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Local Distribution of Three Threatened *Ballota* Species in St. Catherine Protectorate, Southern Sinai, Egypt

M.S. Zaghloul[1*], A.A. Moustafa[1], Wafaa M. Kamel[1], J.L. Hamrick[2] and R.E. Mahmoud[3]
[1]Botany Department, Faculty of Science, Suez Canal University, Ismailia, Egypt[2], Department of Plant Biology, University of Georgia, Athens, GA 30602, USA and [3]Botany Department, Faculty of Science, Alexandria University, Alexandria, Egypt.

BALLOTA species growing in Sinai, Egypt, are subjected to a number of threats, which caused an abrupt decline both in number and size of their populations. Phytosociological data were collected to study *Ballota* species distribution. By using multivariate analyses (TWINSPAN and CCA), *Ballota kaiseri* and *B. saxatilis* were represented as associating species in *Galium sinaicum* vegetation group while *B. undulata* was recorded as associating species in *Teucrium polium–Phlomis aurea*, *Nepeta septemcrenata–Origanum syriacum*, and *Galium sinaicum* vegetation groups beside its own vegetation group. Results revealed that *Ballota* species are significantly and positively affected by elevation. While *B. undulata* prefers low pH values, *B. kaiseri* and *B. saxatilis* share the same microhabitats favoring high soil clay and silt percent, organic matter content, and consequently low sand percent which mean low pH also and high soil moisture content.

Keywords: *Ballota*, Sinai, Threatened species, Multivariate analysis, Classification, Ordination.

Labiatae is one of the most represented plant families in St. Catherine Protectorate. Of which, high percent are endemic, medicinal, and/or threatened (Moustafa, 1990; Moustafa *et al.*, 1999; Zaghloul, 1997 and Zaghloul, 2003). *Ballota* species belong to Labiatae and are subjected to a number of threats, which cause their populations to decline in both number and size. Some of these threats are specific to *Ballota* populations, but the majority affects the functional communities and ecosystems in which *Ballota* populations ultimately exist. These threats are either natural or human-induced.

The natural threats include drought, floods, and natural enemies (mice and pests). Drought and flood years' cycle has been observed in the area (Abd El-Wahab, 2003). While drought and low precipitation (< 20 mm year^{-1}) may be the prevailing weather pattern for 7-10 cosecutive years, it may be followed by rainy year/years in which torrential rainfall sometimes exceed 120 mm in few days that

* Corresponding author. E-mail zaghloul_mohamed@yahoo.com

causes destructive flash floods destroying the vegetation in many valleys (wadis) in Southern Sinai (Abd El-Wahab, 2003 and El-Rayes, 1992).

Disturbances due to human impact are recorded all over the area including over-grazing, over-collecting, uprooting, feral donkeys, over-cutting for fuel wood, urbanization, quarries, tourism, solid wastes, and other land uses (Moustafa *et al.*, 1998 & 1999). These disturbances lead to the destruction of natural habitats and the disappearance of plant communities in which *Ballota* live and interact. Each site may have its specific order of threats but the most important threat to *Ballota* and its community is the over-grazing.

The present study was many aimed to understand the factors affecting the distribution of *Ballota undulata*, *B. saxatilis*, and *B. kaiseri* that should be sufficiently known to deal with their conservation issue.

Material and Methods

Study area and stand selection

The study was carried out in St. Catherine Protectorate which is a part of the southern Sinai massif that is characterized by its altitudinal gradient starting from 1500 m a.s.l. till the highest peak (St. Catherine Mountain) at 2641 m a.s.l. The study area is located between 33° 57' to 34° 00' east, and 28° 30' to 28° 34' north (Fig. 1). The area is approximately 30 km^2 and is characterized by high rugged mountains intersected by vallies (wadis) differ in their deepness and length.

