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Vegetation and Grazing in the St. Katherine Protectorate, South Sinai, Egypt

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ABSTRACT

Plants were surveyed in the St. Katherine Protectorate of South Sinai, Egypt. The most frequently recorded plant species include: *Artemisia herba-alba, Artemisia judaica, Fagonia arabica, Fagonia mollis, Schismus barbatus, Stachys aegyptiaca, Tanacetum sinaicum, Teucrium polium* and *Zilla spinosa*. Dominant plant families were Compositae, Graminae, Labiatae, and Leguminosae. Communities with a high grazing pressure had a lower overall plant vigour. A strong negative correlation was found between plant vigour and grazing pressure. Twelve plant families showed heavy grazing pressure, including Resedaceae, Caryophyllaceae, Polygalaceae, Juncaceae, Solanaceae, Geraniaceae, Ephedraceae, Globulariaceae, Urticaceae, Moraceae, Plantaginaceae, and Salicaceae.

INTRODUCTION

The Sinai Peninsula has geographical importance in that it is where the continents of Africa and Asia meet. The St. Katherine Protectorate covers the mountainous region of Southern Sinai. It was declared as a protected area in 1996 due to its immense biological and cultural interest. It has been recognized by the IUCN as one of the most important regions for floral diversity in the Middle East, containing 30% of the entire flora of Egypt and a great proportion of its endemic species. Within the Protectorate, more than 400 species of higher plants have been recorded, of which 19 species are endemic, 10 are extremely endangered and 53 are endangered. Localised overgrazing, uprooting of plants for fuel or camel fodder, and over-collection of medicinal and herbal plants are greatly threatening the floral diversity of the Protectorate.

The goal of this study was to monitor particular plants in the different wadi systems in St. Katherine's Protectorate, to assess how plant species are distributed, and to determine if grazing is affecting the vigour of these communities.

METHODS

Twenty-nine wadis and farsh (=open areas) systems were surveyed in and around St. Katherine Protectorate. As Fig 1 demonstrates, the surveyed wadis can be divided into three geographical areas:

- Ring Dyke wadis, situated in and around the Ring Dyke, consisting of two subgroups, the high-mountain wadis (Shraig, Arbain, Itlah, Tella^{c}ah, Ferah, Naqb Hawa, Farsh El Roumana, Tynia, Ahmar, Farsh El Luz, Shaq Musa, Gebel Safsafa, Wadi Gebal, Farsh Mesaila) and those just outside the wall of the Ring Dyke (Souria, Koria Shamoun, Gharaba, Erdasia and Esh Shaik)
- Ain Hudra wadis (Elwadi, Abu Matier, Ain Hudra, Kiri and Legaibi)
- Wadi Feiran wadis (Alberega, Emrair, Rem, Ertama, and Eleiqat).

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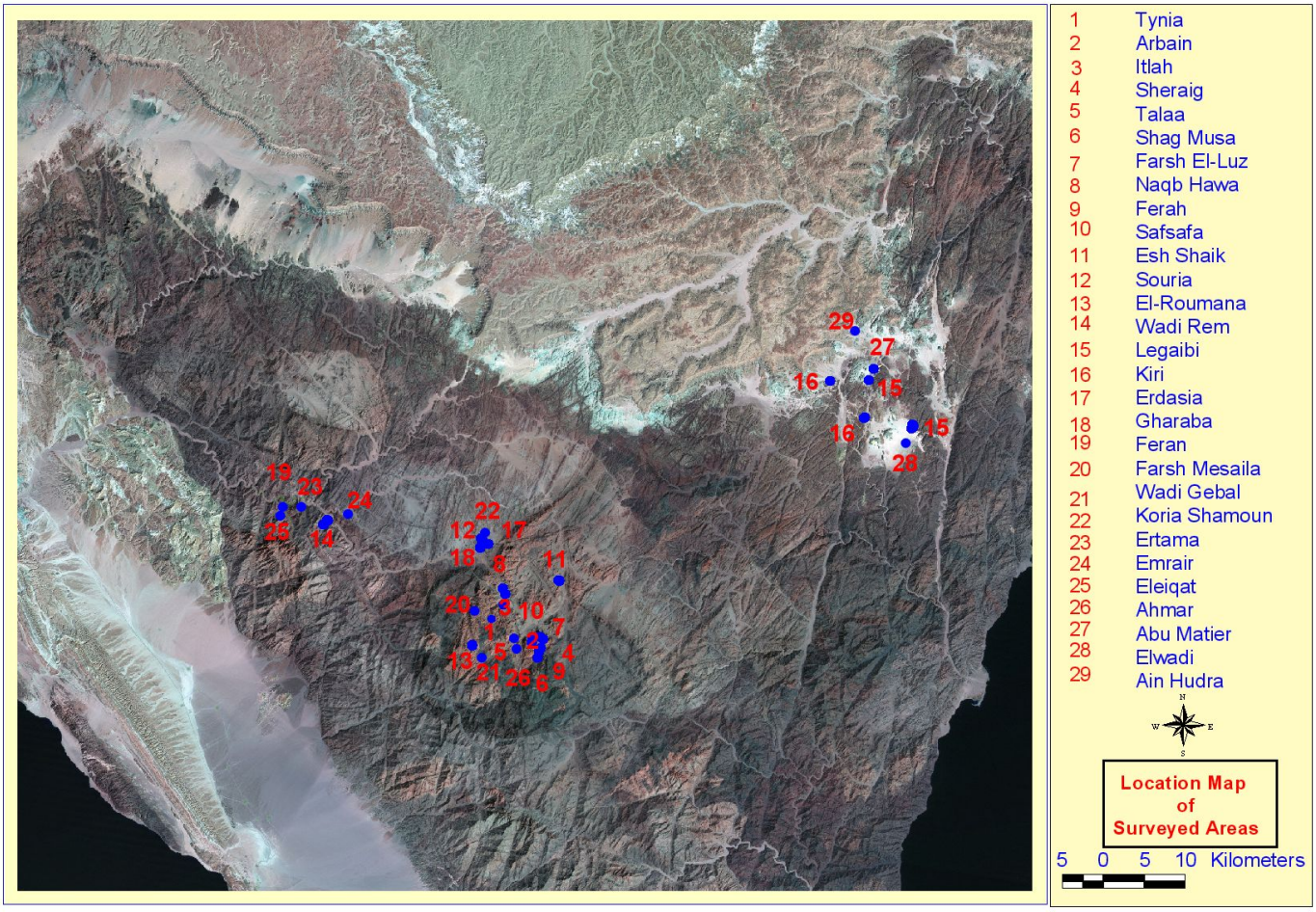
Figure 1: Map of the localities studied in the northern part of the St Katherine Protectorate. The boundary of the Protectorate more or less follows the edge of mountain massif.



