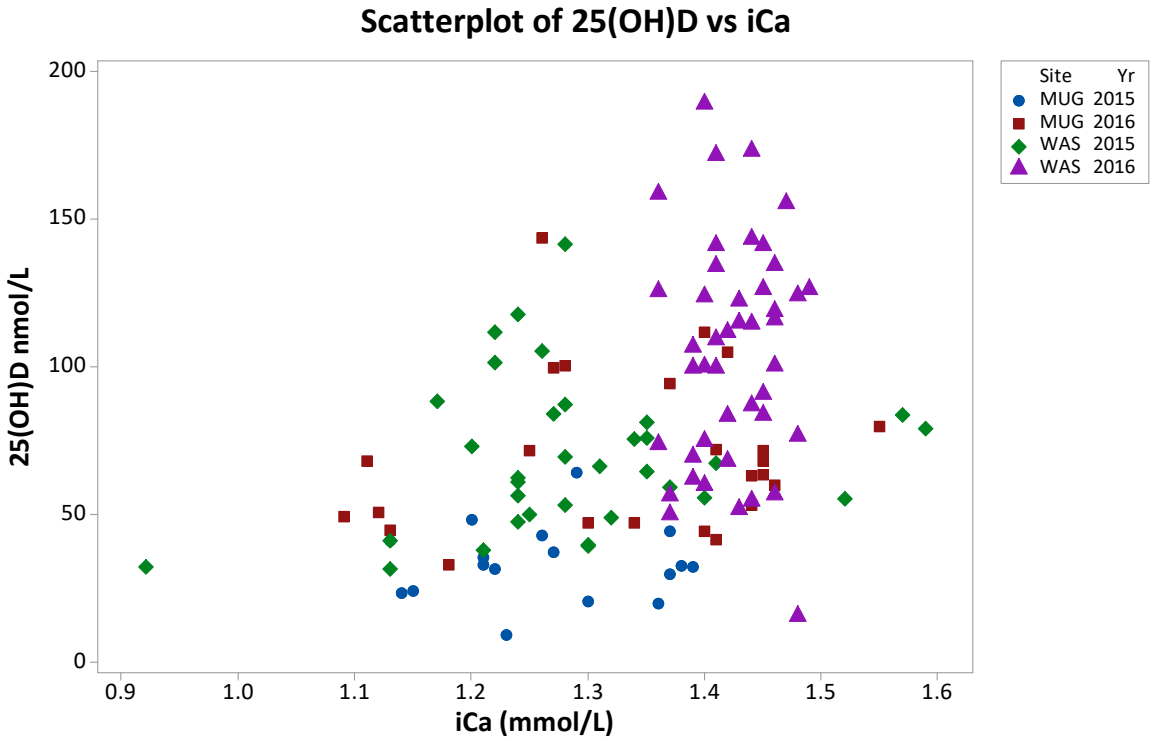


Figure 5-27. Scatter plot showing the relationship between 25(OH)D and iCa for each site and year. Males and females were merged.

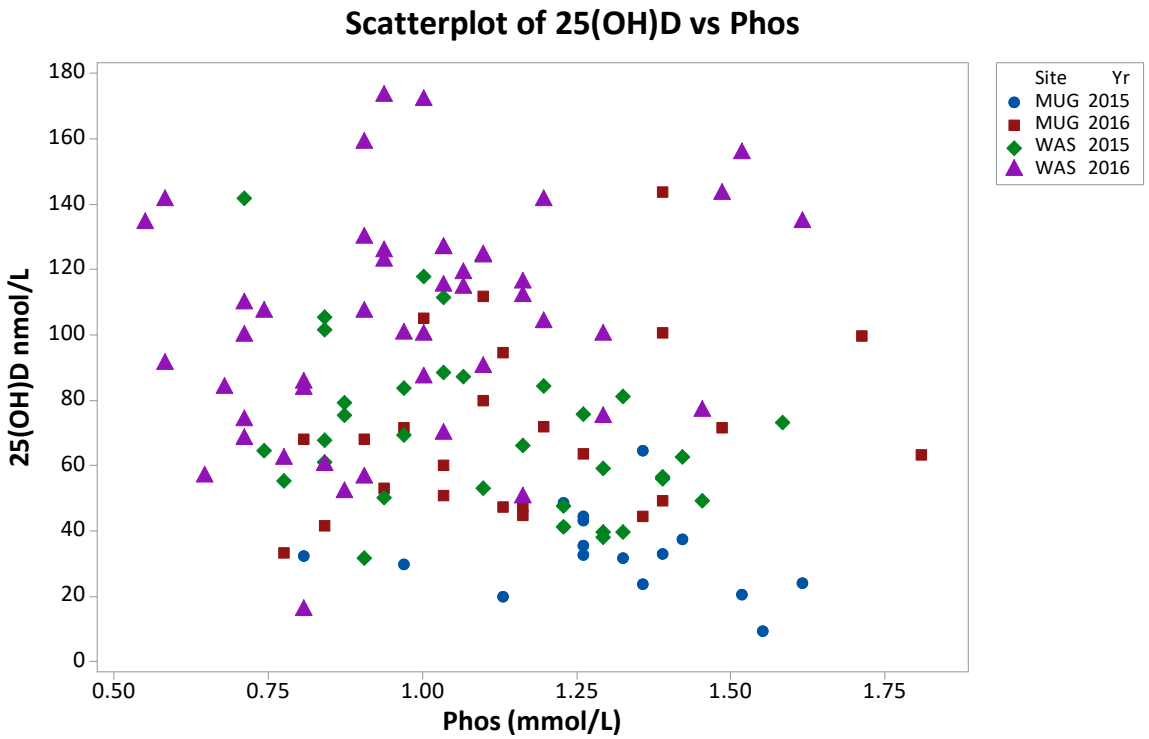


Figure 5-28. Scatter plot showing the relationship between 25(OH)D and Phos for each site and year. Males and females were merged.

Table 5-31. Repeat samples from animals caught multiple times in the same year looking at the results for 25(OH)D_3, calcium (Ca), phosphorus (P) and ionised calcium (iCa^{++}). Samples from 2015 in red. WAS 040 was the animal removed due to its outlier status Grubbs – double sided test (α=0.05).

Animal ID	Year	Date	Site	25(OH)D_3	Ca	P	iCa
WAS 001	2015	04-May-15	WAS	88.3	10.00	4.60	
WAS 001	2015	08-Sep-15	WAS	15.105	10.10	3.20	1.28
WAS 010	2016	21-Mar-16	WAS	111.661	10.10	3.60	1.42
WAS 010	2016	12-Apr-16	WAS	117.465	10.00	2.70	1.26
WAS 010	2016	17-Apr-16	WAS	129.92	11.00	2.80	1.57
WAS 015	2016	20-Mar-16	WAS	126.416	11.30	3.20	1.49
WAS 015	2016	05-Apr-16	WAS	138.97	10.90	2.40	1.47
WAS 038	2015	16-Sep-15	WAS	31.615	9.80	2.80	1.13
WAS 038	2015	22-Sep-15	WAS	42.055	7.60	3.90	1.25
WAS 038	2016	23-Mar-16	WAS	56.595	11.00	2.00	1.46
WAS 040	2016	20-Mar-16	WAS	125.513	10.30	2.90	1.36
WAS 040	2016	10-Apr-16	WAS	78.956	10.10	2.30	1.47
WAS 040	2016	11-Apr-16	WAS	89.324	10.10	3.30	1.37
WAS 060	2015	13-Oct-15	WAS	111.5625	9.40	3.20	1.22
WAS 060	2016	05-Apr-16	WAS	99.769	10.90	3.10	1.39
WAS 060	2016	17-Apr-16	WAS	92.698	10.80	4.50	1.32
WAS 066	2016	02-Mar-16	WAS	90.129	9.30	3.40	1.23
WAS 066	2016	17-Apr-16	WAS	124.665	10.70	3.50	1.37
WAS 069	2016	20-Mar-16	WAS	100.368	11.10	3.00	1.46
WAS 069	2016	05-Apr-16	WAS	116.114	10.70	2.30	1.53
WAS 076	2016	23-Mar-16	WAS	74.733	10.50	4.00	1.4
WAS 076	2016	06-Apr-16	WAS	70.903	12.10	3.00	1.51
WAS 076	2016	13-Apr-16	WAS	78.14	9.90	2.20	1.16

Looking at the plot of the residuals (Figure 5-29) there is a nonconstant variance in the residuals v fitted plot which would suggest a nonconstant variance.

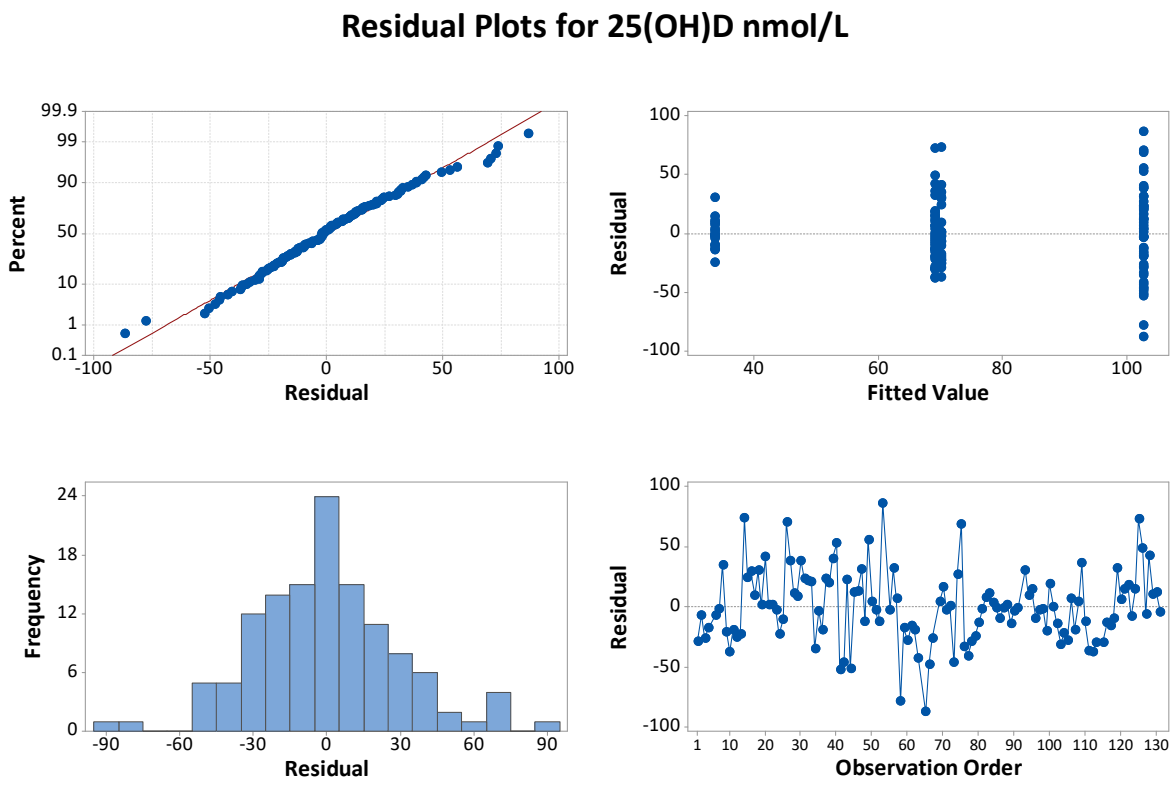


Figure 5-29. Residual plots for Vit D_3

However, when a test for equal variance of Year v Site (Figure 5-29) was run there was a significant difference between these factors.

APPENDIX 5-4 – DESCRIPTIVE STATISTICS

Table 5-32. Descriptive statistics for 25(OH)D in MUG

	MUG			
	2015		2016	
	Female	Male	Female	Male
N	13	11	15	14
Mean	34.658	28.540	66.312	80.019
95% CI	24.459 to 44.857	17.726 to 39.355	52.563 to 80.061	63.030 to 97.008
Variance	284.8581	259.1444	616.4040	865.7692
SD	16.8777	16.0980	24.8275	29.4240
SEM	4.6810	4.8537	6.4104	7.8639
Median	32.870	23.485	67.952	75.723
Minimum	9.168	8.755	32.998	44.702
Maximum	77.892	64.293	116.077	143.812
Normal Distr.	0.0210	0.1575	0.3548	0.5257

Table 5-33. Descriptive statistics for 25(OH)D in WAS

	WAS			
	2015		2016	
	Female	Male	Female	Male
N	18	29	41	32
Mean	72.937	61.786	97.956	108.282
95% CI	57.784 to 88.091	53.395 to 70.176	84.290 to 111.623	96.089 to 120.476
Variance	928.5812	486.6024	1874.6160	1143.7692
SD	30.4726	22.0591	43.2968	33.8197
SEM	7.1825	4.0963	6.7618	5.9785
Median	74.393	59.093	90.917	115.548
Minimum	31.615	15.105	15.543	48.128
Maximum	141.610	117.900	206.770	191.415
Normal Distr.	0.6647	0.2804	0.3427	0.9539

Table 5-34. Descriptive statistics for Ca (mmol/L) in MUG

	MUG			
	2015		2016	
	Female	Male	Female	Male
N	13	11	15	15
Mean	9.692	9.664	10.140	10.493
95% CI	9.570 to 9.814	9.466 to 9.861	9.972 to 10.308	10.150 to 10.836
Variance	0.04077	0.08655	0.09257	0.3835
SD	0.2019	0.2942	0.3043	0.6193
SEM	0.05600	0.08870	0.07856	0.1599
Median	9.700	9.700	10.100	10.300
Minimum	9.300	9.200	9.700	9.700
Maximum	9.900	10.200	11.000	12.300
Normal Distr.	0.4984	0.9761	0.0016	0.0005

Table 5-35. Descriptive statistics for Ca in (mmol/L) WAS

	WAS			
	2015		2016	
	Female	Male	Female	Male
N	19	28	43	32
Mean	9.511	9.625	10.770	10.628
95% CI	9.259 to 9.762	9.505 to 9.745	10.637 to 10.903	10.471 to 10.785
Variance	0.2732	0.09528	0.1874	0.1905
SD	0.5227	0.3087	0.4329	0.4364
SEM	0.1199	0.05833	0.06602	0.07715
Median	9.600	9.700	10.800	10.700
Minimum	7.600	9.000	9.900	9.300
Maximum	10.000	10.100	12.100	11.300
Normal Distr.	<0.0001	0.4412	0.0082	0.0184

Table 5-36. Descriptive statistics for iCa^{++} (mmol/L) in MUG

	MUG			
	2015		2016	
	Female	Male	Female	Male
N	13	11	15	15
Mean	1.247	1.295	1.264	1.385
95% CI	1.200 to 1.294	1.231 to 1.359	1.184 to 1.344	1.293 to 1.476
Variance	0.005990	0.009087	0.02093	0.02716
SD	0.07739	0.09533	0.1447	0.1648
SEM	0.02147	0.02874	0.03735	0.04255
Median	1.230	1.310	1.250	1.420
Minimum	1.130	1.120	1.040	1.120
Maximum	1.390	1.390	1.450	1.780
Normal Distr.	0.7167	0.3248	0.1278	0.2833

Table 5-37. Descriptive statistics for iCa^{++}(mmol/L) in WAS

	WAS			
	2015		2016	
	Female	Male	Female	Male
N	19	28	43	32
Mean	1.261	1.310	1.420	1.426
95% CI	1.193 to 1.329	1.274 to 1.347	1.389 to 1.452	1.403 to 1.449
Variance	0.01969	0.008870	0.01070	0.004077
SD	0.1403	0.09418	0.1034	0.06385
SEM	0.03219	0.01780	0.01577	0.01129
Median	1.270	1.305	1.420	1.425
Minimum	0.920	1.110	1.040	1.230
Maximum	1.590	1.570	1.670	1.570
Normal Distr.	0.1370	0.1434	0.0001	0.0025

Table 5-38. Descriptive statistics for Phos (mmol/L) in MUG

	MUG			
	2015		2016	
	Female	Male	Female	Male
N	13	11	15	14
Mean	3.962	4.055	3.833	3.636
95% CI	3.523 to 4.400	3.641 to 4.468	3.245 to 4.422	3.260 to 4.011
Variance	0.5259	0.3787	1.1295	0.4225
SD	0.7252	0.6154	1.0628	0.6500
SEM	0.2011	0.1856	0.2744	0.1737
Median	3.900	4.200	3.700	3.450
Minimum	2.500	2.600	2.400	2.900
Maximum	5.000	4.900	5.700	5.300
Normal Distr.	0.5967	0.0413	0.6513	0.0221

Table 5-39. Descriptive statistics for Phos (mmol/L) in WAS

	WAS			
	2015		2016	
	Female	Male	Female	Male
N	19	28	43	32
Mean	3.932	3.493	4.528	3.181
95% CI	2.490 to 5.373	3.216 to 3.769	3.044 to 6.012	2.777 to 3.586
Variance	8.9489	0.5088	23.2592	1.2590
SD	2.9915	0.7133	4.8228	1.1220
SEM	0.6863	0.1348	0.7355	0.1984
Median	3.200	3.500	3.200	3.000
Minimum	2.200	2.100	1.800	1.700
Maximum	15.900	4.500	25.000	6.800
Normal Distr.	<0.0001	0.1187	<0.0001	0.0008

Table 5-40. Descriptive statistics for Alb (g/dL) in MUG

	WAS			
	2015		2016	
	Female	Male	Female	Male
N	13	11	15	15
Mean	1.923	1.709	1.833	2.027
95% CI	1.671 to 2.175	1.433 to 1.985	1.669 to 1.998	1.833 to 2.220
Variance	0.1736	0.1689	0.08810	0.1221
SD	0.4166	0.4110	0.2968	0.3494
SEM	0.1156	0.1239	0.07664	0.09022
Median	1.800	1.800	1.900	2.000
Minimum	1.400	0.800	1.400	1.500
Maximum	2.800	2.400	2.400	2.500
Normal Distr.	0.4397	0.1812	0.9169	0.3557

Table 5-41. Descriptive statistics for Alb (g/dL) in WAS

	WAS			
	2015		2016	
	Female	Male	Female	Male
N	19	28	43	32
Mean	2.111	1.982	2.347	2.147
95% CI	1.959 to 2.262	1.785 to 2.179	2.091 to 2.602	1.995 to 2.299
Variance	0.09877	0.2578	0.6878	0.1781
SD	0.3143	0.5078	0.8293	0.4220
SEM	0.07210	0.09596	0.1265	0.07459
Median	2.000	1.800	2.100	2.200
Minimum	1.600	1.500	1.500	1.200
Maximum	2.800	3.400	5.800	2.900
Normal Distr.	0.4652	0.0139	<0.0001	0.3457

Table 5-42. Descriptive statistics for Ca:Phos (mmol/L) in MUG

	MUG			
	2015		2016	
	Female	Male	Female	Male
N	13	11	15	15
Mean	2.4:1.0	2.4:1.0	2.7:1.0	2.9:1.0
SEM	0.06:0.20	0.03:0.20	0.01:0.30	0.16:0.17

Table 5-43. Descriptive statistics for Ca:Phos (mmol/L) in WAS

	WAS			
	2015		2016	
	Female	Male	Female	Male
N	19	28	31	18
Mean	2.4:1.0	2.7:1.0	2.4:1.0	3.3:1.0
SEM	0.12:0.69	0.06:0.13	0.07:0.74	0.08:0.20

APPENDIX 5-5 – STATISTICS (ANOVA)

Table 5-44. ANOVA looking at the interaction between Site, Sex and Year for Albumin (g/dL).