The main criteria used for the selection of stands and determination of their sizes included having a reasonable degree of physiognomic homogeneity in topography and vegetation type, low levels of vegetation disturbance, different grazing intensities, and abundance of the studied species viz., *Ballota undulata* (Fresen.) Benth, *B. kaiseri* Täck, and *B. saxatilis* C. Presl. Thirty-five stands in seven main localities (Fig. 1) were selected to study *Ballota* species, representing as much as possible the prevailing environmental variation associated with the distribution of *Ballota* species. The selected locations nearly represent the entire local distribution range of both *B. saxatilis* and *B. kaiseri*, and the core area of *B. undulata* distribution. In each stand, elevation, slope degree, aspect, and the type of landform were measured. Landform type was determined according to Moustafa & Klopatek (1995) as: terrace, slope, Wadi bed, and gorge.

Soil sampling and analysis

Soil where *Ballota* occurs is very shallow and therefore, samples were collected from notches and crevices in each stand. Typically, particle size analyses, as well as other standard soil analyses, are made on the fine fraction of the soil that is on soil material of less than 2 mm equivalent spherical diameter (Ball, 1976 and Hausenbuiller, 1985). In the laboratory, soil samples were air dried, then passed manually through a 2 mm-mesh sieve to evaluate gravel percent.