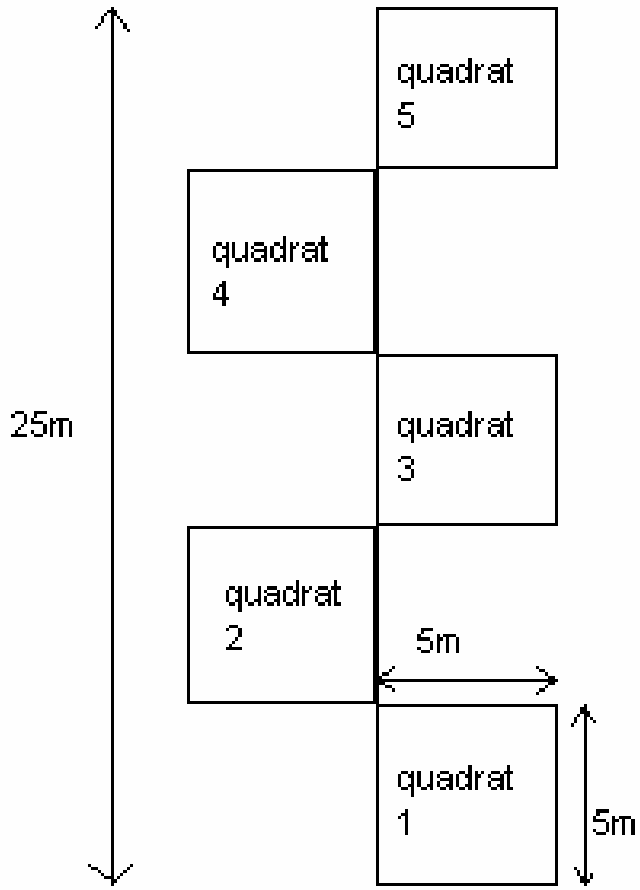
Vegetation was sampled using a transect/quadrant method. A stratified sampling technique was utilised. A 25-m transect rope was established along the center of the wadi bed, and five quadrats, each 5 x 5 m (25 m²), were placed along its length on alternating sides of the rope (Fig 2).

For each plant species present within a quadrant, the following data were recorded for each plant species: the percentage cover, total number of individuals, plant stage, overall vigour, level of grazing, and the presence or absence of vehicle tracks. Plant vigour was assessed over all individuals within the quadrant on a 5-point scale from Excellent (5) to Very Poor (1). This scale was recorded based on the following criteria: (a) amount of reproduction of individuals (flowering and fruiting), (b) overall vigour and vitality of individuals, and (c) plant height and cover. The level of grazing was also averaged over all individuals within the quadrant and recorded along a similar 5-point scale from Heavy (5) to None (1), using the following criteria: (a) number of grazed individuals, (b) number of browsed branches, and (c) plant height and cover. Plant stage was recorded using a 3-point scale: Fruiting (3), Flowering (2) and Vegetative (1).

In addition to data from plants, mammal dung was also surveyed by recording the species concerned (mainly camel, donkey, rabbit, sheep, ibex, and fox), the number of droppings, and the age category of the droppings on a 5-point scale: fresh (1), less than one week old (2), over one week old (3), less than one year old (4), and over one year old (5). The

main criteria of this scale (see AlQamy 2005) were the dryness and the colour of the dung: dry, white dung was the oldest. The dung of ibex and goats are hard to tell apart, and discrimination is likely to be poor; others are very characteristic.

Figure 2: Diagram of the transect and sampling quadrats



Species diversity was calculated using Simpson's Diversity Index (Lande 1993) and analysed for differences among wadis, or among groups of wadis, using Anova.

For each wadi, the Importance Value Index for each species was calculated (Curtis & McIntosh 1950) by expressing its frequency, density and cover relative to the totals for all species (as a percentage). The Importance Value Index for each species is then calculated as 300 - (relative frequency + relative density + relative cover): this scale of the species importance value here runs from 0 to 300.

The recorded plant species along with their importance values in all the study plots were used in constructing a data matrix for use in classification and ordination. Classification of stands was assessed using two-way indicator species analysis (TWINSPAN: Hill 1979), based on the species' importance values. Correspondence analysis (Ter Braak 1986) was used to ordinate stands, implemented by the Multivariate Statistical Analysis Package of Kovach Computing Services (www.kovcomp.co.uk).

RESULTS

Plants and wadis

The plant species recorded during these surveys show remarkably different habitat features between high and low elevational sites. In the high-elevation sites surrounding the ring dyke, dominant plant species include *Peganum harmala, Artemisia herba-alba, Zilla spinosa, Matthiola arabica, Phlomis aurea, Achillea fragrantissima* and *Pulicaria undulata*. These sites have high plant diversity, with a high number of species recorded and a relatively high plant cover. The low-elevation sites have a completely different set of dominant plants, including *Retama raetam, Hamada elegans, Heliotropium digynum, Artemisia judaica* and *Neurada procumbens.* These sites have low plant diversity, with relatively low vegetation cover and a low number of species recorded.