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Site	1	2.6949	2.69492	9.08	**0.003***
Yr	1	0.8898	0.88977	3.00	0.085
Sex	1	0.2738	0.27380	0.92	0.338
Site*Yr	1	0.0673	0.06732	0.23	0.635
Site*Sex	1	0.2128	0.21277	0.72	0.398
Yr*Sex	1	0.2544	0.25436	0.86	0.356
Site*Yr*Sex	1	0.5158	0.51582	1.74	0.189
Error	168	49.8605	0.29679		
Total	175	56.1286			

*Significantly different (*p< 0.05*) statistics in bold and asterisk

Table 5-45. Independent sample t-test for 25(OH)D, calcium, ionised calcium, phosphorous and albumin for September and October 2015 and March and April 2016.

Analyte	N	M	SD	SEM	T-Value	DF	P
25(OH)D 2015	41	51.71	28.69	4.48	-9.62	39	< 0.000
25(OH)D 2016	41	90.26	36.43	5.69			
Ca 2015	42	9.6238	0.2818	0.0435	-10.45	40	< 0.000
Ca 2016	42	10.4544	0.3890	0.0600			
iCa++ 2015	42	1.2690	0.0941	0.0145	-4.83	40	< 0.000
iCa++ 2016	42	1.3788	0.1031	0.0159			
Phos 2015	41	3.989	2.067	0.323	2.36	39	0.023
Phos 2016	41	3.187	0.954	0.149			
ALB 2015	50	2.0103	0.3564	0.0504	-0.44	48	0.660
ALB 2016	50	2.0353	0.3896	0.0551			

APPENDIX 5-6 – BLOOD SAMPLING PROTOCOL

Blood Sampling Protocol for *Uromastyx aegyptia leptieni*

As with most reptiles, typical blood collection sites include the coccygeal ventral vein, jugular vein and abdominal vein. For this study, the ventral coccygeal vein was chosen as the preferred sampling site.

5.5.1 CAPTURE AND HANDLING:

While a robust and tractable animal *U. aegyptia* should be handled gently and with care to avoid undue stress. Blood sampling should be completed as soon after capture as possible.

Following capture from the wild or restraint in enclosures/vivarium's, all animals should have their eyes covered. This is normally done by placing a piece of cotton wool over each of the eyes. These are then wrapped with a narrow strip of gauze (putting pressure on the eyes) and taping in place. (Figure 5-30).



Figure 5-30. Eye covers on *Uromastyx aegyptia leptieni*.

5.5.2 SITE PREPARATION:

The animal should be placed in a dorsal recumbency on the edge of a table/bench/vehicle tail gate.

Ensure the venipuncture site is swabbed, cleaned and aseptically prepared with either alcohol or a premade F10 solution (1:250 dilution). Dab off any remaining F10 solution, avoiding contamination of the cleaned site.

The ventral coccygeal vein can be found along the ventral midline and should be accessed ventrally. Depending on the size of the animal, a 23 to 25 gauge x 25mm needle is preferred.

With one hand holding the tail, choose the insertion site which should be between 20% (to avoid damage to the hemipenes in males) and no more than 80% of the distance from the base to the tip of the tail along the ventral midline of the tail (Figure 5-31).

At an angle of 45°, insert the needle along the midline of the tail between the ventral scales until it reaches the vertebral body. Applying gentle negative pressure to the syringe, pull back slowly until blood flow is seen. Withdraw the required amount of blood as per Table 5-46. If blood flow is not seen, the needle is repositioned and the same procedure is repeated until such time as blood is found.



Figure 5-31. Blood draw technique from *U. aegyptia leptieni* male.

5.5.3 Blood Draw Volumes:

Taking a reptile as having a total blood volume of between 5% to 8% body weight and that 10% of this volume can be taken safely (Stahl 2006), Table 5-46 below shows the volumes allowed.

Table 5-46. Suggested max blood draws from *U. aegyptia leptieni*.

Body Weight (gr)	5% BW (ml)	8% BW (ml)
200	1	1.6
250	1.25	2
300	1.5	2.4
400	2	3.2
500	2.5	4
750	3.75	6
1000	5	8
1250	6.25	10
1500	7.5	12

To avoid contamination with additives, blood should be placed in the collection tubes in the following sequence Figure 5-32.

❶ Red – No additive – for serum collection

❷ Green – Lithium heparin* – for plasma collection

❸ Lavender/Purple – EDTA – mammalian haematology

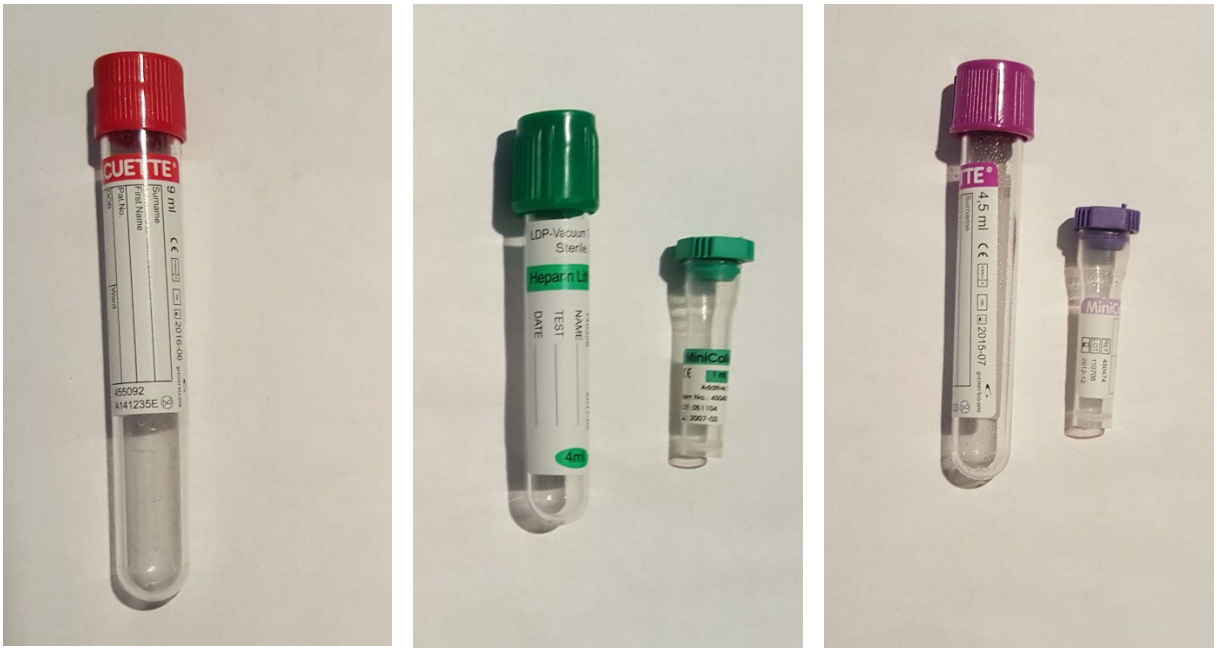


Figure 5-32. Blood collection tubes, with colour and sequence of collection

**As Ca is a primary focus, only lithium heparin tubes should be used for biochemistry. EDTA will bind Ca ions giving false results.*

Tubes containing heparin and EDTA should be inverted 8 to 10 times after collection to ensure thorough mixing of the additive with the blood.

It is essential that samples are processed as quickly as possible after collection.

All tubes must be marked accurately, and a complete log kept of the animal id, burrow id, where and when it was caught, length of time before sampling (restraint time), length of time before sample is processed (Figure 5-33).

Uromastyx aegyptia leptieni Blood Sample Recording Form

	Sample ID	Animal ID	Burrow ID	Sex	Weight	Age (est)	Date	Time of Restraint	Time of Bleeding	Time of Processing	Samples	Notes
1											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:
2											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:
3											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:
4											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:
5											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:
6											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:
7											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:
8											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:
9											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:
10											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:
11											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:
12											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:
13											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:
14											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:
15											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:

...\documents\forms\blood sample collection Rev2c

Figure 5-33. Sample data capture form to record sampling details.

5.5.4 PLASMA:

Lithium heparin (LiHe) green top tubes is preferred to EDTA (lavender top) for reptile plasma sample extraction. Plasma samples do not need to clot and can be centrifuged immediately after collection. Cells are removed from plasma by centrifugation for 7 minutes at 5,000 rpm. The plasma, if not been analysed immediately, should be transferred as 0.5 ml aliquots into 1.0 ml cryovial tubes using a Pasteur pipette. These should be stored and transported at –20°C or lower. It is important to avoid freeze-thaw cycles due to the detrimental effect on many plasma components. Falsely decreased blood glucose values and increased phosphorus and potassium values may occur in plasma samples that have extended exposure to the cell fraction (Stahl 2006).

5.5.5 SERUM:

Serum samples should be allowed to stand at room temperature for 15 – 30 minutes, but no longer than 1 hour. Remove the clot by centrifuging at 1,000-2,000 x g for 10 minutes. Serum should not be in contact with the cells for more than 45 minutes and should be maintained at 2 - 8°C while handling. If it is not been analysed immediately, samples should be transferred as 0.5 ml aliquots into 1.0 ml cryovial tubes using a Pasteur pipette. These should be stored and transported at –20°C or lower. It is important to avoid freeze-thaw cycles due to the detrimental effect on many serum components.

5.5.6 HAEMOGLOBIN AND HAEMATOCRIT

EKF Diagnostics Hemo Vet Blood Analyser was used in the determination of the haemoglobin and

haematocrit values. Add 8µl of the blood sample to the microcuvette and place same into the analyser. Press start and results will be available within 60 seconds. Record these data with the sample details.

APPENDIX 5-7 - SAMPLES REQUIRED FOR UROMASTYX STUDY

5.5.7 SAMPLES FOR VITAMIN D3 ANALYSIS

It is vitally important that these samples are handled consistently throughout the study. 300 μl of plasma is required to run the Vit D3 analysis (LC-MS/MS which is a combination of liquid chromatography (LC) with mass spectrometry (MS)). These samples need to be taken immediately after centrifugation as per instructions above and stored at -40 °C until analysis.

5.5.8 PLASMA FOR BIOCHEMISTRY:

Analytes being investigated AST, ALT, ALB, ALP, BUN, CHOL, CK, UREA, UA, GLU, TP, GLOB, CREA, Phos, Na+, K+, Cl-, Ca, Ca^{++}, LDH, TBIL,

5.5.9 WHOLE BLOOD FOR HAEMATOLOGY

1 ml of whole blood should be taken and kept in a Lithium Heparin microtainer for direct haematological examination.

5.5.10 BLOOD SMEAR FOR HAEMATOLOGY:

Hb, Hct, WBC, Hetrophils, Lymphocytes, Monocytes, Eosinophils, Basophils, Azurophils

APPENDIX 5-8 – BLOOD SMEAR PREPARATION

5.5.11 BLOOD SMEARS SHOULD BE TAKEN AS FOLLOWS:

Use microscope slides with frosted end to allow accurate sample identification to be recorded.

1. Place a small amount of blood (approximately 4 mm diameter) close to the frosted end of the slide
2. Holding the slide with the blood firmly in place, place another slide (spreader slide) at an angle of 45° and pull gently back into the blood as shown below. This will allow the blood to spread by capillary action across the width of spreader slide.
3. Push the spreader across the slide in the direction of the arrow.
4. A smooth action is required to ensure an even smear (Figure 5-34).

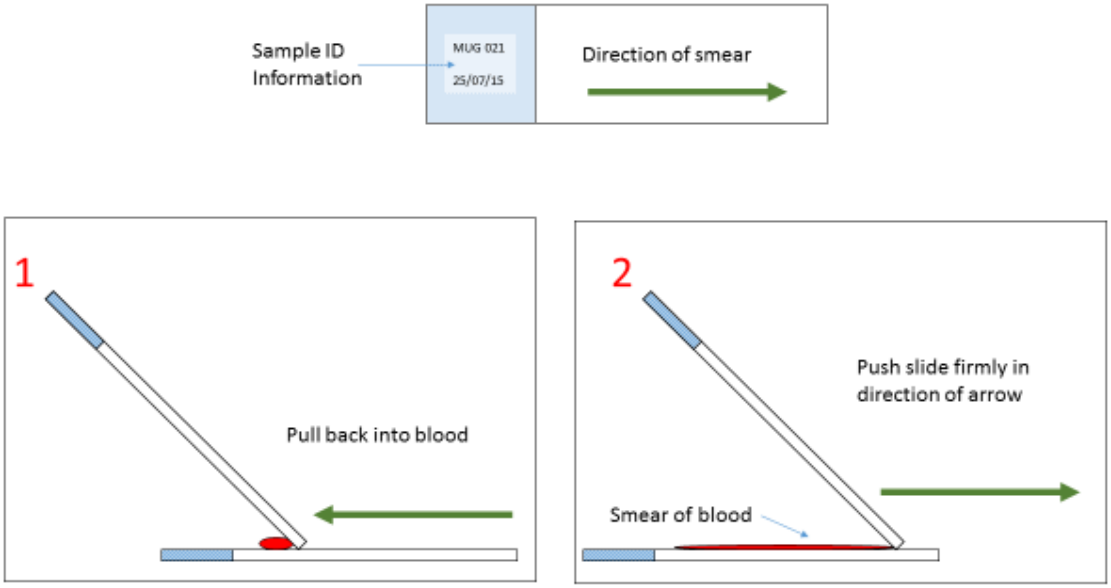


Figure 5-34. Direction of push for a successful blood smear.

1. Smears should be air dried. They can be stored in slide holders once dry.
2. When fully dried, the prepared slides are dipped in 100% methanol for 60 seconds. Slides should be removed and placed on end to allow them to air dry fully again. Be sure that any identification details are not washed off the frosted end of the slide when dipping the slides.

All samples should be analysed as soon after collection as possible.

CHAPTER 6: DHUB TRANSLOCATION

PUBLICATION

A modified form of this chapter has already been published, see details below and . Additional data is included here together with an updated reference list:

O'Donovan, D. & O'Riordan, R. (2018) Translocation trial of spiny-tailed lizard or dhub in Dubai, United Arab Emirates, in Soorae, P. S. (ed), *Global Reintroduction Perspectives: 2018. Case studies from around the globe.* Abu Dhabi: IUCN/SSC Reintroduction Specialist Group (RSG), pp. 69 - 73.

6.1 INTRODUCTION

6.1.1 DEFINITION

Translocation is defined as the movement of living organisms from one area with free release into another (Seddon, 2010). Historically, translocations were predominantly food resources, such as, crops, livestock, fish and game species, including many of the food resources used today. It could be argued that species translocations have been happening for thousands of years through the transfer of parasites, bacteria and viruses from one place to another. Movements for ceremonial purposes, erosion control, nostalgic reasons or simply as a collection item also occurs. The current discontinuous range of the Aesculapian snake (*Zamenis longissimus*) with isolated populations in Germany and Switzerland is a result of numerous translocations by the Romans as a means of rat control in their temples (Mehrtens, 1987). More recently, invasive translocations have been happening in the form of rhododendron (*Rhododendron ponticum*), sika deer (*Cervus nippon*), Nuttall's waterweed (*Elodea nuttallii*) to Ireland, rabbits (*Oryctolagus cuniculus*) to Australia etc. As these species were moved to an area outside of their historically known natural range and are considered harmful to the local environment and biodiversity, they are considered to be invasive species (Soorae *et al*, 2017) rather than translocations. According to Feuka *et al* (2022), invasive species are among the top threats to global biodiversity. It is estimated that battling invasive species such as these in the US cost in the region of $50 billion a year (Sughrue, 2019) while the cost of invasive species on the island of Ireland in 2013 was in the region of €261 million (Kelly *et al*, 2013)

From a conservation perspective, translocation is an umbrella term which covers introductions, re-introduction and re-stocking (IUCN/SSC, 2013; Armstrong et al, 2019). IUCN/SSC (2013) has shifted slightly from the original definition (IUCN, 1998) with the introduction of new terminology (Assisted Colonization and Ecological Replacement) due to effects of climate change and restoring ecosystem function (Zlatanova, 2016). In general, translocations can be divided into either, conservation translocations which are undertaken to reinforce or increase declining populations, or, mitigation translocations, which are designed to remove animals from conflict or development areas in an attempt to avoid loss within these sites. Armstrong *et al* (2019) suggest that the collective term "conservation translocation" should be used to cover all of these types of translocations as long as they are conducted primarily for conservation benefit. While many conservation translocations are often part of species recovery programs and success is measured by the release program producing a viable, self-sustaining population in the wild with a substantial addition of new recruits to the population (Griffith *et al*, 1989; Germano & Bishop, 2008). The present study serves as a pilot project, aiming to assess the feasibility and protocol for translocating *Uromastyx aegyptia leptieni* into a habitat similar and suitable to its needs. In fact, the ability of released animals to successfully overwinter, create burrows, or remain within a protected area does not, by itself, constitute a successful translocation

program. Indeed, Seddon *et al* (2019) suggested that any summary of reintroduction success rate should be viewed with caution, since there are no agreed definitive criteria for assessing outcomes as a simple success or failure.

6.1.2 HISTORY

Since the early 1960s, conservation translocations have increased in numbers due to increased concerns about habitat loss, pollution, invasive species, overharvesting, etc. The Reintroduction Specialist Group (RSG) of the World Conservation Union (IUCN) estimates that between 1993 and 1997 alone, there was a 300% increase in the number of official reintroduction projects (Seddon & Soorae, 1999). Many of the translocations are considered great successes, for example the peregrine falcon (*Falco peregrinus*) reintroductions and reinforcements from 1974, the reintroduction of the Arabian oryx (*Oryx leucoryx*) to Oman using captive-bred animals in 1982 (although this crashed through a fundamental flaw of non-inclusion of some aspects of the local Omani communities (Chatty, 2002)), the reintroduction of the grey wolf (*Canis lupus*) to Yellowstone National Park in 1995 or the reintroduction of Atlantic salmon (*Salmo salar*) to tributaries of Lake Ontario in 2011.

There is limited scientific information regarding consequences of translocation. However, points of concern include, spread of disease and parasites (Griffith *et al*, 1993; Woodford, 1993), humaneness of translocation (Massei *et al*, 2010a), reduction in fitness (Holding *et al*, 2014), movement of relocated animals, impact to resident species at relocation area, and genetic consequences for wildlife species at the relocation area (Craven *et al*, 1998).

Translocations may also take a toll on the species being relocated. Stress of captivity and relocation may predispose individuals to harassment from resident animals, manifestation of latent infections and the transfer of same to the resident population, increased predation, and difficulty in acquiring resources such as food, water, and shelter. Individual survival is dependent on several variables including species behaviour, season of release, habitat characteristics, and environmental conditions. In fact Dodd & Seigel (1991) suggest that amphibian and reptile translocation projects have not demonstrated success as a conservation tool.

6.1.3 SUCCESS

A lot of the earlier translocations were poorly monitored and not a lot was learned from these. As a result, there has been a move towards more specific guidelines (IUCN, 1987, 1998; IUCN/SSC, 2013) to steer these translocations in the right direction with regards to their planning, execution, and monitoring. Scientifically based, evidence driven guidance can help to avoid over-enthusiastic decisions on either end of the spectrum, while improving the efficacy of actions that are taken. The

2013 IUCN Guidelines present conservation translocations as a process of stepwise decision making where alternatives to translocations are considered, feasibility and risk of action or inaction is continuously evaluated, and monitoring data inform subsequent management alternatives (Armstrong *et al*, 2019).