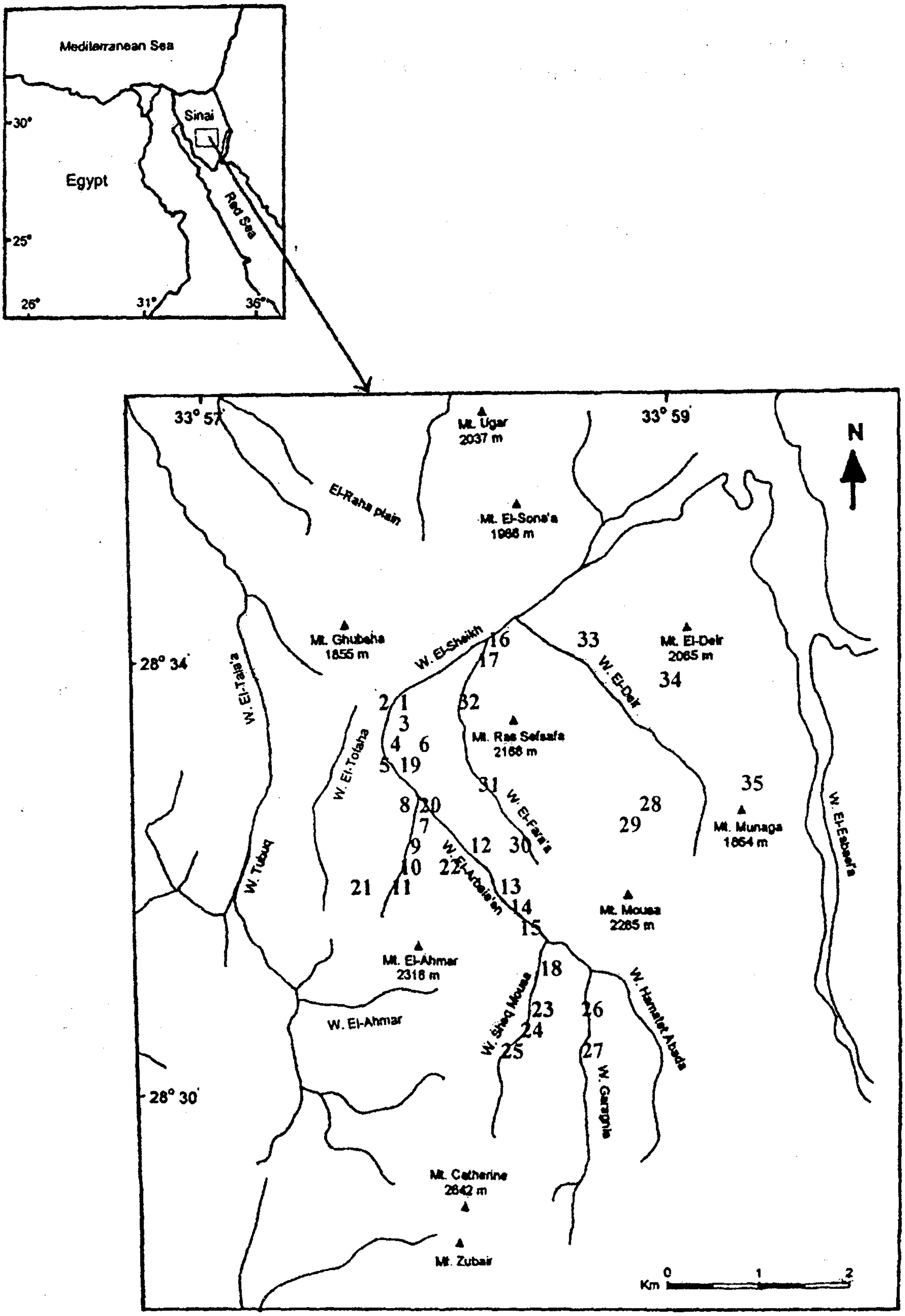

Fig. 1. Map showing the location of studied stands numbers indicate the selected stands and triangle shapes mean the mountains.

The pipette method was applied on the soil suspension to estimate particle size distribution (soil texture) following Wilde *et al.* (1972). Sodium hexame-taphosphate (1N Calgon solution) was added to disperse aggregates, HCl (1N) to remove Calcium Carbonate, and Hydrogen peroxide (6%) to remove organic matter.

The soil saturation percent was measured as grams of water required to wet 100 grams of soil to the saturation point (Gardner, 1986). The organic matter content of soil samples were determined by loss on ignition. The pH values of water extracts of soil samples were determined with a pH meter, using water to soil ratio of 2.5:1 following Allen *et al.* (1976). Specific conductivity (EC) was measured in a conductivity cell by an EC meter as described by Wilde *et al.* (1972).

Quantitative vegetation analysis

1. Multivariate analysis of data

To reduce noisy, very rare species with less than 0.02 densities were excluded. Classification of the phytosociological data set (thirty-five stands and twenty-nine species) was carried out using Two-Way Indicator Species Analysis (TWINSPAN) technique in PC-ORD computer program, version 4.01 for Windows (McCune and Mefford, 1999). In running the program, the following parameters were set in the setup dialog: (1) The pseudospecies cut levels were set to 0.0, 0.02, 0.05, 0.1, and 0.2, (2) Minimum group size for division was set to default, 5, (3) Maximum number of indicators per division was set to default, 5, (4) Maximum number of species in the final tabulation was set to default, 200, and (5) Maximum level of divisions was set to 3. To interpret the species/ environment relationships, Canonical Correspondence Analysis (CCA) technique in PC-ORD computer program (McCune and Mefford, 1999) was also carried out.

2. Statistical evaluation

Variation between the four vegetation groups resulted from TWINSPAN in each environmental factor was tested for significance by one-way ANOVA for those variables with a normal distribution and homogeneity in variance, and by a Kruskal-Walllis nonparametric test for those variables that failed either normality and/or an equal variance test. Anderson-Darling test was used to test significant departures from normality. Bartlett's (for normal variables) and Levene's tests were used to test for variance homogeneity. Tukey's and Steel-Dwass (non-parametric) pairwise comparisons were done to discriminate between different groups.

Statistical evaluation of the ordination has been done by using Pearson correlation analysis and multiple regressions. Pearson correlation analysis was done between the adopted ordination diagram axes and all environmental variables (factors) measured to asses the correlation between ordination axes and different environmental variables. Regression analysis was used to report the effectiveness of the environmental variables in structuring the ordination and describe the relationships of the environmental variables to the ordination axes.

Results

Species and vegetation composition

Table 1 provides a list of the identified species and their life form. Nomenclature is according to Boulos (1995) and life form is according to Raunkiaer (1934) and following Danin (1983), Moustafa (1990), Moustafa & Kamel (1995), and Moustafa *et al.* (1998). Throughout the study, 62 plant species were identified belonging to 26 taxonomic families. The most represented families are: Labiatae (13 species), Compositae, Scrophulariaceae, Cruciferae, Leguminosae, Caryophyllaceae and Solanaceae. All the other families (19 or 73%) are represented by a single species. Endemic species represent 14.5% belonging to Labiatae (55.6%), Caryophyllaceae (11.1%), Guttiferae (11.1%), Primulaceae (11.1%), and Scrophulariaceae (11.1%). Six life-forms were recognized: Chamaephytes (56.6%), Hemicryptophytes (27.4%), Therophytes (8.1%), Phanerophytes (3.2%), and Geophytes (1.6%).