The following plants were recorded as being heavily affected by grazing: Ochradenus baccatus, Bufonia multiceps, Juncus rigidus, Galium sinaica, Plantago sinaica, Polygala sp., Globularia arabica, Ephedra alata, Ballota undulata, Zilla spinosa, Reseda pruinosa and Caylusea hexagyna. It was observed that these plant species were commonly grazed to the plant base, affecting the plant's reproductive vigour. Some species were found to be abundant, such as Zilla spinosa, Ballota undulata and Caylusea hexagyna. However, Ochradenus baccatus, Bufonia multiceps, Globularia arabica and Ephedra alata were rarely encountered.

Classification and ordination

The twenty-nine sites were separated into seven groups according to the TWINSPAN analysis of their importance values (Fig 3). The resultant groupings relate mostly to the elevation of the sites along with the vegetation composition and structure.

Group I wadi's (Elwadi, Abu Matier, Ain Hudra, Kiri, Legaibi) are lowest in elevation, at approximately 600-800 m. Plant cover and richness is noticeably lower in this group. Vegetation cover ranges from 2-15% overall. The indicator species identified by TWINSPAN of this group are *Acacia tortilis* and *Arthrocnemum macrostachyum*, and the associated species are *Hamada elegans, Retama raetam, Aerva javanica, Ochradenus baccatus*, and *Anarrhinum pubescens*. The communities in this group are 95% similar to one another, and have an overall Simpson's diversity index of 0.947 ± 0.005.

Group II wadi's (Eleiqat and Ertama) are near Wadi Feiran, the westernmost of the surveyed sites. They are at a moderate elevation (697-754 m), and are characterized by both granitic and sandstone geology. Vegetation cover ranges from 4-11%, and plant species richness and total cover is low. The sole indicator species identified by TWINSPAN is *Heliotropium digynum*, and the associated species include *Anabasis sp., Hamada elegans, Retama raetam*, and *Lotononis platycarpa*. The communities are 93% similar, and have an overall Simpson's diversity index of 0.844 ± 0.011.

Group III wadi's (Albarega, Souria, Emrair, Rem, Koria Shamoun, Gharaba) are also in close proximity to Wadi Feiran. They have a slightly higher elevation (780-1180 m) than wadis in group II. This group is characterized as having primarily sandstone and granitic geology. Vegetation cover ranges from 5-12%, with a higher plant richness, and moderate plant cover. The indicator species identified by TWINSPAN is *Scrophularia libanotica*, and the associated species include *Artemisia judaica*, *Reseda pruinosa*, *Gymnocarpos decandrus*, and *Ochradenus baccatus*. The communities in this group are 72% similar, and have an overall Simpson's diversity index of 0.741 ± 0.009.

Group IV (Esh Shaik, Erdasia) are mid-elevation wadi's (1143-1421 m) dominated by primarily granitic geology with high slopes and a well-defined wadi bed composed of a high-sand component. Vegetation cover ranges from 12-18% with a relatively high species richness and high plant cover. Plant species richness increases significantly with an increase in slope

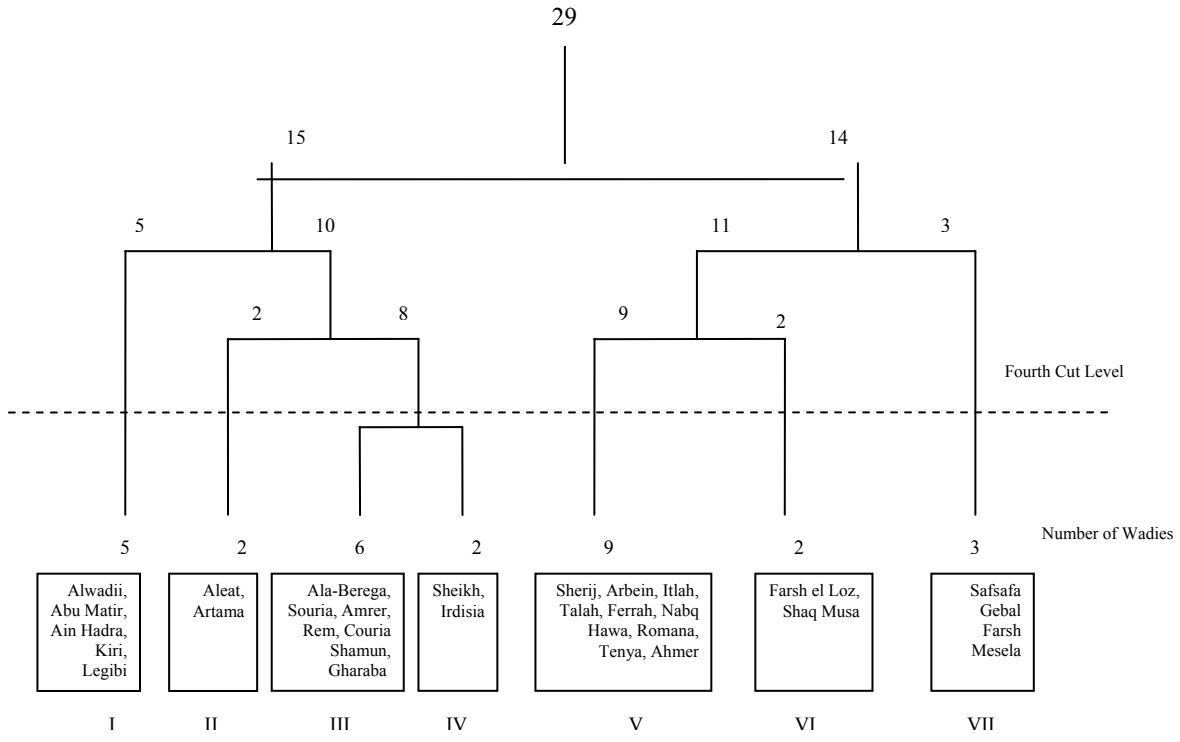
within the habitat. The indicator species identified by TWINSPAN is *Scrophularia libanotica*, and the associated species include *Artemisia herba-alba*, *Ochradenus baccatus*, *Juncus rigidus*, *Teucrium polium*, and *Chiliadenus montanus*. The communities in this group are 91% similar, and have an overall Simpson's diversity index of 0.807 ± 0.028.