6.1.4 REPTILE TRANSLOCATION

It has been reported that reptile translocations driven by human–wildlife conflict mitigation have had a higher failure rate than those motivated by conservation (Soorae *et al*, 2008; Massei *et al*, 2010b; Massei *et al*, 2010a; Sullivan *et al*, 2015; Romijn & Hartley, 2016; Nash *et al*, 2020; Bradley *et al*, 2023), and more recent projects of reptile translocations have had unknown outcomes. Most studies on the translocation of reptiles have been completed in Australia, the US and Asia with the most common reported causes of translocation failure being homing and migration of introduced individuals out of release sites as well as poor habitat availability (Germano & Bishop, 2008; Bellis *et al*, 2020). With the increasing pressure on reptiles, it is important that more proactive measures are investigated (Germano & Bishop, 2008). In the EU, the no net loss (of biodiversity and ecosystem services) requirement underpins the EU Biodiversity Strategy for 2030 which seeks to identify key principles and best practices involved in addressing negative impacts of human activities on biodiversity and ecosystem services (Tucker *et al*, 2020).

Today, more than 4.3 billion people or 55% of the world's population live in urban settings, and the number is expected to rise to 80% by 2050 (Venditti, 2022). It was estimated that almost 90% of the UAE population would be urbanised by 2020, a trend obvious in Dubai in particular (Figure 6-1). Road infrastructure, services and megaproject construction are seriously impacting available habitat for many local species of biota (Howarth *et al*, 2019). Habitat conversion for development and agricultural use are identified as key threats to reptile species of the Arabian Peninsula (Cox *et al*, 2012), while Cordier *et al* (2021) argued that these threats along with silviculture and deforestation have a negative impact on reptiles and amphibians which are the most threatened group of vertebrates globally.

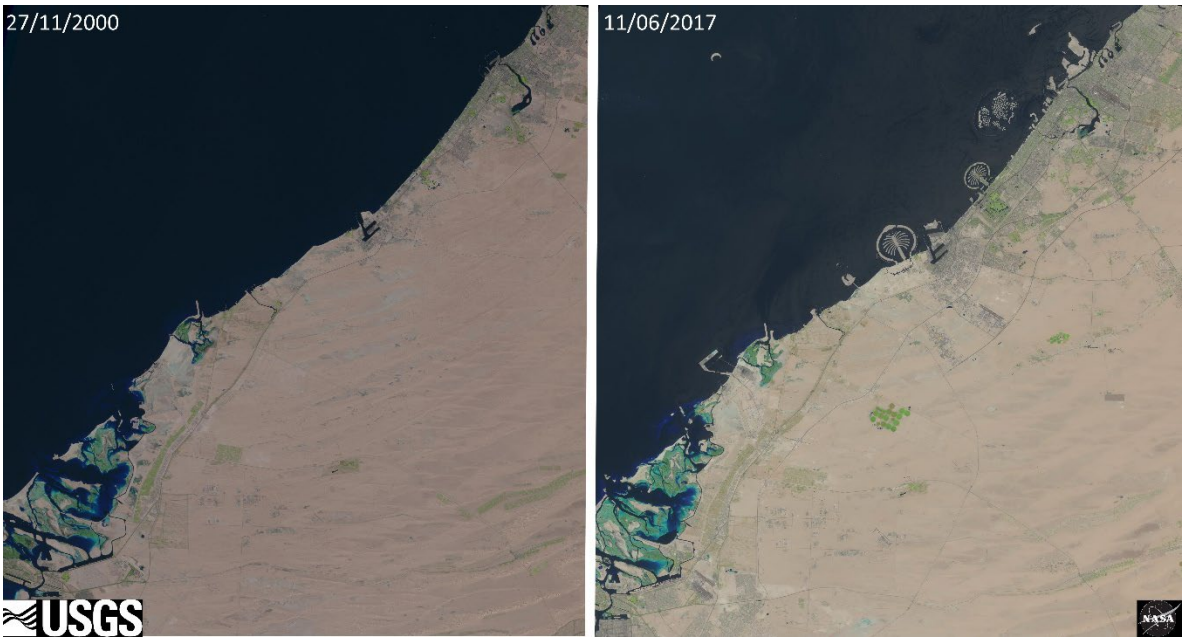


Figure 6-1. Changes in the level of urbanisation from 2000 to 2017 in Dubai (USGS and NASA 2017)

Before a mitigation translocation project is implemented, three questions need to be answered: is there a need for it, what should be the substitute form; and is the project feasible? Seddon *et al* (2005) suggest that in many cases, the selection of candidates for reintroduction programmes is likely to consider national priorities, availability of funding and local community support, over global conservation status. The latter point is extremely relevant as it would be far easier to generate a positive response from decision makers where there is a "wow factor" and, it could be argued, reptiles do not always have this "wow factor". As such there has been a marked taxonomic bias in species that are the focus of reintroduction attempts with the larger and more charismatic vertebrate species being favoured (Seddon *et al*, 2019).

Germano & Bishop (2008) found that the motivation for translocation (i.e. conservation- or mitigation-led) was an important determinant of success; the highest failure levels (63%) were associated with mitigation-led translocations of reptiles. Nash *et al* (2020) suggest that in studies they were involved in, in 50% of the study sites, no translocated reptiles were recaptured. Inappropriate release of dhub, such as those from Dubai Airport and animals removed from the Jebel Ali area of Dubai have led to animals being unable to find adequate food, burrows and most likely territorial competition with wild resident conspecifics, which would have led to serious welfare issues and humane destruction may have been a preferable alternative (Declan O'Donovan *pers obs*).

When this study started, within the Emirate of Dubai, there were no guidelines and only minimal Environmental Impact Assessment requirements by Dubai Government in place. More recently, however, Dubai Government have released two documents directly referencing mitigation

translocation (DM, 2018, 2019) as a requirement during development projects. Throughout their range, dhub can be found on loose to hard gravel plains, avoiding soft sands. This is also prime construction land, as well as being a favoured surface for off-road vehicles and weekend campers. As far as the author is aware, there were no Government of Dubai mandated mitigation translocations for dhub prior to or following this study in the Emirate of Dubai.

Further to conversations with individuals who had been involved in some of the aforementioned ad hoc translocation of dhub within the UAE, (which were by and large unsuccessful), a proof of concept was attempted whereby the requirements of a successful translocation were investigated. The aim of this was to

- Determine if dhub from one location could potentially be caught, moved, released and establish within the new location.
- Would a hard or soft release be the preferred release method for these animals.
    - A hard release in the context of this study refers to the immediate and direct release of the dhub into their intended habitat without any extended acclimatisation or supplementary care period. Dhub would be released with minimal intervention from the author to determine how quickly they would adapt to their new environment and establish themselves in the wild.
    - A soft release in the context of this study involves a more gradual and controlled introduction of the dhub into their new habitat including a period of acclimatisation in a pre-release structure. During this phase, the dhub would be provided with supplementary care, such as food, veterinary care and shelter.

6.2 MATERIALS AND METHODS

6.2.1 STUDY SITE

The study took place within three sites (Figure 6-2), Wadi Al Safa (WAS), Mugatrah (MUG) and Nakhlee (NAK). The first translocation occurred following the rescue of AQ01 from the road where she was found in August 2014. She was placed into a release cage (Figure 6-3) and monitored from there.

6.2.2 EQUIPMENT

AQ01 was fitted with a G10 UltraLITE GPS Logger, a R1605 crystal controlled 2-stage VHF transmitter from ATS Telemetry, MN, USA and a Hygrochron Temperature & Humidity iButton (DS1923-F5# Embedded Data Systems).

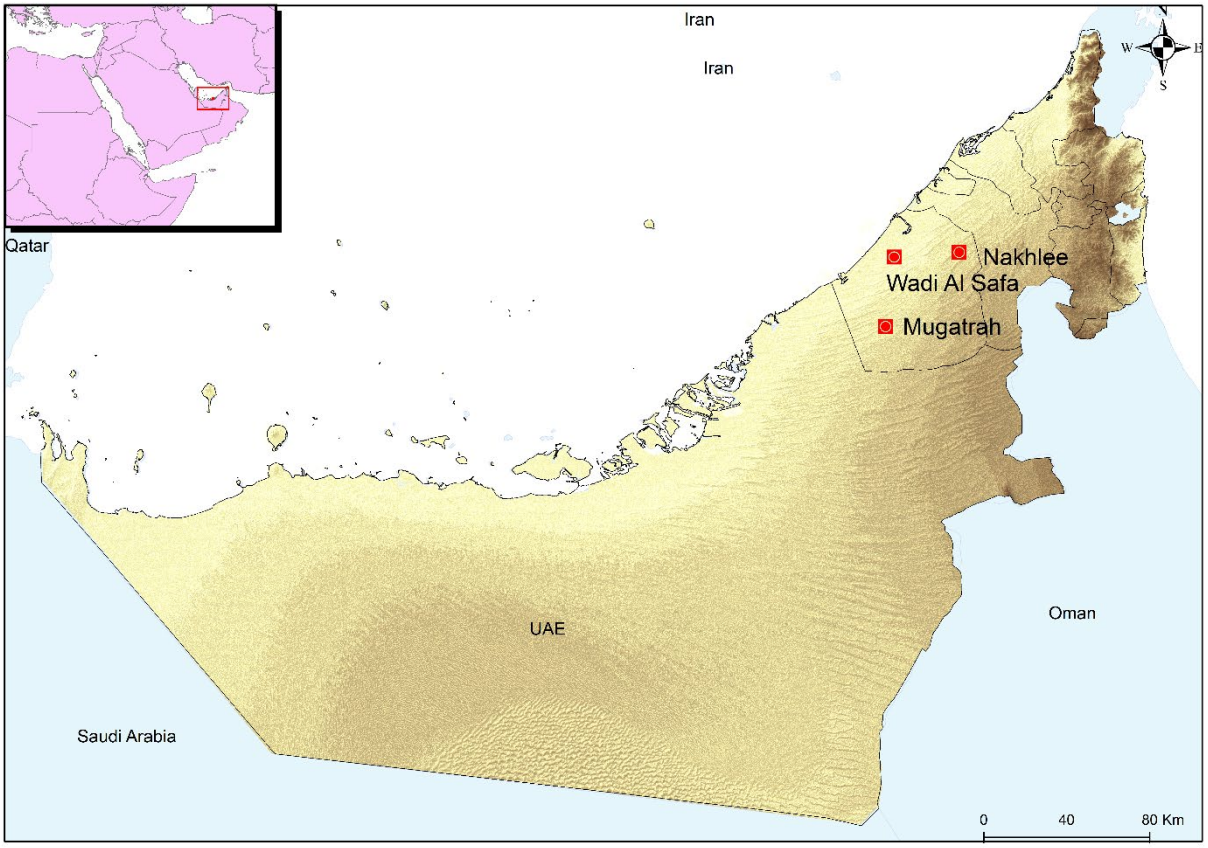


Figure 6-2. Site locations for the three experimental translocation exercises within the UAE.

6.2.3 RELEASE PENS

The next phase of the study involved the monitoring and subsequent translocation of two animals in Nakhlee (Figure 6-4). In September 2014 assistance was requested by Management there to remove two dhub (NAK 003 and NAK 004) from an intended construction area. They were moved approximately 1 Km (Figure 6-8) from their capture location/burrow to their release site and held within a pre-release pen, placed on top of the release burrow (an old burrow which had been filled in, but excavated prior to the translocation), which was left in place for the first seven days after translocation (Figure 6-3). Both dhub were fed in this until such time as they dug under the frame.

Once this was achieved, the pen was removed.

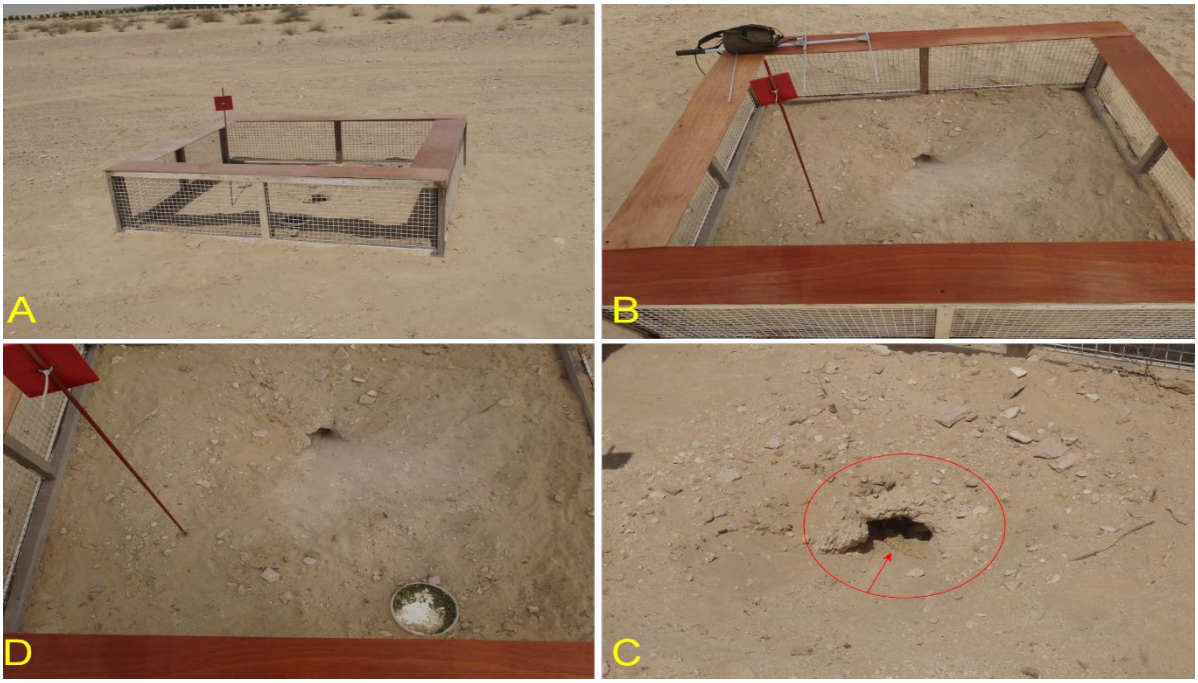


Figure 6-3. AQ01 Release cage (A) complete cage; (B) showing overhang to avoid escape (C) AQ01s tail and transmitter aerial visible (D) supplementary feed dish with signs outside burrow.

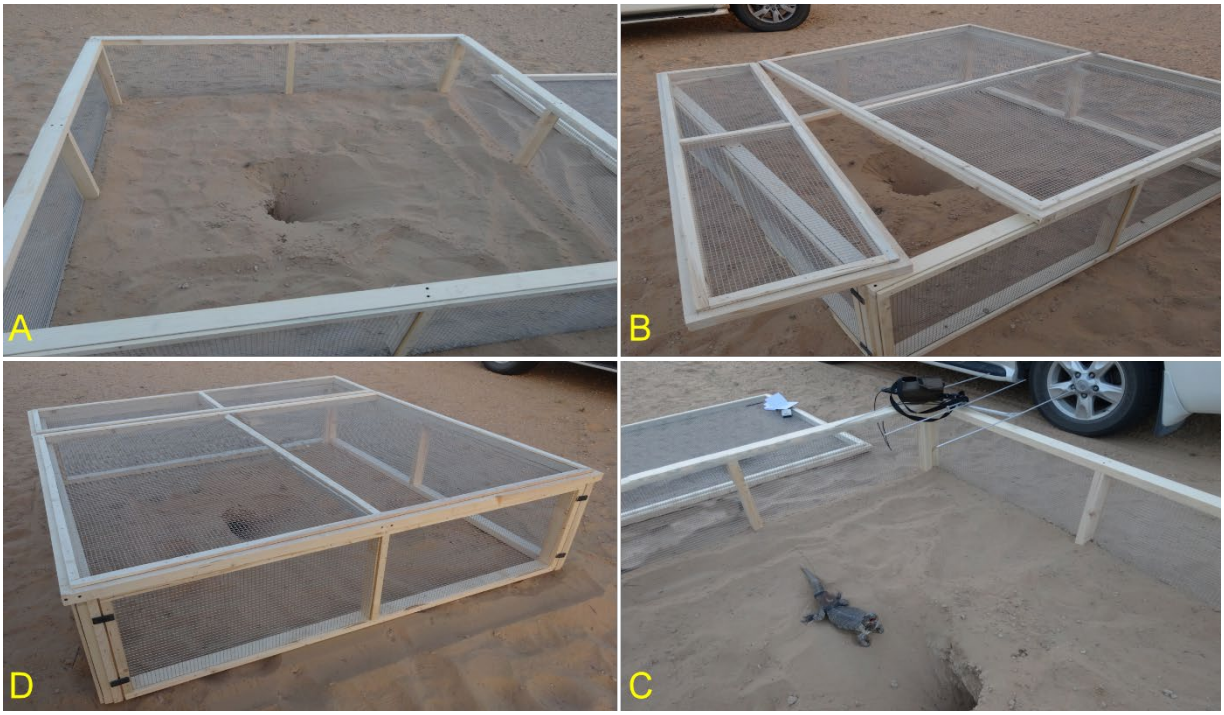


Figure 6-4. Nakhlee release cage (A) open with newly excavated burrow (B) covered showing opening to allow easy access to feed (C) newly translocated animal (D) covered cage.

6.2.4 VHF TRANSMITTER

To establish a baseline of information relating to the usefulness of the tracking equipment, a number of dhub were opportunistically caught in WAS and MUG (Figure 6-5) and fitted with a VHF transmitter.

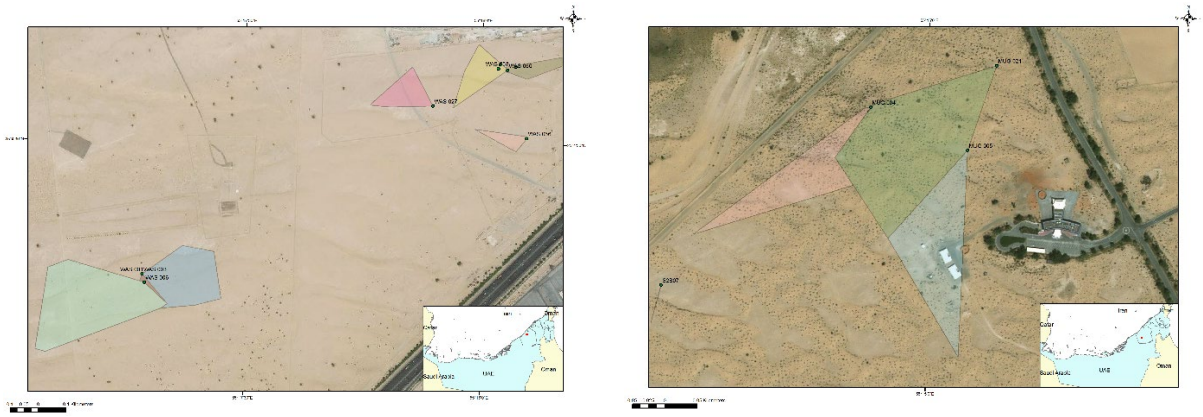


Figure 6-5. MCP of nine animals caught in WAS (left) and four animals from MUG (right) to establish a baseline movement plot prior to translocation.

Two animals in WAS were translocated (WAS 002 and WAS 004) to test the principles of very local translocations (Figure 6-11). Later, a third animal (WAS 059) was translocated from another area within WAS from where it was being monitored.

This was followed by 13 animals being captured and released. All animals were fitted with radio transmitters (Model # R1860 ATS, Isanti, MN, USA) during 2014 and 2015. These 13 animals were monitored throughout subsequent phases allowing the collection of important movement data. A localised trial translocation was attempted with three of these animals (AQ01, WAS 002 and WAS 004).

6.2.5 TRANSLOCATION

In early October 2015, ten more animals were caught on the same day, veterinary checked and fitted with the same transmitter and iButton combinations (see details in Table 6-1). Five were returned to their capture burrows and five translocated to a new site approximately 31 Km away. For these five translocated animals, abandoned burrows, where there was adequate and suitable vegetation (Chapter 4), which had been identified in earlier surveys were excavated and the animals released into these.