Group V (Arbain, Itlah, Ferah, Naqb Hawa, El Roumana, Tynia, Ahmar, Shraig, Tella^{c}ah) are high-elevation (1385-1859 m) wadis with a varied geology (granite, sandstone, and basalt). Vegetation richness and percentage cover is high, perhaps because of a moderately high moisture availability throughout this group of wadi's. The indicator species identified by TWINSPAN of this group is *Panicum turgidum*. Associated species include *Bufonia multiceps, Phlomis aurea, Matthiola arabica, Alkanna orientalis,* and *Andrachne aspera.* The communities in this group are 70% similar, and have an overall Simpson's diversity index of 0.809 ± 0.007.

Group VI (Farsh El Luz, Shaq Musa) can be characterized as having primarily granitic geology with sporadic sandstone features. The high moisture regime in these wadis produces a different vegetation structure than seen in previous wadis. The elevations of this group range from 1892-1996 m. The indicator species identified by TWINSPAN of this group is *Mentha longifolia*, well known in the region to signify abundant water resources. The associated species include *Artemisia herba-alba, Ballota undulata, Tanacetum sinaicum, Teucrium polium*, and *Origanum syriacum sinaicum*. The communities are 96% similar, and have an overall Simpson's diversity index of 0.928 ± 0.004.

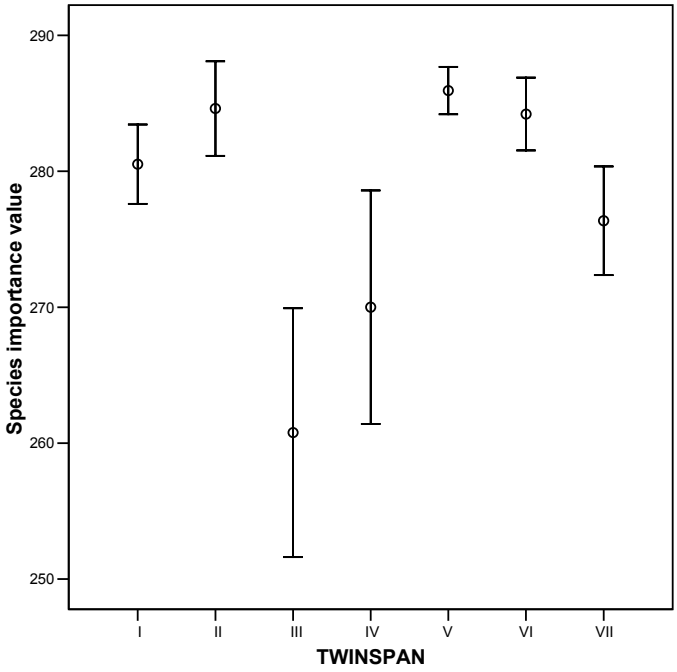
The high-elevation (1763-2004 m) wadis of Group VII (Safsafa, Gebal, Farsh Mesaila) have granitic geology with some sandstone features, and very similar vegetation structure and density. The indicator species identified by TWINSPAN are *Cynodon dactylon* and *Alkanna orientalis*, and associated species include *Artemisia herba-alba, Deverra triradiata, Astragalus sp., Plantago sinaica,* and *Tanacetum sinaicum.* The communities in this group are 82% similar, and have an overall Simpson's diversity index of 0.897 ± 0.007.

Figure 3: Dendrogram illustrating the relationships among wadis, clustered using TWINSPAN.



A two-way analysis of variance of importance values, including grouping and plant-species identity (but not their interaction, since many plants do not occur in all wadi's) was conducted. This indicates that there are no significant differences among the TWINSPAN clusters (Fig 4), after allowing for differences in species importance values among plant species. This implies that all the wadis surveyed have, on average, similar vegetation structure in the relative density, relative frequency, and relative cover of their plants. There were, of course, highly significant differences in importance values among plant species ($F_{107,330}$=2.1, $p<0.001$), as there must inevitably be.

Figure 4: Mean species importance values (± S.E.) for the groupings of wadis identified by the TWINSPAN analysis. There is no evidence for significant different among the groups ($F_{6,330}$ = 1.19, n.s.).



The Correspondence Analysis (Figs 8 & 9) shows much the same thing as the TWINSPAN classification. The first axis (12% of the variation) contrasts the Ain Hudra wadis with those of the Ring Dyke, on the basis of plants such as *Hamada elegans*, *Retama raetam*, *Neurada procumbens*, *Crotalaria aegyptiaca* and *Arthocnemum macrostachyum*. The second axis (8% of the variation) contrasts Wadi Eliqat with Wadis Gebal and Abu Matir, on the basis of plants such as *Chrozophora oblongifolia*, *Forsskaolea tenacissima* and *Lycium shawii*. The simplicity of the 2-dimensional TWINSPAN clusters hides complex multidimensional relationships that appear in the Correspondence Analysis, where 12 axes together account for 70% of the variation, but the 12th axis still contains a reasonable amount of the variation (3.5%).

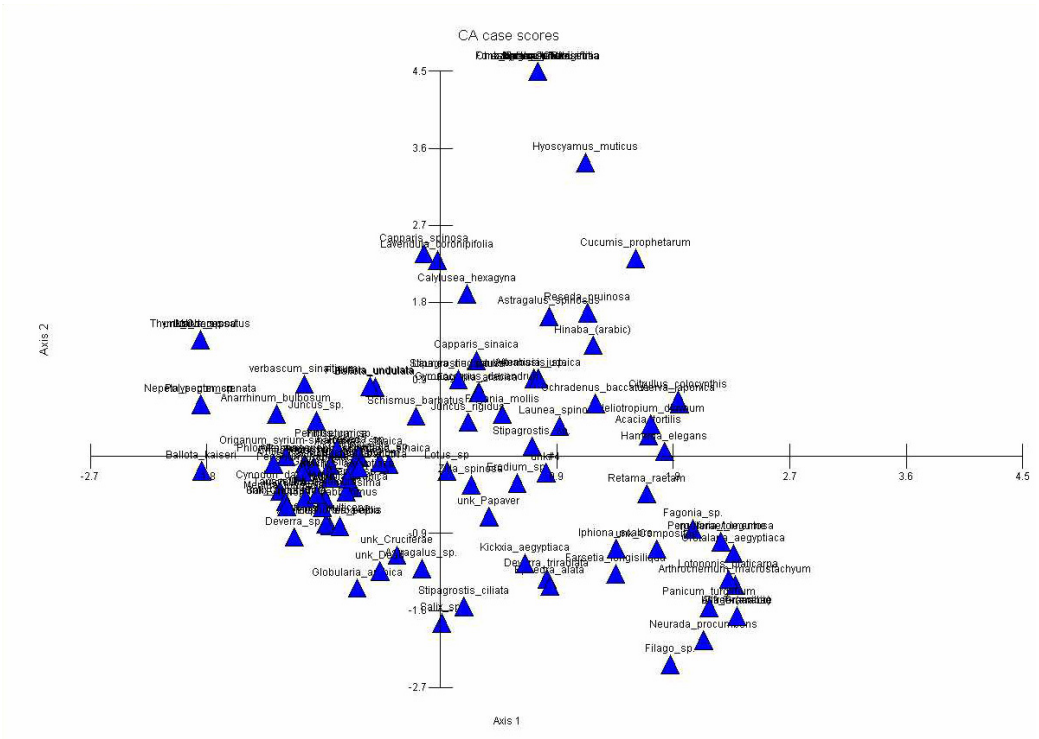
Plant vigour and grazing pressure

Grazing pressure was highest in wadi groups VII, IV, and III, and overall there were significant differences in grazing pressure among the wadi groups (Fig 7). There were significant differences among wadi groups in plant vigour (Fig 8), which had its lowest mean values in wadi groups III, II, and IV. Overall, the clusters with high grazing pressure have a lower overall plant vigour; this impression is underlined by the fact that, using a Spearman's rank correlation, a strong negative relationship was found between overall plant vigour and grazing pressure (Fig 9). An analysis of variance for grazing by plant families demonstrated highly

significant differences among their mean values (Fig 10), showing that certain plant families are grazed intensely while others are grazed less frequently, i.e. some plant families are more palatable to grazing animals than others. Of the thirty-three families, moderate grazing (score of 3) was found in the following eight plant families: Capparaceae, Asclepiadaceae, Scrophulariaceae, Euphorbiaceae, Chenopodiaceae, Umbelliferae, Graminae and Cruciferae. There are twelve plant families that showed heavy grazing (score of 4 or 5), including: Resedaceae, Caryophyllaceae, Polygalaceae, Juncaceae, Solanaceae, Geraniaceae, Ephedraceae, Globulariaceae, Urticaceae, Moraceae, Plantaginaceae, and Salicaceae. It was observed that the following plants within those families are being negatively affected by heavy grazing: *Ochradenus baccatus, Bufonia multiceps, Juncus rigidus, Galium sinaica, Plantago sinaica, Polygala sp., Globularia arabica, Ephedra alata, Ballota undulata, Zilla spinosa, Reseda pruinosa* and *Caylusea hexagyna*.

Further experiments and research is necessary to determine if heavy grazing is the real cause of poor vigour in these plant species; however, our current findings suggest such relationship. The single most effective way of improving plant communities in the St. Katherine Protectorate may be to control levels of grazing.

Figure 5: Plot of the plants of the first two axes (20% of the variation) of a Correspondance Analysis of the plants in the various wadis.



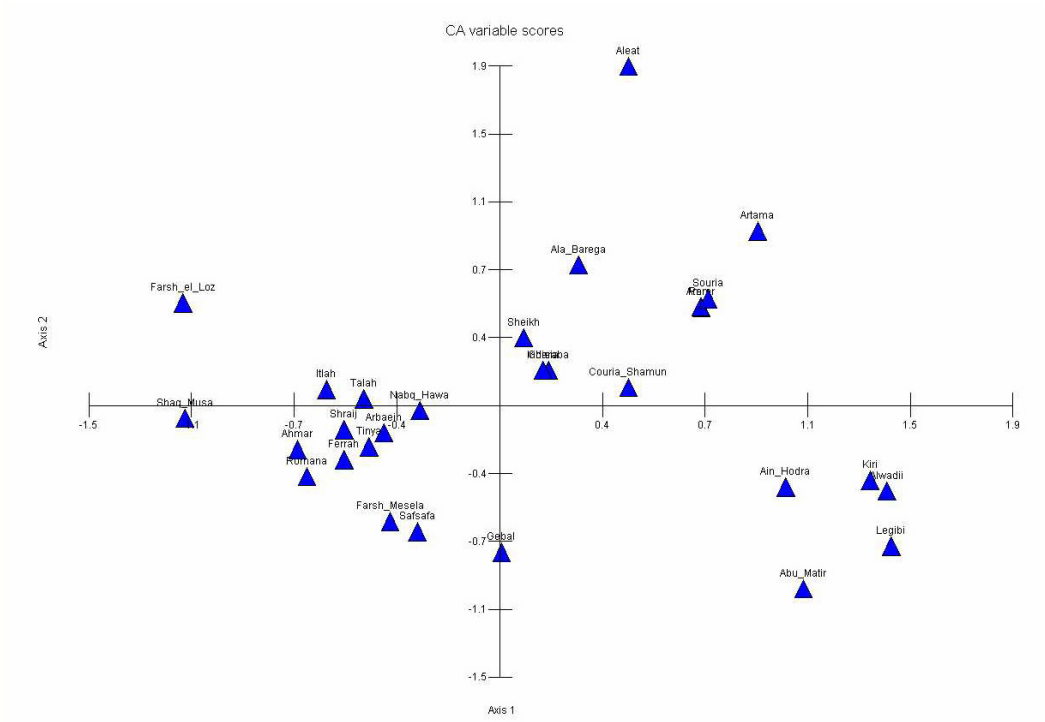


Figure 6: Plot of the sampling sites (wadis) the first two axes (20% of the variation) of a Correspondance Analysis of the plants in the various wadis.