Table 6-1. Description of the 23 animals which were included in the translocation and monitoring phase of the study. Translocated animals highlighted in blue were returned to their release burrow each time following GPS fix of their location. NAK 003 and NAK 004 were soft released and did not require subsequent recapture. All other translocated animals were hard released and allowed to fend for themselves.

	Animal	Date of capture	No of days tracked	Sex	Translocated and if so, date and distance (Km)	Result
Translocated Animals	AQ01	30-Aug-14	562	F	Yes 09-Sep-14 - 21 Km	Alive at end of trial
	WAS 002	06-Oct-14	25	F	Yes 06-Oct-14 - 1 Km	Found dead
	WAS 004	19-Oct-14	9	M	Yes 19-Oct-14 - 1 Km	Lost Transmitter
	NAK 003[†]	04-Sep-14	532	M	Yes 28-Sep-14 - 1 Km	Alive at end of trial
	NAK 004[†]	23-Sep-14	494	M	Yes 28-Sep-14 - 1 Km	Alive at end of trial
	WAS 059[a]	10-Jul-2016	11	M	Yes 10-Jul-16 - 3Km	Found dead
	WAS 064	13-Oct-15	158	M	Yes 13-Oct-15 - 31 Km	Alive at end of trial
	WAS 065[b]	13-Oct-15	190	M	Yes 14-Oct-15 - 31 Km	Alive at end of trial
	WAS 061	13-Oct-15	88	F	Yes 13-Oct-15 - 31 Km	Found dead (Predation)
	WAS 062	13-Oct-15	93	M	Yes 13-Oct-15 - 31 Km	Found dead (Predation)
	WAS 063	13-Oct-15	48	M	Yes 13-Oct-15 - 31 Km	Found dead (Predation)
Monitored Animals	WAS 001	04-Oct-14	583	M	No	Alive at end of trial
	WAS 003	12-Oct-14	169	F	No	Lost Transmitter
	WAS 006	08-Mar-15	401	F	No	Alive at end of trial
	S2B07	03-Mar-15	823	F	No	Alive at end of trial
	MUG 005	11-Mar-15	253	M	No	Found dead
	MUG 004	11-Mar-15	433	M	No	Alive at end of trial
	MUG 021	31-May-15	321	M	No	Alive at end of trial
	WAS 027	25-Jun-15	327	M	No	Alive at end of trial
	WAS 056	13-Oct-15	241	M	No	Alive at end of trial
	WAS 057	13-Oct-15	217	F	No	Alive at end of trial
	WAS 058	13-Oct-15	154	M	No	Alive at end of trial
	WAS 059 [a]	13-Oct-15	271	M	No	Presumed dead
	WAS 060	13-Oct-15	271	F	No	Alive at end of trial

[†]NAK 003 and 004 were removed from a construction site. [a]WAS 059 was moved due to its proximity to a new construction site. [b]WAS 065 was removed for a short time to receive veterinary treatment.

6.3 RESULTS

This study directly monitored 24 dhub (Table 6-1) from 2014 through to 2017. In 2017, the remaining dhub in the study which still had transmitters attached were recaught and the transmitters removed. In total there has been the equivalent of 6,674 days (18 years, 3 months) of location data collected for these dhub. Basic location data using the RFID traps (Chapter 3) could have been used for some of these animals but wasn't included in this part of the study.

6.3.1 GPS TAGS

The results from the GPS data were believed to have several issues associated with them which precluded them from long term use. Some of the issues included; the storage capacity, the frequency with which the animal had to be recaptured to download the data, the need to remove the unit which was in the bespoke saddle attached to the animal, thereby necessitating a new saddle after each download and the perceived accuracy of the positioning.

6.3.2 KERNEL DENSITY INDEX (KDE)

Figure 6-6 and Figure 6-7 show the kernel density estimate (KDE) for two test animals and the dispersal of points around burrows. AQ01 (Figure 6-6) release burrow was 14-123F and over the 5 days (9th Sep 2014

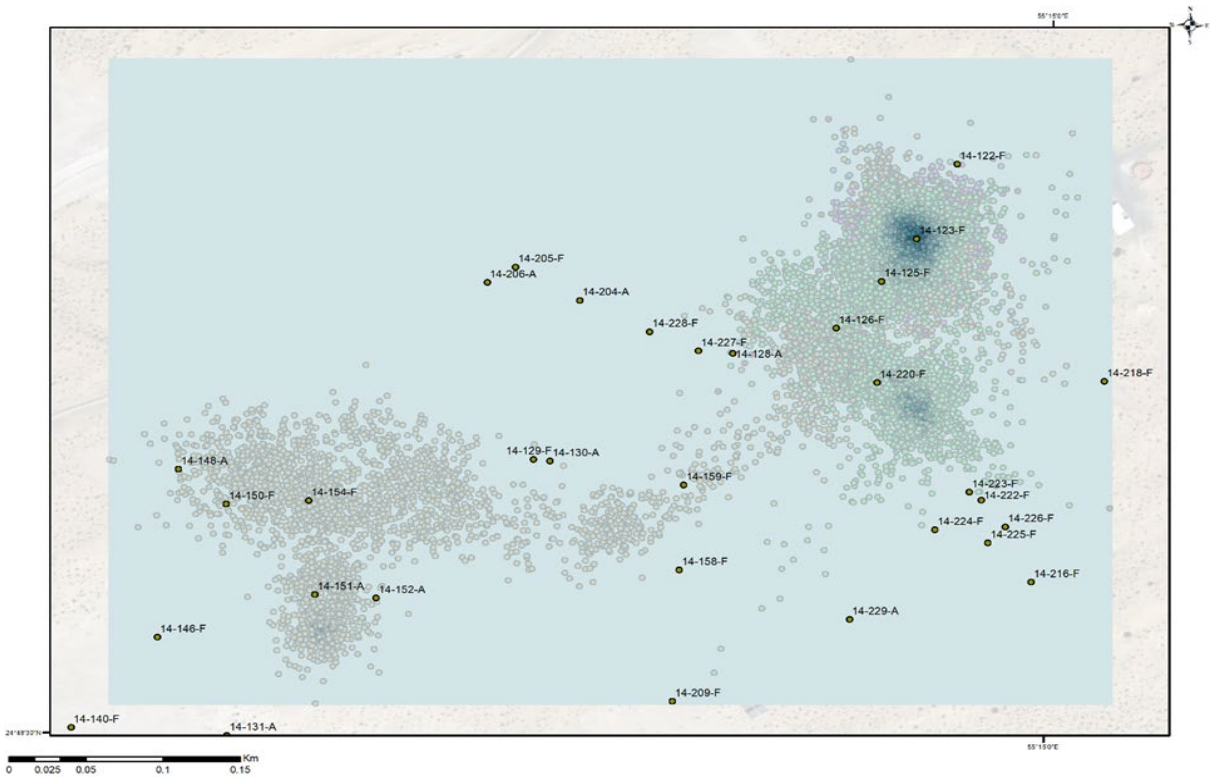


Figure 6-6. The Kernel Density Estimate (KDE) for AQ01 over a 5-day period from 9th Sep 2014 through to 13th Sep 2014 with more than 28,200 records ranging over 550 metres from the original release burrow.

through to 13th Sep 2014) was found more than 500 m away in the open. She was subsequently returned to 14-123F. While the distance for a translocated animal was not dissimilar, there were a lot of data which had to be discarded where outliers were greater than 3 standard deviations (1,000 records). The GPS tracker was removed to download the data and was replaced with an iButton R1806 transmitter combination only.

WAS 02 (Figure 6-7), was captured and released back into burrow 14-018 but had a recorded range of over 550 m from the capture burrow on her GPS data. As it was not translocated, it was believed that there were a number of erroneous records as visible by the extended KDE. Many of the tracks recorded for

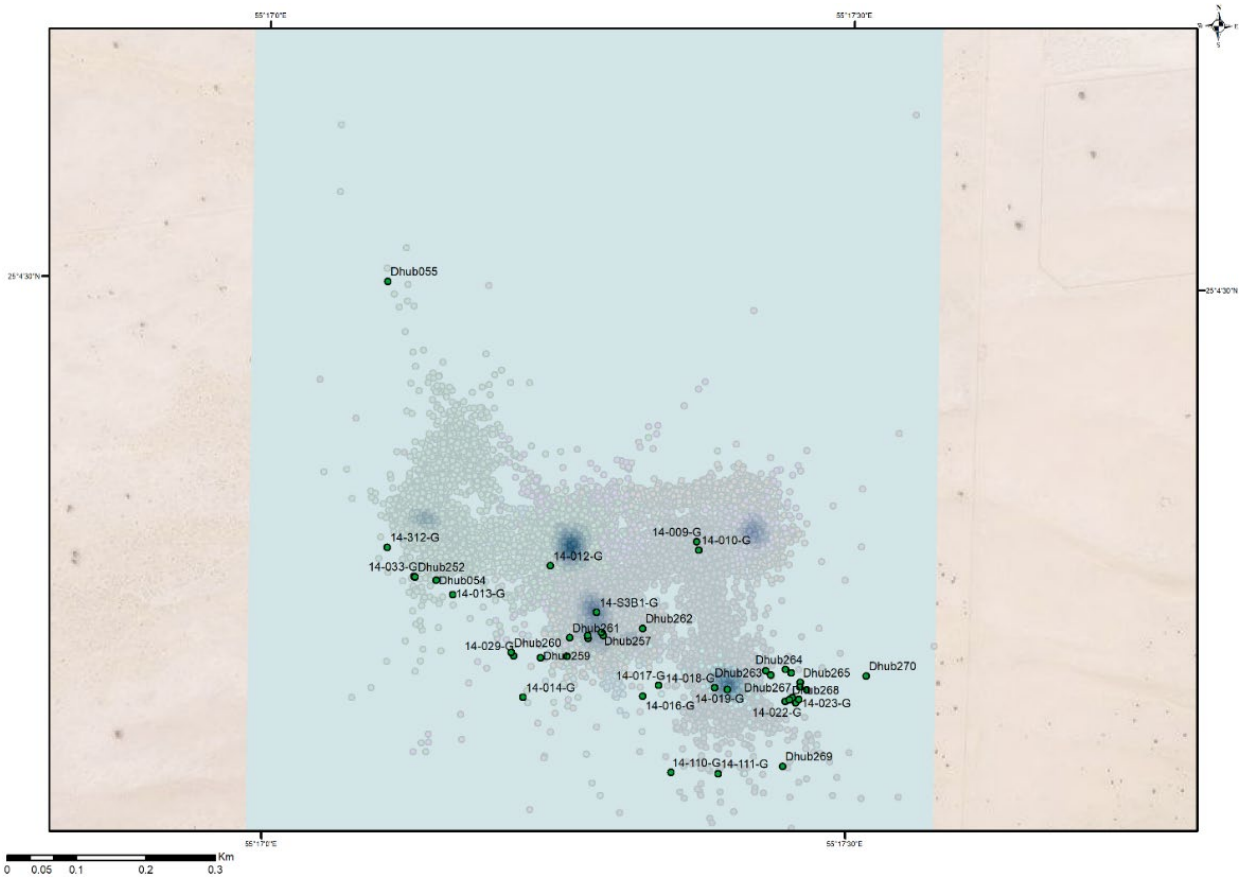


Figure 6-7. The Kernel Density Estimate (KDE) for WAS 02 over a 5-day period from 6th Oct 2014 through to 10th Oct 2014 with more than 18,500 records ranging over 550 metres from the original release burrow.

different animals for another part of this project and feeding range studies (Chapter 3) had a maximum round distance from the burrow of 150 m.

6.3.3 NAKHLEE TRANSLOCATION

With respect to the two dhub (NAK 003 and NAK 004) from an intended construction area. They were

moved approximately 1 Km (Figure 6-8) from their capture location to their release site and held within a pre-release pen. They were fed in this until such time as they dug under the frame (approximately 30 days). Once this was achieved, the pen was removed.

Following their initial translocation and self-release, they were located through VHF tracking every two to three days in their new burrows and their position recorded. These data (Figure 6-8) suggest that NAK003 used his burrow as a central location and was always observed to the West of the burrow. NAK004 was observed to the North of the burrow which might be related to the road found just South of his burrow.



Figure 6-8. Outline of Nakhlee site with the translocation burrows of NAK 003 (532 days tracking) and NAK 004 (494 days tracking) showing the mean convex polygon (MCP) for both translocated animals.

6.3.4 HOME RANGE/MEAN CONVEX POLYGON (MCP)

Calculating the mean convex polygon (MCP) for each of the observed dhub (Table 6-2) showed that there were similarities in the average MCP area and perimeter length between both sites (Table 6-3).

However, there was one dhub in each site (S2B07 in MUG and WAS 057 in WAS) who were always recorded close to their burrow as the average MCP (S2B07=14.1 m^2 and WAS 057=23.7 m^2) suggested that these animals did not venture very far from what was considered their home burrow.

Table 6-2. Mean Convex Polygon of all observed (not translocated) animals showing the observed range area (m^2) and length of the home range perimeter.

Dhub ID	Area (m^2)	Perimeter Length (m)	Site
MUG 004	24,757.7	942.5	MUG
MUG 005	36,640.7	930.6	MUG
MUG 021	32,156.1	767.7	MUG
S2B07	14.1	122.2	MUG
WAS 001	46,495.9	830.2	WAS
WAS 003	2,168.9	298.3	WAS
WAS 006	88,379.6	1,267.1	WAS
WAS 027	16,111.7	580.1	WAS
WAS 056	5,617.7	419.6	WAS
WAS 057	23.7	24.8	WAS
WAS 058	159.2	108.4	WAS
WAS 059[a]	10,503.1	786.8	WAS
WAS 060	17,164.3	616.1	WAS
Summary statistics			
N	13	13	
Minimum	14.1	24.8	
Maximum	88,379.6	1,267.1	
Mean	21,553.3	591.9	
Median	16,111.7	616.1	
SD	25,205.9	377.7	
SEM	6,990.9	104.8	

[a]WAS 059 was initially observed but at the end of the study he was translocated locally (3Km distance).

Table 6-3. Average MCP for the area and length in MUG and WAS for the observed animals.

Aspect	Site	No Dhub	Mean	SEM	StDev	Minimum	Median	Maximum
Area (m^2)	MUG	4	23,392	8,169	16,337	14	28,457	36,641
	WAS	9	20,736	9,721	29,163	24	10,503	88,380
Length (m)	MUG	4	691	194	387	122	849	943
	WAS	9	548	129	388	25	580	1,267

6.3.5 LOCAL TRANSLOCATION

WAS 002 and WAS 004 were both translocated as the initial part of the study. WAS 004 lost his transmitter in an attempt to return to the original capture burrow while WAS 002 was believed dead within a burrow three weeks after release. The signal was located and the tracker and dead dhub were recovered by excavation of the burrow (Figure 6-9).

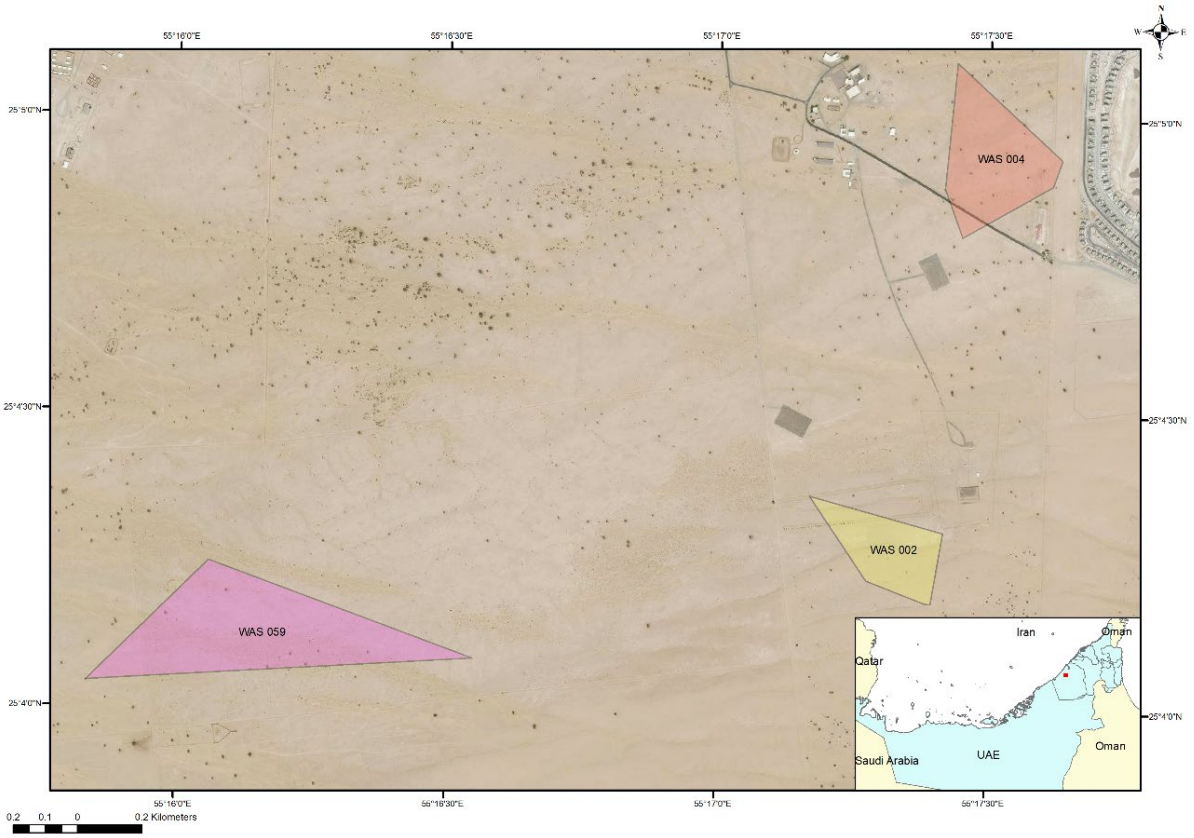


Figure 6-9. The MCP for each of the three dhub translocated locally within WAS site.

WAS 059 was the third local translocation that was attempted. He was unique in that while he was being observed in his original capture burrow, (over a period of 271 days), his MCP was calculated at 10,503 m^2 which was less than the mean of the studied animals (Table 6-2). Following translocation and over a period of 11 days that increased to 211,424 m^2 (Figure 6-10) which was twice as large as WAS 004



Figure 6-10. WAS 059 MCP area when he was observed (WAS 059 Obs) compared to the MCP when he was translocated (WAS 059 Trans).

and three times as large as WAS 002 for the same site. When compared to all the other animals, the MCP was almost twice as large as the mean MCP for translocated animals (Figure 6-11 and Table 6-4).

Table 6-4. Mean Convex Polygon of all translocated dhub showing the observed range area (m^2) and length of the home range perimeter.

Dhub ID	Area (m^2)	Perimeter Length (m)	Site
AQ01	109,337.4	1,502.0	WAS
NAK 003	20,382.2	659.3	NAK
NAK 004	4,069.7	867.0	NAK
WAS 002	68,703.1	1,186.4	MUG
WAS 004	109,338.6	1,410.8	MUG
WAS 059[a]	211,424.0	2,615.8	MUG
WAS 061	182,835.3	1,832.6	MUG
WAS 062	163,270.6	1,770.8	MUG
WAS 063	228,078.4	2,169.3	MUG
WAS 064	34,669.3	878.7	MUG
WAS 065	137,202.8	1,495.6	MUG
	Summary statistics		
N	11	11	
Minimum	4,069.7	659.3	
Maximum	228,078.4	2,615.8	
Mean	115,391.9	1,489.8	
Median	109,338.6	1,495.6	
SD	77,088.2	589.5	
SEM	23,243.0	177.8	

[a]WAS 059 was initially observed but at the end of the study he was translocated locally (3Km distance).