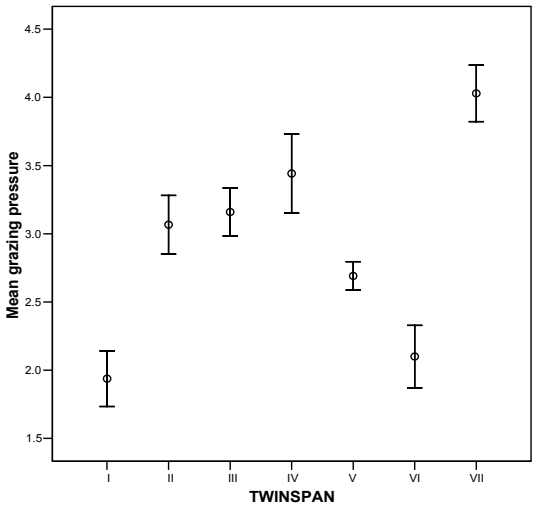


Figure 7: Mean grazing pressure (± S.E.) in the wadi groupings identified by TWINSPAN. There are highly significant differences among these mean values ($F_{6, 330}$=5.3, p<0.001).

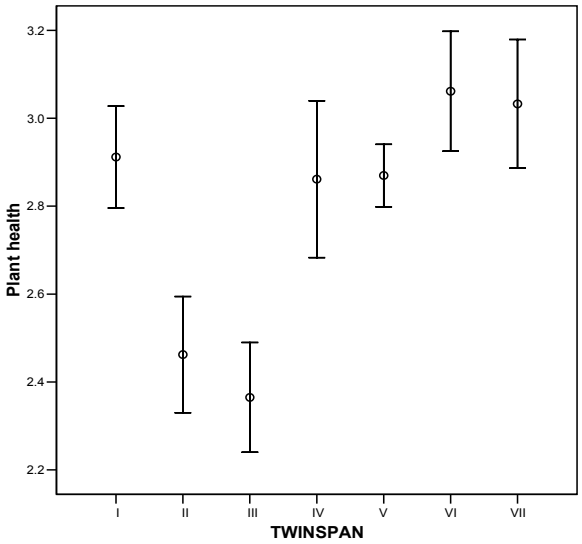


Figure 8: Mean plant vigour (± S.E.) in the wadi groupings identified by TWINSPAN. There are highly significant differences among these mean values ($F_{6, 330}$=8.8, p<0.001).

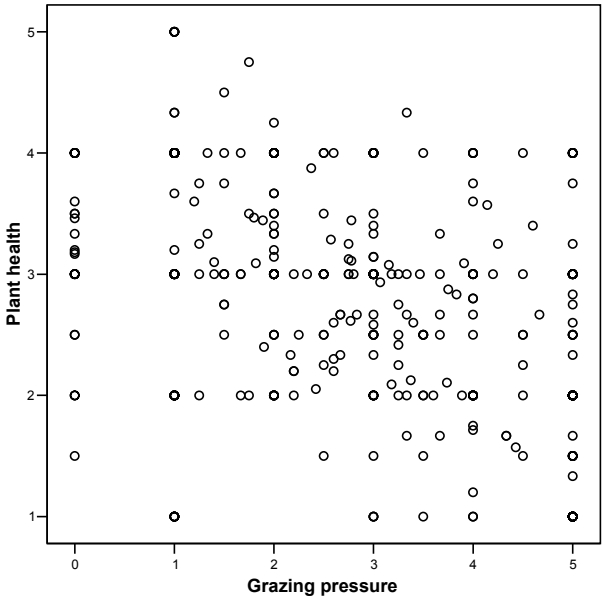


Figure 9: Relationship between grazing pressure and plant vigour, for all the recorded plant species in the wadis surveyed. There is a highly significant negative relationship (r_s = -0.454, n=445, p<0.001). If causal, this implies that grazing is currently having a significant impact on plant condition.

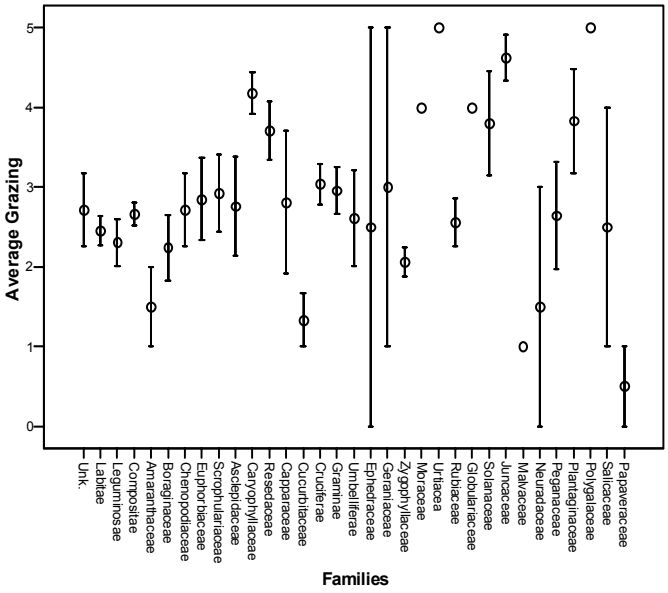


Figure 10: Mean grazing pressure (±S.E.) for plant families encountered during 2005 surveys of St. Katherine Protectorate. There are highly significant differences among these mean values ($F_{32,412}$=2.060, n=33, p=0.001).

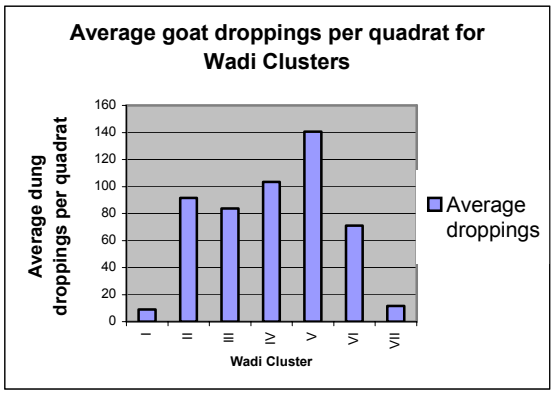
The abundance of dung

We calculated the average number of droppings per mammalian species over all the sites within each of the TWINSPAN clusters (Fig 11). The vast majority of the dung recorded was either class 4 (less than 1 year but more than 1 month) or 5 (greater than 1 year), suggesting nearly all the dung was greater than a month old; because of this, the age categorization was ignored. There was a significant difference in the average dung droppings ($F_{7,88}$=3.303, p<0.005) found within the TWINSPAN clusters, along with a highly significant difference for the mammalian species status, whether it is wild or domestic, ($F_{7,88}$=127.153, p<0.001) in the surveyed sites (Figures 12 & 13). This suggests that domestic animals, rather than wild animals, are more abundant in the wadi system. However, it also suggests that these domestic animals are using the wadis with different regularity.

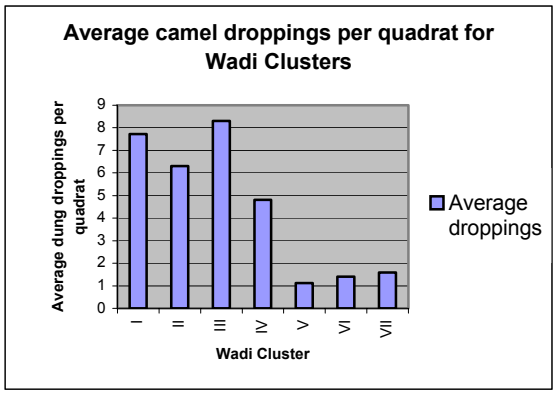
There were large numbers of camel droppings recorded in the Ain Hudra and Wadi Feiran wadis (groups I, II, III, and IV): these low-elevation sites are easily accessible and used heavily by tourists and camels. Wadis in Feiran and around St Katherine (Clusters II, III, IV, V, and VI) contained the highest amounts of goat dung, indicating that goats are intensely grazing the majority of these sites. Ain Hudra (I) and high-elevation wadis (VII) showed low amounts of goat dung, which corresponded to the low density of palatable plant species to goats. The frequency of donkey dung was low and rarely encountered in most of the surveyed sites: only around St Katherine (V) and the high elevation wadis (VII) showed a substantial

amounts of donkey dung. Ibex dung was found in low quantities in the low- and mid-elevation wadis (I, II, III, IV, and V) during the surveys: wadis near Feiran (II) showed the highest amounts at approximately two pieces per quadrat. Fox dung was recorded in many of the low- and mid-elevation wadis (I, II, IV, and V), the highest densities around St. Katherine (V). No gazelle or hyena dung was encountered during the surveys. Overall, wadi clusters II, III, and IV have the largest amounts of dung from domestic grazing animals (camels, goats, and donkeys), while clusters I, II, IV and V have moderate amounts of dung from native animals (ibex and fox). There was significantly more domestic mammal dung encountered than native mammal dung.

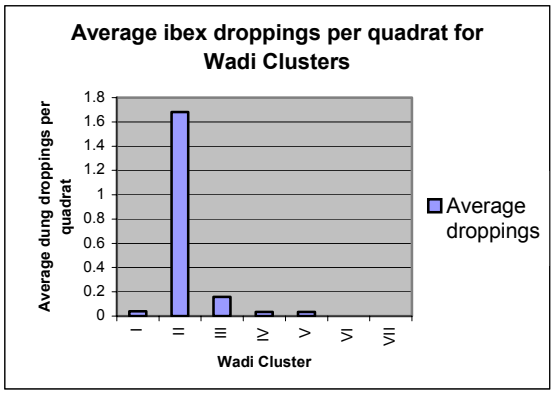
Figure 11: Average number of dung droppings per quadrat for (a) camel, (b) goat, (c) donkey, (d) ibex, (e) fox, grouped by TWINSPAN wadi clusters.



(b)



(a)



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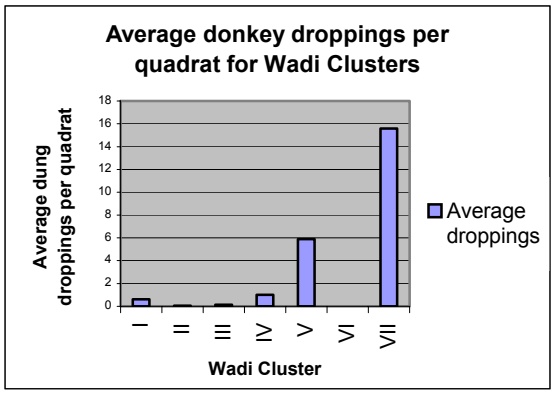
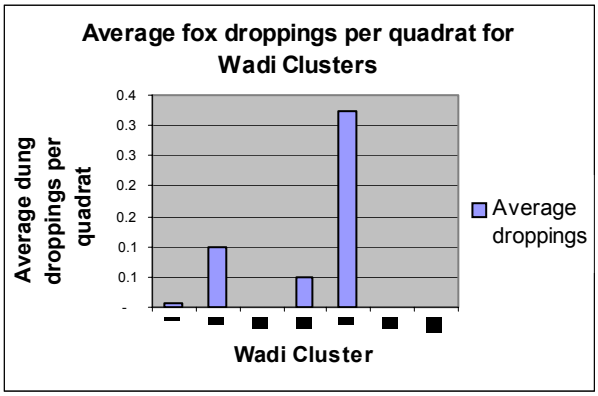


(d)



(e)