These data show that translocated animals were far less settled and had a mean MCP area of 115,319 m^2 compared to the mean area of 21,553 m^2 for the observed (not translocated) animals. This apparent requirement to move about the new area is confirmed when one looks at WAS 059 who had an MCP of 10,503 m^2 compared to 201,424 m^2 when he was translocated.

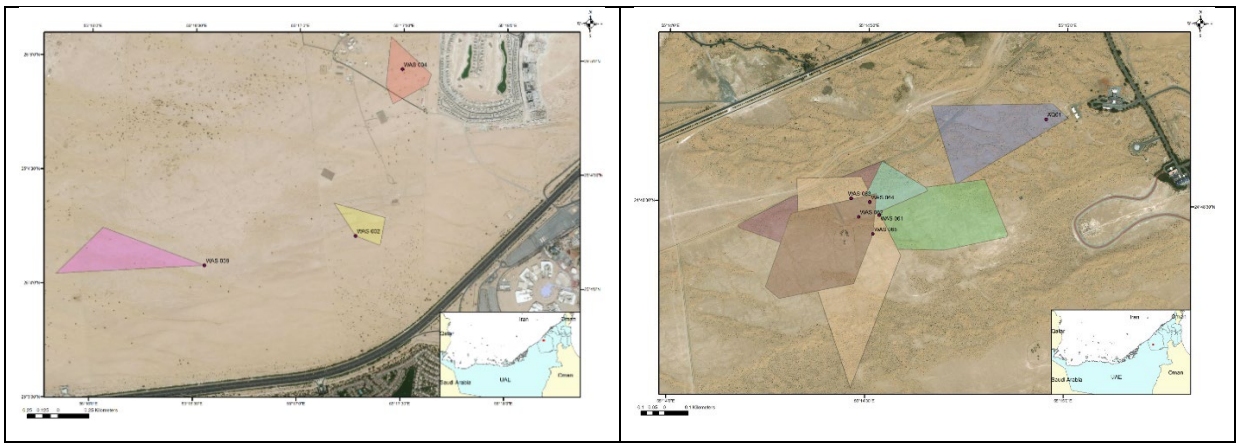


Figure 6-11. MCP of three translocated animals in WAS (left) and six animals from MUG (right).

Both of the animals which were soft released had a noticeably smaller area than the animals which were hard released. NAK 003 and NAK 004 had similar MCP areas to those of the non-translocated animals.

6.4 DISCUSSION

Restoration of a species to a region from which it has been extirpated may often be possible only through the release of new individuals (Kachamakova *et al*, 2022). Some mammal and avian examples include the Arabian oryx (*Oryx leucoryx*) (Price, 1989), Przewalski's horse (*Equus przewalskii*) (Ryder, 1988), the Red-billed chough (*Pyrrhocorax pyrrhocorax*) (Corry *et al*, 2021), and the European bison (*Bison bonasus*) (Catanoiu *et al*, 2021). Similarly, protecting a species from uncontrolled development might also be only possible through the moving of species from areas of potential conflict. Currently, there appears to be a general lack of knowledge and little agreement on how land-use changes affect either amphibians or reptiles (Burriel-Carranza *et al*, 2019; Cordier *et al*, 2021). However, Wedding *et al* (2007) suggests that as reptiles tend to be among the least mobile of New Zealand's fauna, they may be particularly susceptible to the impacts of human intrusion, while Tolley *et al* (2016) suggest that land transformation for agriculture, particularly subsistence farming, constitutes the primary threat to African reptiles. Al-Sayegh *et al* (2020) showed that there was a significant effect on the body condition index between dhub in protected and non protected areas. This is particularly pertinent to the UAE where there have been exponential growths in population and requirements for building land over the past 30 years. As a result, the 60 species of UAE terrestrial reptiles, as well as numerous plant and invertebrate taxa are coming under increasing pressure (pers obs). One method which could potentially alleviate some of this pressure would be by mitigation translocation to new and protected sites. Although some authors question the success of translocation of reptiles in reptile-development conflicts (Berger-Tal *et al*, 2020; Nash *et al*, 2020), there have been no reported trials within the UAE to compare.

Prior to any translocation programme it is imperative that the basic ecology and behaviour of the species concerned be known, in particular for dhub, its burrow fidelity and possible homing instincts (see Chapter 2 and 3). There are numerous ways of obtaining some of these data such as through the use of VHF transmitters, hand-held gps or the use of remote gps tracking units. Using Snapshot Global Navigation Satellite Systems (GNSS) requires milliseconds of satellite signals to infer the position of a receiver. Latitudes and longitudes are not calculated on-board but reconstructed after data retrieval in a cloud based platform (Wild *et al*, 2022). However, Cochrane *et al* (2019) suggest that the fix success rate for land locations was 38% (SD = 9), for their study. As such, additional techniques might be needed to identify use of habitat structures (e.g., burrows, tree cavities, rock crevices) that could affect micro-GPS performance and bias study results (McMahon *et al*, 2017). There is also a fine balance between sample interval and battery life. The UltraLite units used in this study, while small and compact had large inconsistent data fixes. Together with the fact that the animal had to be recaptured and the complete saddle (Figure 6-12) used to attach the units to the animal had to be destroyed,

together with other logistical and political[1] issues meant that they were not extensively used past the initial trial with the two animals reported here.

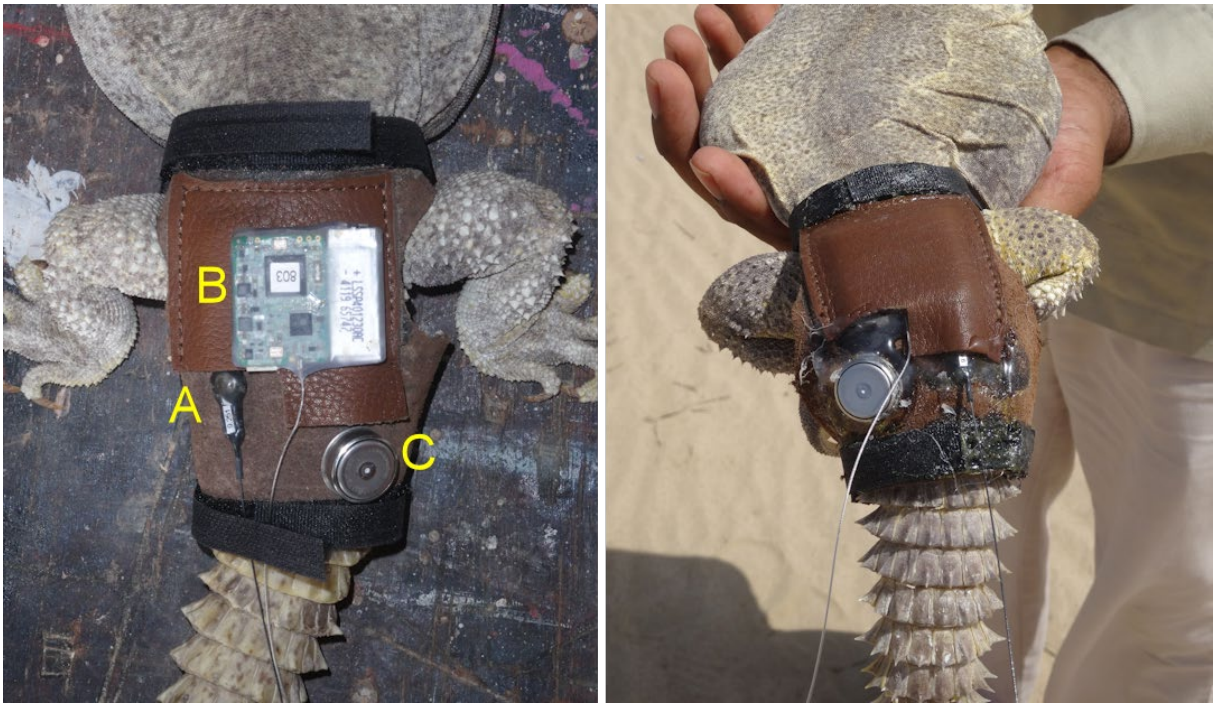


Figure 6-12. The bespoke saddle made to carry the (A). ATS VHF transmitter; (B). the ATS Ultralite GPS tracker; and (C) the iButton temperature and humidity logger.

Burt (1943) suggested that the home range of an animal is "that area traversed by the individual in its normal activities of food gathering, mating, and caring for young". Silva *et al* (2020) argue that the use of the home range concept has been questioned in recent years but suggested its estimation continues to have a wide range of applications, such as inferring habitat use as in the case of this study. Many terrestrial reptile species are said to move less frequently than similarly sized mammals having distinct natural histories from mammals (Hailey, 1989; Wedding *et al*, 2007). In the present study, the average distance that a dhub travelled during a journey from their burrow (recorded by walking the route with a handheld GPS) was 80.4 m in the Spring (*N=51, SE=9.69*) and 155.5 m in the Summer (*N=130, SE=9.93*) and was always based around a burrow. Mata-Silva *et al* (2018) found the average daily movement of rock rattlesnakes (*Crotalus lepidus*) to be 8.46 ± 1.45 m/d, with a mean home range (based on MCP) 13.69 Ha.

While short distance translocations are a possible option, they were not considered to be effective in

[1] At the time of the study, post collection data processing was completed through servers based in Israel. At the time, there were no diplomatic relations between the UAE and Israel which was a security concern.

dealing with problem animals, as in many cases the translocated animals return back to the capture site (Dodd & Seigel, 1991; Brown *et al*, 2009). This homing instinct was also demonstrated within the current study where the use of artificial burrows was tested, but the translocated animal returned to its capture location within 48 hours. A similar movement pattern was observed for some of the locally translocated animals (WAS 002, WAS 004 and WAS 059), where the area they were observed post translocation was 20 times greater in the case of WAS 059.

Aggregated telemetry locations (Powell & Mitchell, 2012) such as this study should provide insights into what dhubs call home and allows one to estimate the total use of space, commonly considered to represent an animal's home range. Accepting that the MCP is a reflection of dhubs' home range and a 2D representation of the area covered by an animal, then it was clear that those animals which were moved to a new location required a much greater area (on average 5 times larger) than those which were not moved, which was similar to other studies (Brown *et al*, 2009). As many taxa exhibit a form of site fidelity and live in restricted areas for long periods, they have a familiarity with the areas where they live and they know the locations of resources, escape routes, and potential mates (Powell & Mitchell, 2012). Removing animals from these safe situations exposes them to many stressors which would increase the potential inability to locate suitable refugia leading to hypo or hyperthermia, malnutrition, intraspecific conflict with other conspecifics in the release area as well as being very prone to predation. The increased exposure to predation was ultimately the cause of death of three of the five animals translocated on the 13th Oct 2015.

The exception to increased home range for translocated animals were the NAK animals which were translocated and held in a small pre-release pen to facilitate a soft release. The use of soft release techniques has been shown to be far more effective in reptile translocations with a 77% better success rate than other terrestrial species translocations when compared to hard release programmes (Resende *et al*, 2021). Sasmal *et al* (2015) suggest that the 60-day post release survival of translocated animals had a direct bearing on the release method (soft or hard), where a soft release involves holding the animals in the translocation area to allow for acclimation to the area of release, monitoring the animals for veterinary issues and allowing the animals to orientate themselves in their environment as well as providing an area refuge in the future. Hard releases on the other hand involve the direct release of the translocated animal into the release area, as was done previously in dhub translocation where the mantra was "a dhub is a lizard that lives in the desert and will be able to survive if released back into the desert".

The reduced home range area for the NAK animals is similar to that observed in the settled and monitored dhub. This reinforces Sasmal *et al* (2015) argument that how animals are released into an

area will have a direct impact on the survival, behaviour and reproductive capacity of these animals. Both animals translocated in NAK were one such example. Placed within a small pen, over a previously filled in burrow which was re-opened prior to the animals been put in, gave both animals sufficient advantage to keep the animals in that location long enough to familiarise themselves with the terrain. Following their successful digging out from this pen, they were seen in the vicinity of the release area for as long as the study continued. Perhaps juvenile animals which have not established the same site fidelity as adults might have a better chance of success.

Unfortunately, 170 days post release when looking for NAK 004, it was found where construction workers had started to excavate the burrow (Figure 6-13) to try and catch it. This again reinforces a pre-requisite that sufficient enforcement and legal measures are in place to protect translocated animals. While there appeared to be some avoidance patterns in the observations of the animals, it would be important that any translocation be completed in areas where this would not happen. In fact, NAK 004's MCP suggests he spent most of his time going North of the release burrow, most probably avoiding the off-road track just south of his burrow (Figure 6-8) whereas NAK 003 went west on the gravel and into the sand dunes near his release burrow, appearing to have a similar MCP to the animals which were simply monitored at the beginning of the trial.



Figure 6-13. Site of illegal excavation of NAK 004.

Similar to the two NAK animals, AQ01, WAS 002 and WAS 004 were returned to their release burrow post release whenever they were located away from it. This again ensured that while these animals were prone to predation, they were at least given the opportunity to familiarise themselves with their

new locality prior to being allowed free range continually.

6.4.1 CONCLUSION

To be a truly successful mitigation translocation, it would mean moving all biota from the area of concern which would be impractical. Drawing attention to flagship or iconic species might help mitigate some of the issues, but longer-term protection models and policies are needed. The current study has shown that it is possible to successfully move a species like *U. aegyptia leptieni* from one area to another and get them to successfully survive the translocation phase. This does have to be managed in a way where a soft release would be the preferred option. Protected areas where there were previous animals resident offer the ideal release location. Existing burrows which are filled in should have the correct burrow structure for the animals to utilise in the initial introduction. Once established animals can migrate from these to different areas if needed.

The study did not, however, prove that the animals reproduced or that the population increased, two very difficult factors to determine in reptile translocations. It does show that with the correct pre-planning and preparation the translocation of dhub to remove the animal/land-use conflicts is certainly possible.

Further studies such as this should be attempted, potentially using a series of cages close to each other and allowing the dhub to again dig their own escape route. The close proximity will allow for more dhub to be translocated (for example a full colony) allowing the maintenance of some group structure if it existed prior to the translocation. It is believed (*pers obs*) that given a period of 20 to 30 days within an area, dhub will have had sufficient time to orientate themselves and should be able to locate sufficient refuge to allow them to establish successfully.

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Reptiles

Translocation trial of spiny-tailed lizard or *dhub* in Dubai, United Arab Emirates

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Introduction

The spiny-tailed lizard or *dhub (Uromastyx aegyptia leptieni*) is one of three subspecies of *Uromastyx aegyptia* and is found from Oman's Hajar al-Gharbi Mountains through to the northeastern United Arab Emirates (UAE). The species is listed on CITES Appendix II and categorised as vulnerable by the IUCN. Within the UAE, where this project is taking place, it is protected specifically under Federal Decree Law Number 9 of 1983. An estimated 1.5 million people are moving to cities globally each week. It is estimated that almost 90% of the UAE population will be urbanised by 2020, a trend obvious in Dubai in particular. Road infrastructure, services and megaproject construction are seriously impacting on available habitat for many local species of biota. Habitat conversion for development and agricultural use are identified as key threats to threatened reptile species of the Arabian Peninsula (Cox *et al.*, 2012).

A translocation attempt moved dhubs from the Abu Dhabi Airport expansion (Barcello & Tourenq, 2005), with the subsequent recovery of animals at one of the release sites (Soorae *et al.*, 2008). There is no other official documentation of translocating dhubs within the UAE, although there have been attempts within the Emirate of Dubai during the Al Maktoum Airport development and development of other coastal projects.

Goals

- Goal 1: Evaluate burrow usage and animal movements.
- Goal 2: Determine the feasibility and protocol for translocating *U. a. leptieni*.
- Goal 3: Monitor the release site fidelity in preparation for future translocations.

Success Indicators

- Indicator 1: Released animals remain within the release area over one brumation period.



Spiny-tailed lizard or *dhub*

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Holding pens placed on top of burrows for seven days

- Indicator 2: Released animals follow a similar activity pattern to animals that were not translocated but monitored in a similar fashion.
- Indicator 3: Capture of animals with no mortality or injury.

Project Summary:

Feasibility: Throughout their range, *dhubs* can be found on loose to hard gravel plains, avoiding soft sands. This is also prime construction land, as well as being a favoured surface for off road vehicles and weekend campers. There is some debate as to whether *dhub* are completely vegetarian or, as suggested by some authors (Castilla *et al.*, 2011) whether they are selective scavengers. The authors (O'Donovan and O'Riordan, in prep.) suggest that those in the UAE are more likely to be incidental scavengers and consume non-vegetative items as they forage and therefore have specific dietary requirements. Preferred forage species from the study sites include, *Heliotropium kotschyi, Tribulus* sp., *Fagonia bruguieri, Stipagrostis plumosa, Panicum turgidum, Helianthemum lippii, Pennisetum divisum* and *Leptadenia pyrotechnica* seed pods when they were available. During the initial survey period, a total of 1,653 individual burrows (both active and abandoned) were identified. Of these the orientation of 784 were recorded with more than 50% orientated in a westerly direction, which was different to the primary orientation previously recorded for *Uromastyx aegyptia* (Cuningham, 2001).

Implementation: The initial phase of the present study saw 13 animals captured and fitted with radio transmitters (Model # R1860 ATS, Isanti, MN, USA) and Hygrochron Temperature & Humidity iButton (DS1923-F5# Embedded Data Systems) during 2014 and 2015. These 13 animals were monitored throughout subsequent phases allowing the collection of important movement data (O'Donovan and O'Riordan, in prep.). A localised trial translocation was attempted with three of these animals (AQ01, WAS 002 and WAS 004). Subsequently, in September 2014, two animals, NAK 003 and NAK 004, were moved from a proposed construction site to a new area approximately 1 km from their capture burrow. These two animals were each released into a holding pen placed on top of the release burrow, which was left in place for the first seven days after translocation.

In early October 2015, 10 more animals were caught on the same day, subjected to veterinary checks and fitted with the same transmitter and iButton combinations. Five were returned to their capture burrows and five translocated to a new site approximately 31 km away. For these five translocated animals, abandoned burrows, where there was adequate and suitable vegetation, which had been identified in earlier surveys (O'Donovan and O'Riordan, in prep.) were excavated and the animals released into these.

Post-release monitoring: Of the first three early localised translocations, AQ01 was successful, WAS 002 survived for 25 days before being predated and WAS 004 lost its transmitter. The other two dhubs, NAK 003 and NAK 004, who had been kept within holding pens for the first seven days after release, remained in their release area and were observed there in early 2017. All ten of the October 2015 tagged animals were monitored on a daily basis for the first 14 days and every alternate second day thereafter for four months. Of the five translocated animals, three died, two from predation as they did not settle in any specific burrow and one was presumed dead in a burrow where it took up residence in. All the deaths were within 90 days of release. The other two were considered to have established in the release area.

Of the five dhubs that had been tagged in October 2015 but were not translocated, four were found alive at the end of the monitoring, while one, WAS 059, was presumed predated as it disappeared with no radio signal detected. Of the remaining monitored but not translocated animals throughout the study, there was only one other mortality, MUG 005 which died of natural causes. The monitored animals showed a lot of movement between burrows and while there was certain burrow fidelity, animals were often recorded (using bespoke RFID traps - RFIDRW-E-232, Priority 1 Design, Melbourne, Australia) in burrows up to several hundred metres apart (O'Donovan and O'Riordan, in prep.). Also two of the translocated animals were recorded in RFID traps during January 2018.