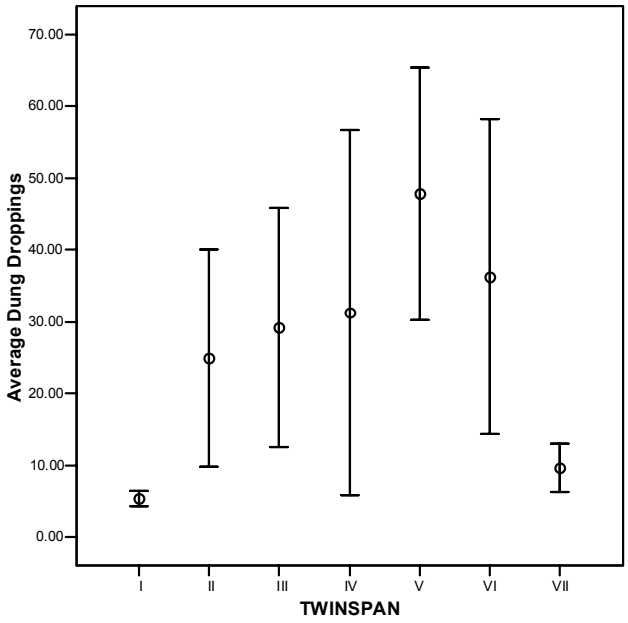


Figure 12: Mean dung droppings (±S.E.) for TWINSPAN clusters encountered during 2005 surveys of St. Katherine Protectorate. There are significant differences among these mean values ($F_{7,88}$=3.3, p<0.005).

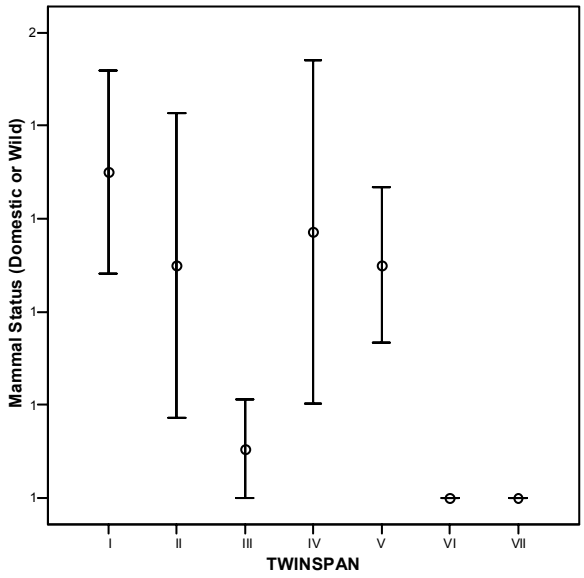


Figure 13: Mean differences in mammalian species status (±S.E.) for TWINSPAN clusters during 2005 dung surveys of St. Katherine Protectorate. There are highly significant differences in the mammalian species status ($F_{7,88}$=127.2, p<0.001).

DISCUSSION

The aim of this project was to monitor vegetation in the different wadi systems in the St. Katherine Protectorate, to assess how plant species are distributed, and to determine if grazing is affecting the vigour of the plant communities. The results indicate that the different wadi systems have notably different vegetation components depending on their elevation. Low elevational wadis were dominated by *Retama raetam, Hamada elegans*, and *Heliotropium digynum* with low plant coverage and low species richness. High elevation sites were dominated by *Artemisia herba-alba*, *Zilla spinosa, Matthiola arabica, Achillea fragrantissima* and *Pulicaria undulata* with considerably higher plant coverage and species richness. However, all the wadis surveyed have, on average, similar vegetation structure in the relative density, relative frequency, and relative cover of their plants. This indicates that although the different sites have different vegetation components, their vegetation structure is similar.

The grazing analysis indicated that sites with a high grazing pressure have a lower overall plant vigour. A strong negative relationship was found between overall plant vigour and grazing pressure. The grazing analysis also indicated that certain plant families are grazed intensely while others are grazed less frequently.

When the dung data was analyzed, it was found that camel droppings were mainly recorded in low elevation sites that are easily accessable and are used heavily by tourists and camels. Goats are intensely grazing the majority of the sites surveyed. Fox dung was recorded in moderate amounts at a variation of sites. Ibex dung was recorded very rarely, and is easily confused with goat dung. No gazelle or hyena dung was encountered during this survey. Overall, low elevation sites had the largest amount of dung from domestic grazing animals, while dung from native mammals was encountered rarely.

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الملخص العربى

الكساء الخضرى والرعى الجائر فى محمية سانت كاترين – جنوب سيناء – مصر

ريبيكا جونزير[1] - فرانسيس جلبرت[2،3] – سامى زلط[3،4] – كامل سليم[5] – طلاب اوباريشين واليسيا صيف 2005م[6]

1. جامعة كاليفورنيا – الولايات المتحدة الامريكية
2. قسم البيولوجى – جامعة نوتنجهام – المملكة المتحدة
3. مشروع البيوماب – وزارة الدولة لشئون البيئة – مصر
4. قسم علم الحيوان – جامعة قناة السويس – مصر
5. قسم علم النبات – جامعة قناة السويس – مصر
6. هيئة أورباريشين واليسيا – المملكة المتحدة

تم **حصر وتقييم حالة النباتات البرية فى تسعة وعشرون وادياً من وديان محمية سانت كاترين بسيناء خلال صيف 2005م. أوضحت الدراسة أن أكثر الفصائل النباتية إنتشاراً بتلك الوديان هى: الفصيلة المركبة، النجيلية، الشفوية، والبقولية. وكانت أكثر الآنواع إنتشاراً فى الوديان المختلفة هى: الشيح, البعيثران, الدمجة, الوراقة, السفسوف, الفرطم, المر, الجعدة والثلة.**

أوضحت الدراسة أن جماعات النباتات الأكثر تعرضا لضغط الرعى تكون أقل إزدهارا، حيث وجدت علاقة عكسية معنوية بين إزدهار النبات والضغط الذى يسببه الرعى.

أظهرت إثنا عشر فصيلة تأثرها الشديد بالرعى الجائر فى المنطقة وهم: Resedaceae، Caryophyllaceae، Polygalaceae، Juncaceae، Geraniaceae، Ephedraceae، Globulariaceae، Urticaceae، Moraceae، Plantaginaceae، وSalicaceae