Major difficulties faced

- Released animals establishing in release burrows.
- Predation from feral cats, foxes or raptors.
- Ability to identify release animals after removal of transmitter either after battery depletion or loss of transmitter. Follow up monitoring would be difficult without further captures.

Major lessons learned

- Release animals need to be retained in a



Overview of habitat at release site (yellow arrow shows dhub)

temporary holding pen for several days at the release location and allowed to excavate their own way out.
- Old abandoned burrows can be utilised in translocation projects.

Success of project

Highly Successful	Successful	**Partially Successful**	Failure
		√	

Reason(s) for success/failure:
- There were too many mortalities which could be attributed to the homing instincts of dhub exposing them to increased risk of predation or chilling/ heating extremes.
- The chance of success was much greater when animals were held in release pens or caught and returned to the release burrow until it had established in the release area.
- Capture and monitoring protocols have now been established and can be implemented rapidly in the case of urgent translocation from construction projects.
- As this was a short-term pilot project the measurement of success was the ability to complete one brumation cycle effectively. Whether any of the translocated animals have contributed to the increase of the local population would be difficult to determine.

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CHAPTER 7: MITIGATION TRANSLOCATION PROTOCOL FOR *UROMASTYX AEGYPTIA LEPTIENI.*

7.1 INTRODUCTION

Reptile translocations have been carried out in many countries for many years (Romijn & Hartley, 2016; Woodfine *et al*, 2017; O'Donovan & O'Riordan, 2018; Nash *et al*, 2020) yet they still frequently fail (Bradley *et al*, 2023; Germano, 2023). Mitigation translocations now outnumber other conservation translocations (Bradley *et al*, 2022) and can be an attractive option for generating publicity as they are media-friendly events showing concrete action being taken by concerned authorities. Evidence suggests that many mitigation-driven translocations fail, although the application of scientific principles and best practices would probably improve the success rate . Major knowledge gaps surround the basic ecology of reptile species, including basic factors such as habitat preference, which have a critical influence on translocation success. To align mitigation translocations with the relative success of other conservation translocations, it is critical that future mitigation translocations conform to an established experimental approach to improve their effectiveness (Anon, 2018; Bradley *et al*, 2022). Seddon *et al* (2007) recommend that researchers contemplating future reintroductions carefully determine a priori the specific goals, overall ecological purpose, and inherent technical and biological limitations of a given reintroduction and that evaluation processes incorporate both experimental and modeling approaches.

Please see APPENDIX 7-1 for a process driven flowchart on developing a successful mitigation translocation for *Uromastyx aegyptia leptieni* (dhub).

7.2 ANIMAL WELFARE CONSIDERATIONS

7.2.1 ACUTE STRESS

In natural circumstances, the acute stress response is composed of adaptive physiological and behavioural responses to a stressor. Such a response to a single acute stressor is generally beneficial to the animal.

When an animal encounters a stressor, two parts of the acute stress response are activated: the fast fight-or-flight response, mediated by the sympathetic nervous system (SNS) and the slower glucocorticoid response, the release of the catecholamines, epinephrine (E) and norepinephrine (NE).

Initiation of the fight-or-flight response allows for a quick reaction to the stressor and includes elevation in heart rate (HR), increased blood pressure, and mobilization of energy sources to the

central nervous system (CNS) and somatic muscle. The fight-or-flight response is then followed by the slower hormonal stress response, in which the adrenal gland secretes glucocorticoid hormones as an end result of a hormonal cascade along the hypothalamic-pituitary–adrenal (HPA) axis. Negative feedback quickly suppresses glucocorticoid release once the stressor diminishes or ceases.

7.2.2 CHRONIC STRESS

If a stressor persists or a series of acute stressors initiate multiple consecutive stress responses, an animal becomes chronically stressed. For example, the fight-or-flight response system, when chronically stimulated, can have a negative impact on cardiovascular health through excess catecholamines exposure leading to hypertension, myocardial infarction, increased cardiac output and arrhythmias (Dickens *et al*, 2010).

Chronic stress makes translocated animals more vulnerable to other environmental factors, and thereby amplifies the potential problems encountered when released such as predation or disease. Although species will differ in their sensitivity to stress and the amount of time it takes the population to fully recover from translocation, decreasing overall exposure to stress will commensurately increase the probability of translocation success (Dickens *et al*, 2010).

7.3 CONSULTATION

7.3.1 STAKEHOLDERS

It is vitally important that all stakeholders are consulted and included within the planning stage of the translocation. It is also critically important that in order to ensure the welfare of animals during translocation and to maximise the chance of a successful translocation outcome; the team of people carrying out the translocation needs to include members with suitable training and experience in the capture, handling, holding and release techniques that will be used. These expert operators are needed on site to demonstrate best practise to less well trained or experienced operators.

7.4 PLANNING AND PREPARING FOR TRANSLOCATION

7.4.1 DONOR SITE

A thorough site survey must be carried out on the donor site. For terrestrial mammal and reptile species, a variety of survey methods have been used by researchers (de Kock & Gallacher, 2016; Draper, 2016) to determine occurrence and abundance. However, according to Peterson & Dorcas (1992) a major problem associated with herpetological surveys and monitoring programs is that environmental variation affects animal activity and, thus, one's ability to determine the presence and abundance of amphibians and reptiles. This is more pronounced with ectothermic organisms as they are more coupled to environmental conditions than endothermic organisms. Garden *et al* (2007)

found pit-fall traps and direct observations were the most cost-effective methods for maximising the number of reptile species identified. Wilms *et al* (2010) found newly hatched *Uromastyx* during early August in their study, a similar finding to the current study. Michael *et al* (2012), suggested that a key result of their surveys was that in all study areas, active searches detected the highest mean species richness per site. The population count of affected dhub must be accurately determined and recorded prior to any capture effort.

7.4.2 Receiving Site

Similar to the donor site, the receiving site must be surveyed in detail to determine the availability of suitable native forage for the species to be translocated as well as the availability of suitable refugia for dhub involved in the translocation. Suitable forage species found on a number of studies (Bouskila, 1985; Robinson, 1995; Jongbloed, 1997; Al-Hazmi, 2001; Cunningham, 2001b, a; Al-Sayegh *et al*, 2020) include some of those listed in Table 7-1.

Table 7-1. Species of plant known to be eaten by dhub throughout some of their range. Species in bold have been confirmed as a forage species in the current study. Species with an * were not confirmed as a definite forage species during the current study but were present during the surveys.

No.	Species	No.	Species
1	*Aerva javanica**	23	*Malcolmia grandiflora*
2	*Aristida plumosa*	24	*Moltkiopsis ciliata**
3	*Astragalus gyzensis*	25	*Neotorularia torulosa*
4	*Astragalus spinosus*	26	*Neurada procumbens**
5	*Cakile arabica*	27	***Panicum turgidum***
6	***Calligonum comosum***	28	***Pennisetum divisum***
7	*Carduus pycnocephalus*	29	*Plantago boissieri*
8	*Cenchrus setigerus*	30	*Plantago ciliata**
9	*Citrullus colocynthis*	31	*Plantago coronopus*
10	***Fagonia bruguieri***	32	*Plantago lanceolata*
11	*Farsetia aegyptia*	33	*Polycarpaea repens**
12	*Filago pyramidata*	34	*Polygala erioptera*
13	*Haloxylon salicornicum**	35	*Pulicaria glutinosa*
14	***Helianthemum lippii***	36	*Rhanterium epapposum*
15	***Heliotropium kotschyi***	37	*Savignya parviflora**
16	*Horwoodia dicksoneae*	38	*Schismus barbatus*
17	*Ifloga spicata*	39	*Senecio glaucus*
18	*Launaea angustifolia*	40	*Stipa capensis*
19	*Launaea capitata**	41	***Stipagrostis plumosa***
20	*Launaea mucronata**	42	*Suaeda vermiculata*
21	*Leptadenia pyrotechnica**	43	*Tavemiera cuneifolia*
22	*Loeflingia hispanica*	44	***Tribulus* spp.**

After (Jongbloed, 1997; Cunningham, 2001a; Al-Sayegh *et al*, 2020; O'Donovan, 2023)

The population count of dhub, and available burrows must be determined accurately prior to any translocation. If possible, a general health screening should also be completed on the receiving site animals to determine the health status of that population to determine the risk of introducing alien organisms and disease with the translocated dhub.

A detailed land management plan should be obtained for the receiving site to ensure the long-term survival and persistence of the dhub into the future at that site.

7.4.3 HOLDING SPACE

In the event that dhub are going to be held for a period of time at the donor site or similar location, then it is essential that sufficiently sized holding areas are constructed with adequate basking and hiding areas are available. These can be brought to site and assembled when and wherever they are required.

Figure 7-1 and Figure 7-2 demonstrate an example of a cheap and easily mobilised holding cage for captured dhub either while at the donor site or these they can be used as quarantine and soft release pens at the receiving site.



Figure 7-1. Modular temporary holding pen for dhub. Note the flat plywood surface inside the enclosure to stop them from climbing.



Figure 7-2. Internal of holding cage/release cage showing the sliding door which can be used to feed the dhub through or release if being used as release pens. Areas to hide inside are provided by the rock slabs layered to allow the dhub dig its own secure area.

7.4.4 Survey Methods

Two burrow classifications for the donor site should be used, Active (still in use) and Abandoned (open but no animal is in residence) while three burrow classifications within receiving site of Active, Abandoned and Filled In (the burrow is filled in with sand and there was no evidence of animals in the area) should be utilised.

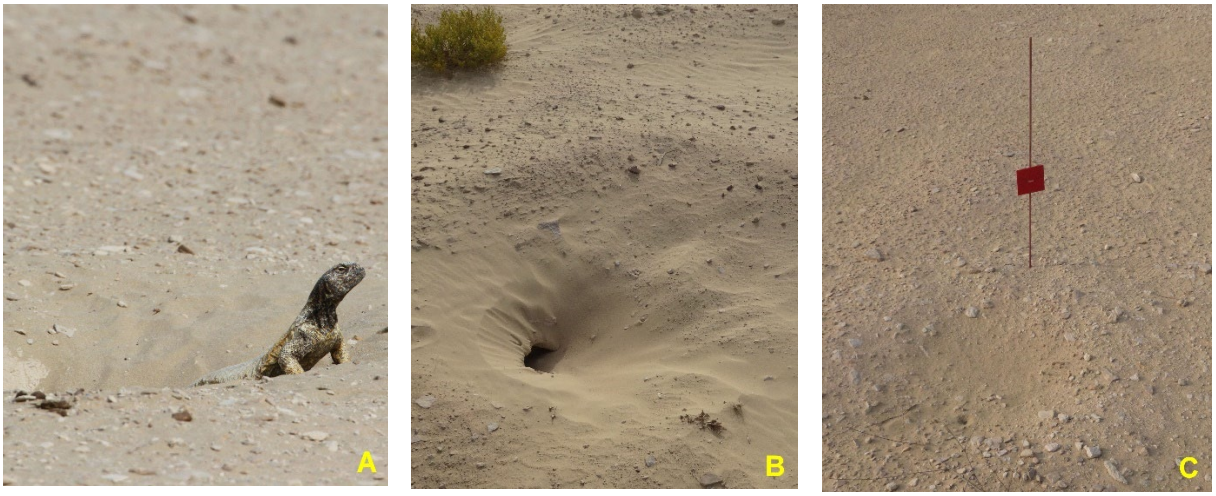


Figure 7-3. Burrow type Active (A), Abandoned (B) and Filled In (C).

Uromastyx aegyptia burrow surveys at the donor site are relatively straight forward and burrows should be recorded as either active or abandoned. Each active and abandoned burrow should be recorded on GPS to allow easy location for trap setting in the future. In the donor site survey, it is not necessary to record filled in burrows.

Camera traps (trail cam etc.) set up outside burrows will give an indication of other species such as red fox (*Vulpes vulpes arabica*), desert monitor (*Varanus griseus*), Arabian hare (*Lepus capensis*) and other small rodents that might be nocturnal or crepuscular visitors. Tracks and scat marks can also be used to identify other species which would give an indication of potential translocation species. A further, and ever increasingly popular method of species identification which could potentially be utilized is some form of passive bioacoustic technology and machine learning for cryptic or nocturnal species such as owls.

7.5 CARRYING OUT THE SURVEY

7.5.1 Dhub Survey

The most effective way to determine the population and location of active burrows is to drive the site in a systematic way. It is suggested that an all-terrain vehicle suitable for desert work be utilised. A GPS unit similar to the Garmin GPSMap 62sc is suggested as it can be fitted to the vehicle (Figure 7-4). The view on the GPS display is set to 50m and a transect is driven across the site. When burrows are

observed, the vehicle is dismounted, and all relevant data is collected for each burrow. These data should be recorded on a form similar to (APPENDIX 7-2). The return leg of the transect is driven at a spacing of 50 m as shown on the GPS unit.



Figure 7-4. Polaris ATV used in the survey with GPS fitted and a close up of the distance between tracks demonstrating how return legs can be completed.

7.5.2 Species to be moved

Following the donor site survey, a decision has to be made as to which species should be translocated. At this time all veterinary requirements which need to be completed as part of the translocation must be agreed upon and resources set aside to facilitate the testing and treatment required. It is essential that the receiving site has the resources and carrying capacity to support the numbers being translocated. The remainder of this document will relate to the translocation of dhub, *Uromastyx aegyptia*.

7.5.3 Vegetation Survey

The vegetation survey at the donor site should concentrate on the areas around the abandoned and filled in burrows. These are the areas into which the translocated dhub will be released. One has to remember that if the burrows have been abandoned or filled in, then there was a reason why this happened. It is important, if possible, to determine what that reason is.

While it would be good to sample all the burrows, this would not be practical in a large area. A random sample can be taken of the burrows to determine the vegetation associated with the burrows.

7.5.4 Vegetation Sampling Procedure

- Divide receiving site area into manageable sampling zones. This could be done based on vegetation characteristics, topography, or other ecological features.
- Decide on the number of burrows to sample within each zone. This will depend on the level of precision required and the resources available for the survey. Ensure that the sample size is statistically sufficient to make meaningful inferences about the vegetation in each zone.

- Use a random sampling approach to select burrows within each zone. This can be done using random coordinate generators or a systematic random sampling method. Assigning codes to the surveyed burrows and using a random number generator will assist with this.
- Given that dhub move approximately 50 m from their burrows for foraging, consider sampling vegetation in areas surrounding burrows within this foraging radius. This will capture the vegetation that is directly relevant to the lizard's daily activities.
- Conduct vegetation surveys around the selected burrows. Define sampling plots or transects based on the specific goals of your study. Collect data on vegetation type, density, cover, and any other relevant parameters.
- Analyse the collected vegetation data and compare the results across different burrow types and zones. This analysis will guide decisions regarding translocation and habitat suitability for the dhub.

For example, in the current study, 25% of the total number of burrows for each category (Active, Abandoned, and Filled In) were used. As all data were recorded in a bespoke MS Access database, it was easy to write a query to separate out the burrows into site and status. MiniTab v 18 was used (Calc, Random Data, Sample From Columns) to generate the random numbers to choose the burrow numbers. MiniTab was again used (Calc, Random Data, Uniform with a lower endpoint of 1 and upper endpoint of 360) to generate the bearings to be taken from each burrow.

Once the burrow details were determined it was imported back into MS Access for further processing and to attach the correct burrow coordinates. This was then saved as a CSV file and imported into GPSBabel (GPSBabel v 1.5.3 https://www.gpsbabel.org/index.html). GPSBabel was then able to export it as a KML file which was imported into Garmin Basecamp (Garmin Inc. https://www.garmin.com/en-US/shop/downloads/basecamp) and uploaded to the Garmin GPS. The GPX file with the burrow details was then imported into ArcGIS 10.2 and the location maps of the vegetation quadrats to be surveyed were generated.

The burrow was approached on foot and a note recorded in the Survey Collection Log (APPENDIX 7-3) as to the status of the burrow at that time. The date, location, burrow number and bearing were also recorded. Using the GPS, the correct bearing was followed for 50 paces (approx. 40 m). This distance was chosen as it brought the survey away from the burrow but was also within the recorded foraging range for the species (O'Donovan *unpublished data*).

A survey quadrat of 10 m x 10 m was created using rope as the outside line. This first line of the quadrat followed the same bearing as that from the burrow and was placed to the right of the

recorder.

The different substrate types were determined by the amount of each substrate type in the survey quadrat. For example, Gravel/Sand would primarily contain gravel with some sand whereas, Sand/Gravel would have the reverse, primarily sand with some gravel.

The 10 x 10 m quadrat was further subdivided arbitrarily but as equally as possible into a further 16 smaller quadrats to assist in accurate recording. This was completed by drawing 4 x 4 intersecting lines in the sand within the quadrat. Care was taken to avoid damaging any of the smaller species present. This helped to demarcate areas of heavy vegetation as well as visualising % coverage for each species.

Data once collected on the recording log were transferred to the bespoke MS Access database where they could be manipulated and exported as required. Exported data were saved as an MS Excel spreadsheet which could be imported into statistics packages (MiniTab 18 and MedCalc v 18.10) as well as PC Ord.

7.6 TRANSLOCATION CAPTURE TECHNIQUE

7.6.1 STAFF

The availability and engagement of suitably qualified staff to manage the survey, capture, care, movement, and subsequent release of the translocated dhub is essential.

7.6.2 OPPORTUNISTIC



Figure 7-5. Example of small hand net

Animals found away from the burrows could be caught and restrained if one got between them and the burrow they were retreating to. However, as they were capable of short bursts of speed, capture by this method was not always possible.

A small hand net such as that in Figure 8-5 should always be available for opportunistic dhub captures.

7.6.3 NOOSE

A traditional method of capture was to use a noose from heavy fishing line and place this in front of a burrow. This has also been used by people to illegally hunt and capture dhub (Figure 7-6), often with disastrous results when the traps are not checked regularly.



Figure 7-6. Poachers noose with dead dhub at the burrow where the animal was caught but the traps were not checked. An unfortunately common occurrence throughout many of the study sites.

When the animal emerged or re-entered the burrow it would get caught in the noose. While successful in the initial development of this project (Figure 7-7), the method was discontinued due to welfare issues. In many cases, the animal was caught around the neck which could have resulted in strangulation. The other issue was the potential damage the very fine fishing line might do to the skin of the animal as it was caught.



Figure 7-7. Similar method as in Figure 7-6, but burrow is checked regularly and animals which are caught are released.

7.6.4 TRAP CAGE

A special baited trap cage was designed and built (Figure 7-8) with two compartments to encourage

the animal out of its burrow and restrict its ability to return with very limited success.

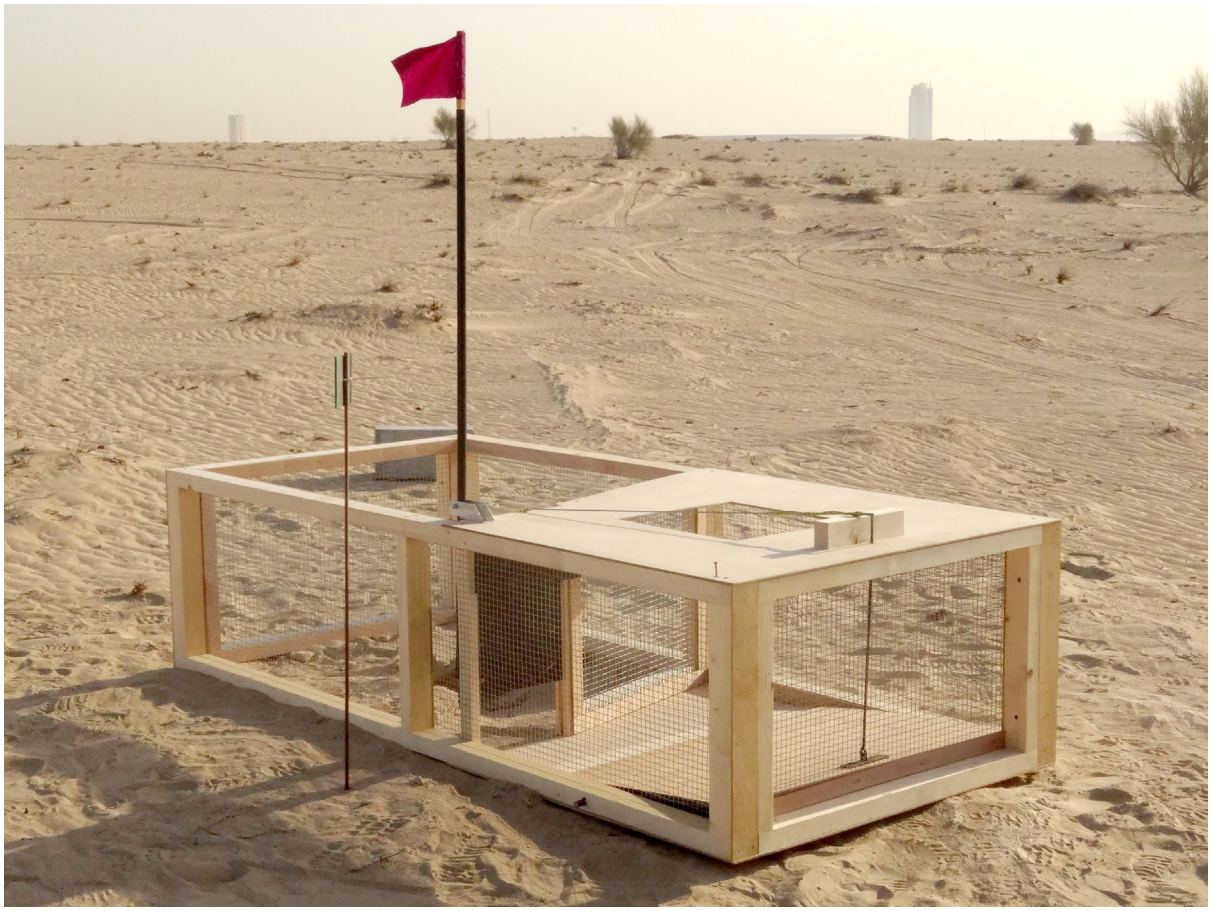


Figure 7-8. Custom built trap cage placed over the burrow of an animal. When the animal is caught and the trap door closes it will raise the red flag indicating an animal is in the trap.

7.6.5 Nets

The final and most successful method employed the use of a 1m^2 fishing net (Figure 7-9) made of 25 mm^2 cotton mesh placed strategically over the burrow opening. The animal usually exited without difficulty and was caught on its way back into the burrow.

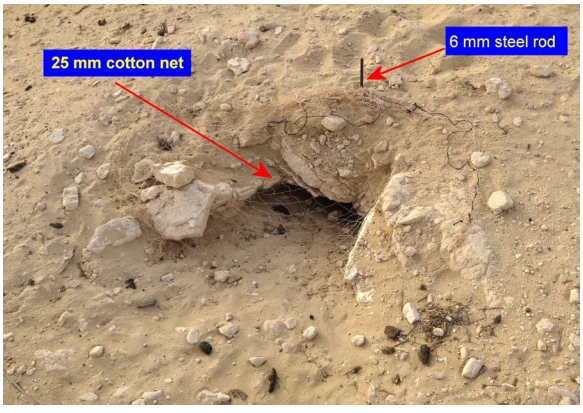




Figure 7-9. The most used and effective method of capture using a 25 mm cotton net over the front of the burrow. This is held in place with a 6 mm steel pin hammered into the ground behind the burrow. Animals were caught in the net which was checked regularly.

A steel metal rod was hammered into the ground at the back of the burrow opening. The net was attached to this rod to ensure the animal was not able to pull the net into the burrow. The 1 m^2 net was found to give the best coverage and ability for the animal to retreat slightly into the burrow, thereby avoiding potential heat stress.

When not in use, the net was rolled up, placed in a ball next to the rod and a heavy stone placed on top to avoid any accidental capture of collateral species at night. On completion of the trapping sequence, the net was removed and used on another burrow. The rod stayed in place.

During the warmer months, nets were set twice a day and checked approximately at 12.00 midday, rolled up and placed under the rock. They were then setup again about 14.30 and rechecked approximately 17.00. The ability to walk to the burrow and reset the nets with minimal disturbance was found to be effective.

When working alone, a maximum of 15 nets (usually 10) were set at any one time. Animals that were trapped were removed from the net, had their eyes covered to reduce stress and were marked to ensure they were returned to the correct burrow. The net would be removed from that burrow and used in the next burrow to be sampled. Animals were placed into individual boxes (Figure 7-10) and kept in a shaded area until all the nets were checked.



Figure 7-10. When caught the animals were placed inside a clean cardboard box with tape covering their eyes. Once all the hardware was added they were released back into the original capture burrow.

Having ensured that all nets were checked, the new animals were then removed to a clean location where they would be processed. Animals that were being recaptured for data download were usually processed onsite. Processing in new animals would include sexing of the animal, the length (nose to tip of tail), weight of the animal and general body condition. A small blood sample was usually taken

and these were analysed for biochemistry, haematology (APPENDIX 7-5). All data were recorded manually in a notebook as well as electronically onto a bespoke database where the data could be accessed quickly and downloaded for later analysis. A small RFID transmitter (12 mm FDX-B transmitting at 134.2 kHz frequency) should be implanted in all captured dhub to ensure the accurate identification during the monitoring phase. 8 mm RFID chips are much harder to read when RFID traps are deployed.



Figure 7-11. Implanting 12 mm FDXB RFID transponder into the nape of the neck during a health assessment and checking the successful insertion of the RFID.

Once completed a detailed Health Assessment Worksheet for Animal Movements (APPENDIX 7-4) must be completed in full.

7.6.6 Data Loggers

A representative animal was used in the initial design of the bespoke saddle which was to hold all the hardware for data capture. This involved designing a leather holder which has been described later as a saddle, placed over the base of the tail with a strap either side of the back legs to keep it in place (Figure 7-10).

Data recorders in the form of iButton temperature and humidity logger can be added to a certain subset of animals. Tracking was facilitated by attaching the R1860 crystal controlled 2-stage VHF transmitter from ATS, MN, USA. This allowed the accurate identification and location of the study animals.

Animals with this attachment would be recaught at regular intervals to allow the recovery of the data from the loggers. iButton data retrieval was usually completed at the capture area with the aid of a small portable PC.

7.6.7 Veterinary Risk Assessment

A generic data recording form (APPENDIX 7-4) should be completed in relation to the health exam and

diagnostic results obtained. If, on the advice of the veterinarian involved with the translocation or in the view of the project manager the translocation can continue, then the next phase, the translocation/release should commence. Ensure that all veterinary procedures are carried out in an area where the dhub will not be subjected to excessive cold (an air-conditioned laboratory or building). Dhub should be returned to the translocation site as quickly as possible following any examination to reduce the risk of stress induced disease.

7.6.8 Capture and Translocation Time Frame

No capture or translocations should take place between late October and late January. Activity and foraging decrease's for dhub during these months. Burrow surveys during these periods could potentially give false results.

The best window of opportunity would be February through to May and September through to mid October. While it would be possible to translocate dhub during the summer, extra care should be given to avoid heat exhaustion and chronic stress. Dhub should be moved to the donor site and into the soft release pens as quickly as practical.

The first release method involves the release burrows within the receiving site being identified and prepared. This can be accomplished with a small builders hand trowel or similar to remove the sand from at least the first 40 cm of the burrow (Figure 7-12).



Figure 7-12. Filled In dhub burrow which was excavated for translocation use.

The safety cage (Figure 7-13), which is large enough to allow the dhub full access and egress from the burrow together with some exploratory area, is placed over the burrow. This must be completed prior to the capture being started. The translocated dhub will excavate to their requirements once settled. Animals can be translocated directly to these and complete their quarantine (minimum 30 days) before

being allowed out (ie, the pen removed). Two or three females can be translocated in this way providing there is a burrow for each individual. Adult males should always be translocated on their own.

a



b



Figure 7-13. **a.** Release cage with no overhead cover. Used in the successful translocation and release of AQ01. **b**. Release cage used in Nakhlee translocation and release with cover against predators.

The second method involves the dhub being transported after veterinary checks directly to the translocation site. They can be held in the holding pens in (Figure 7-1 and Figure 7-2) without the need for old burrows. If these pens are placed in areas where there is a suitable amount of forage and burrow sites available and the dhub are given a minimum of 30 days settling in period, then they will radiate out from these areas establishing in the surrounding habitat.

During the captive phase of the program, it is essential that the dhub are kept nutritionally fit. In the current study, food was supplemented by sourcing small amounts of, for example, *Calligonum comosum, Panicum turgidum, Heliotropium kotschyi* etc., cutting these small and mixing with different variety of locally sourced dal (Masoor Dal, Mung Dal, Chana Dal etc). This was provided fresh on a daily

basis. The exact amount varies but will depend on soilage and wastage due to the dhub walking through the food. Start with 50 g and adjust upwards or downwards as necessary. All old food was removed, and trays washed and cleaned to reduce the possibility of infection.

7.7 MONITORING

Some of the translocated dhub will dig out under the frame of the release pen during their 30 day acclimatisation phase. It is important within the first 21 days to retrieve these (which is possible by following their tracks) and return them to the soft release pens. After the 30 days acclimatisation phase all dhub should have settled enough to reduce their previous homing urge. It is possible at that stage to remove the surrounding cage above the excavated tunnels and open the slide release for the portable cage type.

7.7.1 RADIO TRACKING

Each of the dhub with the vhf radio transmitters must be located and found at least every second day. Those still within burrows are to be left alone (even if it wasn't their release burrow) but those still wandering need to be returned to the release pens and the acclimatisation process started again. Any dhub found wandering in the desert should be captured, microchip checked and returned to the release pens again to restart the acclimatisation phase again.



Figure 7-14. Using the VHF receiver to

7.7.2 BURROW MONITORING

RFID traps can be set up on the outside of the burrows to determine which animals are entering and leaving the burrow. If the smaller 8 mm ISO RFID was used, the traps do not pick these up with great success.

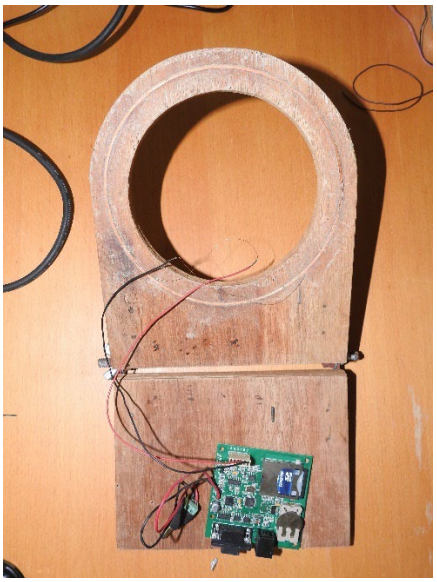




Figure 7-15. RFID trap being prepped in the workshop and installed over an active dhub burrow.

Data from these methods will be used to inform the success or otherwise of the translocation and must be reported back to the client.

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7.8.1 APPENDIX 7-1 – TRANSLOCATION DECISION TREE

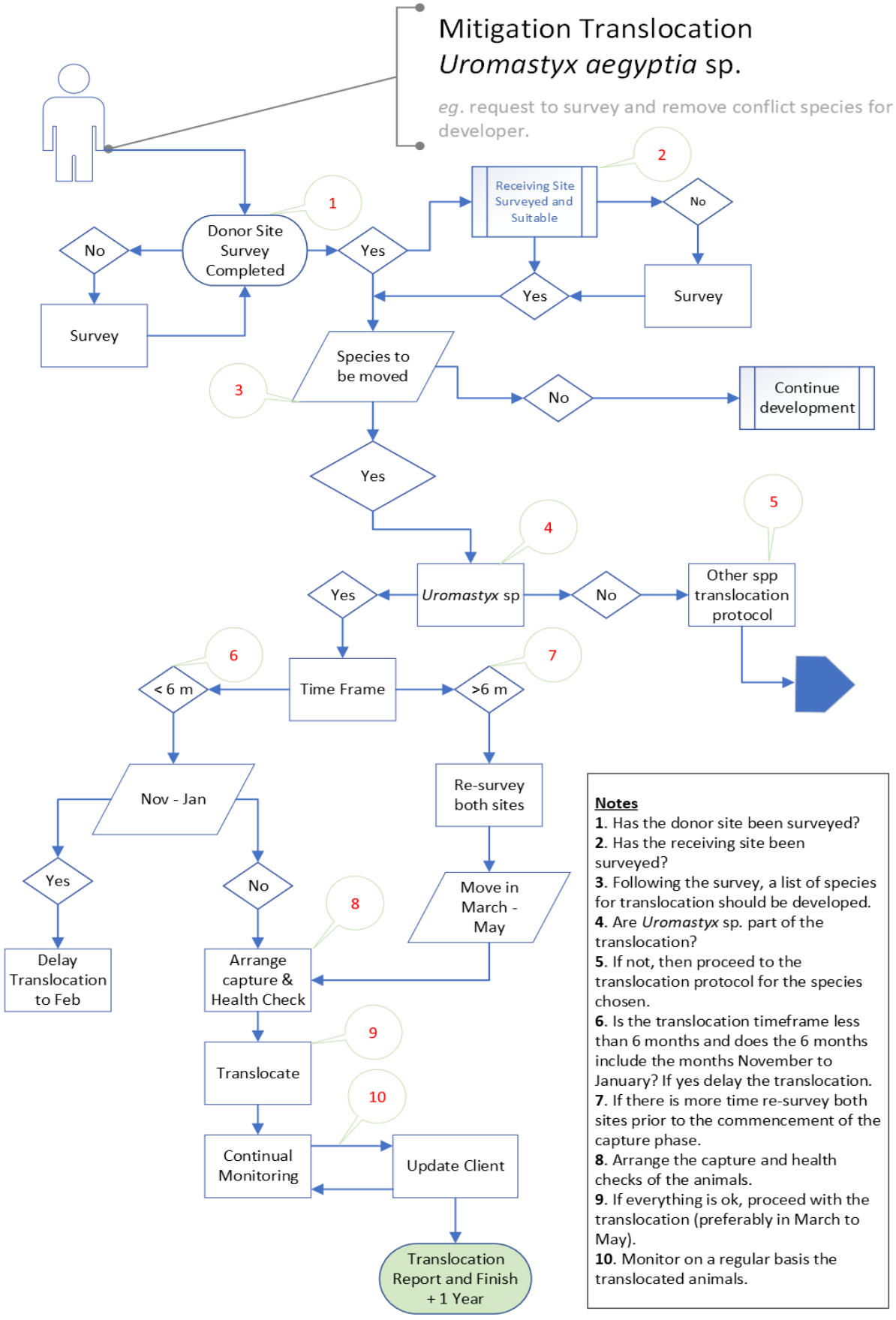


Figure 7-16. Flow chart through the translocation decision process for *Uromastyx aegypti leptieni*.

7.8.2 APPENDIX 7-2 – ANIMAL DATA CAPTURE FORM

Animal Details

ID No:		Date:		N:		E:	
Seen	Yes / No	Time		Elevation (m)			

Burrow Details

Height (cm)		Width (cm)		Orientation		Temp Out		Temp In	

Location of burrow (✓)

Level with ground	On top of rock	Lower than ground	Other

Burrow status (✓)

Active	Inactive	Abandoned	Possible	Unsure

Photo #: _____ **Sex** Male / Female

_____ **Age Est.** _____

_____

Observations:

Morphometric Details

snout-vent-length (SVL)		tail length	
head width, measured between the anterior margins of the ear openings		head length, measured from the tip of the snout to the anterior margin of the ear opening	
on the left side		tail width between the 4th and 5th whorl	
maximum tail width at the 5th whorl		number of scales around mid-body	
number of scales between gular and inguinal fold (= ventrals)		number of gular scales (from the mental scale to a line between the anterior margins of the ear openings)	
number of scales from the mid of the lower end of the ear opening to the mental scale (left and right)		number of scales between supralabial and enlarged subocular scale	
number of scales around the 5th whorl		number of tail whorls	
number of scales beneath the 4th toe on the left side		number of preanofemoral pores on either side	
number of enlarged scales at the anterior margin of the ear opening		number of scales from the upper to the lower end of the left ear opening (approximately three scale rows before the anterior margin of the ear opening)	
number of scales from the upper end of the left ear opening to the first enlarged subocular scale		intercalary scales between the whorls (presence or absence)	
presence or absence of enlarged tubercular scales at the flanks and on the dorsum			

Uromastyx recording sheet rev 4

7.8.3 APPENDIX 7-3 – VEGETATION RECORDING LOG

Vegetation Survey Log (Rev 3)

Date _____ Location _____ _____

Burrow # _____ Heading _____ GPS _____

Tracks @ Burrow YES / NO Tracks @ Survey YES / NO

Notes _____

_____

Substrate

Sand (S)		Gravel (G)		Cemented Sand (CS)		Other		Mix	
	%		%		%		%		%

	Species	Count (A/D)	% Cover	Pic #
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

If mixed substrate include the % of each type and tick mix; Count (A/D) A = Alive and D = Dead
Prec/Est = Precise or estimated count?

Vegetation Survey Log (Rev 3)

Notes and Tallies

1		11	
2		12	
3		13	
4		14	
5		15	
6		16	
7		17	
8		18	
9		19	
10		20	

If mixed substrate include the % of each type and tick mix; Count (A/D) A = Alive and D = Dead
Prec/Est = Precise or estimated count?

7.8.4 APPENDIX 7-4 – HEALTH ASSESSMENT WORKSHEET

Health Assessment Worksheet for Animal Movements

(Please refer to explanatory notes while completing this Worksheet)

1. SPECIES TO BE MOVED: _____

2a. FROM: _____ **2b. TO:** _____

3. TOTAL NUMBER OF ANIMALS: _____

4. ANIMAL IDENTIFICATION: (attach additional sheets if needed)

5a. MOVEMENT CATEGORY: Wild to wild ☐ Wild to captivity ☐ Captivity to wild ☐ Captivity to captivity ☐

5b. PERMITS TO MOVE ANIMALS RECEIVED **YES** ☐ **NO** ☐ (Tick one)

(List all permits and their expiry dates)

_____

_____

_____

_____

6a. PROJECT MANAGER: _____ Tel. _____

6b. TITLE, INSTITUTION: _____ E-mail: _____

7. PROJECT VETERINARIAN: _____ Tel. _____ E-mail: _____

O'Donovan 2016 adapted from *Animal Movements and Disease Risk*

8. HEALTH SCREEN & CONTROL MEASURES FOR DISEASES OF CONCERN TO THIS ANIMAL MOVEMENT

(Diseases of Concern are as identified from Appendix 1)

9. DIAGNOSTIC METHODS AND SAMPLE COLLECTION

For results refer to Section 17a on this form

*Contact your sample testing facility to advise of date of sample collection and obtain guidance on sample handling, storage and shipment. Also check permit requirements for collection and shipment of samples.

10. PROPHYLACTIC TREATMENTS, VACCINATIONS AND CONTROL MEASURES

For documentation refer to individual animal records.

O'Donovan 2016 adapted from *Animal Movements and Disease Risk*

Quarantine Details *If no quarantine explain reason(s) in 13 below and go to 16.*

11. LOCATION OF QUARANTINE: _____

12. FACILITY: _____

13. QUARANTINE DURATION (Based on animal management, diagnostic and disease criteria):

Begins *(date)* _____ **Ends** *(date)* _____ **Total days:** _____

Specify reason(s) for the duration below:

_____

_____

_____

14. PERSON SUPERVISING QUARANTINE: _____

Tel: _____ E-mail: _____

15. QUARANTINE EQUIPMENT AND SET UP:

Check		*Check*	
☐	**"Quarantine - No Unauthorized Entry Sign"**	☐	**Bags for waste disposal**
☐	**Insect/rodent traps/screens/baits**	☐	**Feeding, watering and cleaning utensils**
☐	**Diagnostic sample collection, storage and transport equipment**	☐	**Animal capture and restraint equipment**
☐	**Lock for facility**	☐	**Quarantine register**
☐	**Footbath/boot changes**	☐	**Animal caregiver personal health check**
☐	**Protective clothing**	☐	**Written quarantine protocol**
☐	**Cage furniture as appropriate for species**	☐	**Briefing of veterinarian with quarantine supervisor**
☐	**Animal record forms, pens**	☐	**Other:** _____

16. BUDGET: (I*f not required go to 17*)

O'Donovan 2016 adapted from *Animal Movements and Disease Risk*

17a. RESULTS OF HEALTH SCREEN

17b. OVERALL ASSESSMENT AND COMMENTS ON RESULTS

O'Donovan 2016 adapted from *Animal Movements and Disease Risk*

18. Movement Recommendation

*If move delayed state time and condition for release:

19. EXPLANATION AND JUSTIFICATION FOR ANIMAL MOVEMENT RECOMMENDATION:

20. FOLLOW UP ACTIONS

21. SIGNED OFF BY: _____ **DATE:** _____

Project Manager

_____ **DATE:** _____

Project Veterinarian

O'Donovan 2016 adapted from *Animal Movements and Disease Risk*

INFECTIOUS AND NON-INFECTIOUS DISEASE SUSCEPTIBILITIES OF SPECIES AFFECTED BY THIS ANIMAL MOVEMENT*

(List below potential in-contact wildlife, domestic animals and humans. Veterinary assistance is strongly recommended for developing this list)

Disease/Problem	Exposure threat	Infectivity	Pathogenicity	Transmissibility	Susceptibility	Disease of Concern? Y/N	Source(s) of information

*For each disease rank High (H), Medium (M) or Low (L) for infectivity, pathogenicity, transmission and susceptibility. Select as "disease of concern" if, overall the veterinarian ranks the disease or health problem as a Moderate to High risk based on this, or a more quantitative, analysis.
** Number each source of information and reference this to a bibliography which should be attached to this document

Species potentially affected by this movement:

O'Donovan 2016 adapted from *Animal Movements and Disease Risk*

7.8.5 APPENDIX 7-5 BLOOD SAMPLE RECORDING FORM

Uromastyx aegyptia leptieni Blood Sample Recording Form

	Sample ID	Animal ID	Burrow ID	Sex	Weight	Age (est)	Date	Time of Restraint	Time of Bleeding	Time of Processing	Samples	Notes
1											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:
2											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:
3											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:
4											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:
5											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:
6											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:
7											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:
8											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:
9											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:
10											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:
11											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:
12											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:
13											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:
14											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:
15											□ LeHe □ EDTA □ Serum □ Slide	Hb: HCT:

...\documents\forms\blood sample collection Rev2c

CHAPTER 8: CONCLUSION

It is now the tail end of 2022, 8 years after this project first started. A lot has happened in those intervening years but unfortunately, little in the way of conserving the native *Uromastyx aegyptia leptieni* in the Emirate of Dubai. While the official trade in live dhub specimens from the UAE has not happened since 2012/2013 when 491 dhub were traded to the US and 20 to the Netherlands (CITES, 2022), within the Emirate of Dubai, the human population has increased by more than 44%. The area of "green space" managed by Dubai Municipality has increased from 1.8% of the total land area of the Emirate to 2.8 % in 2021 and passengers through Dubai airports since 2014 have increased by 25% to 88 million in 2019 (Dubai Statistics Center, 2021). Further to these increased pressures, in November 2022 Dubai Media Office released details of the "Dubai Countryside and Rural Areas Development Master Plan" with plans for a 100 Km trekking path to "unlock" more of the desert to visitors. This new plan will cover an area of 2,216 square kilometres of previously inaccessible desert (Dubai Government, 2022).

The continued threats to reptile species throughout the world is not going to abate. Jenkins & Broad (1994) estimated that at that time at least 10 million reptiles were killed, processed and manufactured into products for the reptile skin trade. More recent estimates suggest that approximately 90% of traded reptile species and half of traded individuals are captured from the wild (Marshall *et al*, 2020). While wildlife trade can provide commercial incentives to conserve biodiversity, if unsustainable, can also pose a major threat (Harfoot *et al*, 2018). Ireland, even though it has a questionable definition of what a reptile is (DAFM, 2019) has its own legislation controlling the importation of reptile meat to the country.

With the increased tourism and desert land use over the coming years, the future for a considerable amount of the native species in the Emirate does not look good. Previously, a lot of the desert was inaccessible to many but the experienced desert drivers. Today, many of the residents of Dubai with access to a four wheel drive vehicle can now travel to any parts of the desert (*pers obs*). This extra uncontrolled traffic has caused immeasurable damage to burrows (such as those of dhubs) and other fragile habitats (Figure 8-1) within the desert (*pers obs*). Larger plant species such as Rimth, (*Haloxylon salicornicum*), Markh (*Leptadenia pyrotechnica*) are often broken up and used in campfires (*pers obs*). While dhub could be considered a flagship species, the fact that they do not appear to be very active (retreating rapidly sub surface at any sign of danger) makes them invisible to many desert visitors. Even while above ground, the current research found that only 6% of the observed time was spent in any active behaviours and only 2% of this was spent foraging.



Figure 8-1. Some of the consequences of increased access to the desert where vehicles have driven over the burrow entrance and rubbish including plastic bags are abandoned in the desert, which can result in mortality.

The potential consequences of urbanisation on dhubs was the driver for the current study. Moule *et al* (2016) have found with the delicate skink, (*Lampropholis delicata*), in Australia, where urbanisation has occurred relatively recently, changes in behaviour might be related to the degree of urbanisation that has occurred. While this is not the case in the current research, as most of the surveys and observations were carried out in a private reserve, the author has noted that in areas of more frequent human contact, dhub have moved away of their own volition or been extirpated completely.

Prior to this study, there had been smaller scale behavioural studies (Cunningham, 2000a; Cunningham, 2000b; Cunningham, 2001, 2009; Wilms *et al*, 2009; Wilms *et al*, 2010; Wilms *et al*, 2011) looking at *Uromastyx aegyptia*, but none for the duration that this study has analysed. The behavioural results of this study do need to be treated with caution due to the small numbers of confirmed dhub of each sex that were observed. The data does suggest that males are more active than females apart from May and June which was the most active time for the females and also coincided with the breeding season. The data also allows one to design captive protocols for any potential translocation of dhub. For example, dhub can be kept in a colony setting, but there would be a likelihood of aggression between animals if suitable space was not available. As such, it would be best if dhub were housed separately. Lighting can be adjusted to allow for the bimodal activity patterns which have been confirmed for the species. Although other factors such as space, humidity, and nutrition are involved in captive management of reptiles, thermal distribution patterns and substrate materials, particularly in outdoor enclosures, are important factors to be taken into account in reptile husbandry (Meek, 1995). When any translocation is to be considered, these issues along with the seasonal requirements of the dhub are paramount. Food should also be available either early in the morning or else later in the afternoon (15:00 to 16:00) and while not essential, the lighting and heat available to the captive dhub should be cycled to mimic the wild state. The temperatures at the basking point do not have to be extreme though.

One of the primary questions which needed to be answered relates to the environmental factors which dhub require to survive in their natural environment. Looking at these in the wild state should allow one to make far more accurate inferences from the data collected. For example, the operative temperatures T_e , which is the body temperatures that non-regulating animals would achieve was estimated to have a range of ± 19 °C (19 °C to 38 °C). As the determination of T_{set} range was considered to be a welfare issue, those already determined (Zari, 1991; Al-Johany, 2003) were used during the study (38 °C).

The bimodal summer behaviours as reported by a number of authors was also demonstrated and it was determined that it was when the outside temperature approached the upper end of the T_e value that the animal returned to its burrow. The level of UV-B did not appear to affect any of its behaviours and the thermotactic requirement for shelter as the animal reached T_{max} was the driving force.

While a number of studies have looked at the orientation of burrow openings, this study had by far the most data available and the predominant orientation differed from other research. The opening width and height did not differ significantly across the study sites, and it is believed (Figure 8-2) that the shape and size is directly related to the animal's defence and cooling during the summer. Temperatures and humidity were constant when the animal was in the burrow and certainly protected it from extremes above ground. It could be argued that the high levels of humidity recorded in the burrows reduced the evaporative effects of the heat on the animal and assisted as a means of water conservation.

Radio Frequency Identification (RFID) transponders have been used in fish monitoring for a long time. This is the first time they have been used to monitor the activity and burrow usage in dhub. Using this method, it was found that only one dhub, a juvenile male, did not venture away from its original home burrow while the RFID trap was present. All others were found to travel in the region of 120 to 130 m from one burrow to another burrow. This was corroborated with the data from the repeat captures, where only a few dhub were caught in the same burrow repeatedly. While philopatry has been suggested in a number of species, the current study showed a large degree of burrow fidelity, which taken in context of the mean distance dhub travelled between burrows would suggest that *Uromastyx aegyptia leptieni* were also philopatric. Proximity to forage sites and low disturbance would be a primary driver for burrow selection.

The Gulf region, including the United Arab Emirates (UAE), has been experiencing warming trends since the late 1980s. Climate projections, even under low greenhouse gas emission pathways, indicate significant and relatively rapid warming, together with substantial changes of precipitation (Komuscu,

2017; Zittis *et al*, 2021). There are differing reported rain rates within the Emirate of Dubai, with one



Figure 8-2. The shape and size of the burrow often made it difficult to retrieve the dhub during the capture phase of the study.

set at 34 mm between 1958 and 1953 (Anon, 2013), 120 mm between 1965 and 1992 (Boer, 1997), while NCM (2022) give the mean rainfall at 50 mm between 2003 and 2021 and 73 mm for the same time period (World Bank Group, 2022) which all suggest the vagaries of rainfall within the UAE.

Since the current vegetation study was undertaken after an extreme rain episode in 2016, the species abundance recorded would most probably have been the exception rather than the norm. However, the UAE has continued with its cloud seeding strategy with Rubin (2022) reporting that in early 2022, cloud seeding coincided with a storm that produced about 140 mm of rain in three days — more rain than the United Arab Emirates often gets in a year.

The current study has identified the potential forage species required for dhub in the study location. However, there are various influencing factors which determine the food and foraging behaviour of any species such as time of day, season, rainfall and other environmental factors. Robinson (1995) suggests that a 1Kg dhub at 40 °C would require 3.7g of food per day based on an energy expenditure of approx 11.8 kcal whereas a small 65g dhub (550 cal) would require 0.17g per day. Although primary productivity in dhub habitats is low, dhub do not spend a lot of time foraging and on average are away from their burrow for less than 10 minutes (Chapter 2). The rest of the time is spent close to the

burrow basking or sub-surface. It has been suggested that differences in diet quality in other species such as the chuckwallas (*Sauromalus obesus*) had negligible effects on their resting metabolic rates and body temperatures (Nussear *et al*, 1998).

Having a food source directly available near the burrow entrance may lower ecological stress for dhub, due to the supposedly relative low costs associated with foraging (Wilms *et al*, 2009). With eight forage plant species definitely confirmed and using the 12 confirmed forage species from other studies that were identified in the current study, it can be stated that if given a protected area with suitable gravel plains and sand dunes, translocated dhub would have adequate forage available to survive.

Dhub depend on food resources of a small area (see average forage track length, Chapter 3) and while natural habitat degradation is a regular phenomenon that occurs in arid deserts throughout the world, increased desertification is one of the main types of land degradation in these environments (El-Keblawy, 2017). The absence of two plant species *Calligonum comosum* and *Haloxylon salicornicum*, which have been described by Jongbloed *et al* (2003) as widespread and common in sand dunes and plains, might not have a major impact on the forage availability for dhub but maybe more of an indicator of the health of the environment itself.

While increased temperatures have been noted (Komuscu, 2017; Zittis *et al*, 2021; NCM, 2022; World Bank Group, 2022) as a result of climate change, it has been suggested that changes by mid-century could lead to 'super and ultra-extreme heatwaves', where temperatures above 56°C could last for weeks on end (Zittis *et al*, 2021). Taken in tandem with these concerns, perhaps a new concern should be the effects of continued cloud seeding and whether this will change the plant species availability for species such as dhub.

Naldo *et al* (2006) described some of the parasite species present in a natural group of dhub in Abu Dhabi which included a new *Haemocystidium* sp. (Telford *et al*, 2012) suggesting that as with this study, further and more detailed investigation of the health status of natural populations should be investigated. It is imperative that in all conservation translocation procedures, the health status of the animals being considered for translocation needs to be determined (IUCN/SSC, 2013). In many instances, animals will need to be housed for varying durations prior to any translocation or for veterinary procedures prior to the translocation (Barcello & Tourenq, 2005). While basic haematological and biochemical parameters are known about similar species it is essential to get as much specific data as possible on the animals concerned. One of the main physiological issues with captive reptiles is Metabolic Bone Disease (MBD) which is the collective name given to a number of symptoms and problems commonly seen in captive mammals, birds and reptiles (Kumar *et al*, 2018).

MBD in reptiles at its root is caused by a lack of Vitamin D, primarily linked to the lack of UV-B radiation in the 280-315 nm range in the animal's environment and one of the main manifestations of this is secondary nutritional hyperparathyroidism. This is where due to the lack of serum calcium, parathyroid hormone is stimulated (a natural feedback loop in calcium synthesis) and results in the stripping of bones of their calcium causing osteomalacia or rickets.

Raphael *et al* (1999) recorded 25(OH)D levels of 54 ± 34 nmol/L (n=14) in the animals that they studied which is similar to the current study but they were captive animals with unknown husbandry or dietary status. These are the only two studies known to have looked at the vitamin D status in this species that has been found in the literature (A comparison of haematological and biochemical analytes where available is presented in Chapter 5, Appendix 5-2) . The current study is the only one known to look at *Uromastyx aegyptia leptieni* vitamin D levels in the wild state.

Reference intervals (RI) are by no means easy to determine or should not be used interchangeably unless the full details of where the samples came from, when they were collected, age of the animals, health of the animals etc. are known. For example, the results from Gillespie *et al* (2000) use a commercial radioimmunoassay kit which gave results considered extreme by National Institue of Health (2016). It is then up to the clinician to determine the value of the RI that they will be using. The current study does just this and all of the information is detailed (Chapter 5, Appendix 5-1).

This study has gone a long way to determine what these RI should be. However, due to the relationship between parathyroid hormone (PTH) and circulating levels of 25(OH)D it would be advantageous for future studies to determine levels for PTH, to see whether there is an equilibrium between the two.

What is clear from these results is that there is not much agreement on what the Vitamin D reference intervals should be in human or non-human animals. It is believed that one is at risk of anthropomorphising the requirements of reptiles in our quest for what is a normal reference interval and perhaps reptiles, who in their natural environment are exposed to high levels of UV radiation, do not require similar levels to humans. Dhub are diurnal and ectothermic and spend up 28% of daylight hours in direct sunlight where UVI values could reach between UVI five or six before retreating to their burrow. Perhaps, the basal rate of circulating 25(OH)D is much lower in dhub as suggested in the results. Sequestered vitamin D might be released as required and then topped up with minimum exposure. It is concluded that the RI for dhub is seasonal and actually much lower than one would expect of humans under the same conditions during the summer. Within a few days of capture there could be significant differences in the circulating 25(OH)D levels in the same animal (Chapter 5,

Appendix 3). For example, WAS 040 was captured 3 times in 2016. After the first capture and over a period of 21 days levels dropped 25.8 nmol/L but increased by 10.4 nmol/L the next day. One could suggest that perhaps dhub are regulating their vitamin D levels rather than maximising them as has been suggested by some authors for other iguanids (Laing & Fraser, 1999; Ferguson *et al*, 2015). This is most likely why we see the differences between years.

While we now have a better understanding of vitamin D status in non-captive dhub, there are still issues which need to be addressed when it comes to the captive environment. This was highlighted from the three collections where animals housed under artificial lights were sampled. Two of these collections maintained their animals in an environment where levels were considered sufficient, but the third had animals which would be considered deficient. Since the current study primarily focused on wild dhub, the captive held dhub' results were not presented in that results section, to reduce the risk of bias. Three animals (one male and two females) from a captive environment that were exposed to UV lights showed the highest levels of 25(OH)D. These had a mean 25(OH)D of 136.4 nmol/L and a Ca:P ratio of 2.3:1. The question has to be asked, are we incorrectly using values from artificial environments to guide the veterinary care of our animals? This certainly would need to be investigated further. Another very important factor to take into consideration is the method of Vitamin D elucidation. At the time of processing, liquid chromatography with tandem mass spectrometry (LC-MS-MS) was the gold standard in Vit D analysis. It is, however, vitally important when considering translocation programmes to manage all of these variables to ensure the health and welfare of any animals during the translocation process.

The final part of this research was to investigate the possibility of completing a successful translocation. While a truly successful mitigation translocation would mean moving all biota from the area of concern this would be impractical, but perhaps not impossible within the Emirate of Dubai considering the financial resources available. Drawing attention to flagship or iconic species might help mitigate some of the issues, but longer-term protection models and policies are needed. The current study has shown that it is possible to successfully move a species like *U. aegyptia leptieni* from one area to another and get them to successfully survive the translocation phase. This does have to be managed in a way where a soft release would be the preferred option. Protected areas where there were previous animals resident offer the ideal release location. Existing burrows which are filled in should have the correct burrow structure for the animals to utilise in the initial introduction and would be the preferred release areas. Once established, animals can migrate from these to different areas if needed.

Further studies such as this should be attempted, potentially using a series of cages close to each other

and allowing the dhub to again dig their own escape route. The close proximity would allow for more dhub to be translocated (for example a full colony) allowing the maintenance of some group structure if it existed prior to the translocation. It is believed (*pers obs*) that given a period of 20 to 30 days within an area, dhub will have had sufficient time to orientate themselves and should be able to locate sufficient refuge to allow them to establish successfully providing there are sufficient refugia and forage species available.

The study did not, however, prove that the animals reproduced or that the population increased, two very difficult factors to determine in reptile translocations. It does show that with the correct pre-planning and preparation the translocation of dhub to remove the animal/land-use conflicts is certainly possible.

8.1.1 Future Studies

This study was limited in the number of RFID traps at its disposal. As they were bespoke and designed specifically for this project, they have proved to be very successful in what they were designed to do. They ensured an accurate identification of dhub and also ensured that disturbance in relation to observer bias was removed or dramatically reduced. While this study was an initial effort to establish a baseline in relation to burrow choice and fidelity, it would be important to perhaps establish more RFID traps in several colonies within close proximity to get a better understanding of potential gene flow. Evidence collected from different facets of the study indicate that dhub, for whatever reason, simply vacate a burrow. For translocation projects to succeed it would be important to understand why this is happening.

As the vegetation analysis study was one season in one year, a more detailed study looking at the possible changes associated with increased rainfall would be a worthy continuation, especially bearing in mind the comments above as regards cloud seeding .

Now that this research has provided the most detailed study of the daily and seasonal activity patterns of dhubs (females, males and unknown sex) in the UAE, the basic building blocks of a successful captive management programme prior to translocation have been developed in relation to the behavioural requirements of the species.

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