TABLE 1. Species list, family, life-form, and abbreviation used in quantitative analysis. * is endemic species; CH–Chamaephyte or shrub; G–Geophyte; H–Hemicryptophyte; G–Geophyte; PH–Phanerophyte; and TH–Therophyte.

Family	Species	Life form	Abbreviation
Asclepiadaceae	*Asclepias sinaica* (Boiss.) Muschl.	CH	Asce sin
Boraginaceae	*Alkanna orientalis* (L.) Boiss.	CH	Alka ori
Caryophylaceae	*Arenaria deflexa* Decne.	H	Aren def
	* *Bufonia multiceps* Decne.	CH	Buff mul
	Silene linearis Decne.	An	Sile lin
Compositae	*Achillea fragrantissima* (Forssk.) Sch. Bip.	H	Achi fra
	Artemisia herba-alba Asso	CH	Arte her
	Centaurea scoparia Sieber ex Spreng.	CH	Cent sco
	Echinops glaberrimus DC.	H	Echi gla
	Echinops hussonii Boiss.	H	Echi hus

TABLE 1. Contd.

Family	Species	Life form	Abbreviation
Rubiaceae	*Galium sinaicum* (Delile ex Decne.) Boiss.	CH	Gali sin
Scrophulariaceae	* *Anarrhinum pubescens* Fresen.	H	Anna pub
	Kickxia macilenta (Decne.) Danin	H	Kick mac
	Scrophularia sp.	H	Schr sp.
	Verbascum decaisneanum Kuntze	CH	Verb dec
	Verbascum sinaiticum Benth.	CH	Verb sin
Solanaceae	Lycium shawii Roem. & Schult.	PH	Lyci sha
	Solanum nigrum L.	An	Sola nig
Umbelliferae	*Deverra triradiata* Hochst. Ex Boiss.	CH	Deve tri
Zygophyllaceae	*Fagonia mollis* Delile	CH	Fago mol

1- Classification of stands

Based on the floristic composition (species density), the stands were classified at the second level, by TWINSPAN to four main vegetation groups (Table 2)

Vegetation group I: *Ballota undulata*
Vegetation group II: *Teucrium polium – Phlomis aurea*
Vegetation group III: *Galium sinaicum*
Vegetation group IV: *Nepeta septemcrenata – Origanum syriacum*

Vegetation group I has only one species (*Ballota undulata*) with 100% presence and average abundance of 4.47. In the second vegetation group, two species have 100% presence *i.e., Teucrium polium* and *Phlomis aurea*; with an average abundance of 4.11 and 3.33, respectively. In the third vegetation group, *Galium sinaicum* is the only species that occurs with 100% presence (average abundance is 4.29). *Nepeta septemcrenata*, *Origanum syriacum*, and *Tanacetum santolinoides* are species that have 100% presence in the fourth (last) vegetation group and with 4.5, 3.75, and 3.00 average abundance values, respectively.

TABLE 2. TWINSPAN output of vegetational classification shows stand number at the top and differential clusters at bottom. Species names arranged at the left hand-side and species clusters on right hand-side.

		13 11111123	12223333	1122	2222	
		941345623456755	282370123	7890109	1468	
3	Andr asp	-5-------------	--------4	-------	----	000
9	Bitu bit	-5----------2-2	--------5	-------	----	000
23	Plan sin	----------2----	--2-5-45-	-------	----	000
27	Thym dec	---------------	--5----5-	-------	----	000
4	Anna pub	--------52523--	5-------4	-------	----	001
10	Buff mul	---4-2-55-53--2	3-1--11--	-------	----	001
11	Caly hex	-------32---5--	----5----	-------	----	001
13	Fago mol	--333-2353343-5	2-1------	-4-----	----	001
16	Lact ori	-----5-4--4---3	---------	-------	----	001
17	Lava pub	-5-------------	---------	-------	----	001
18	Lyci sha	5--------------	---------	-------	----	001
19	Matt ara	-----2242-23---	2---42---	-------	-14-	001
29	Zill spi	--25---22-33--5	---2-----	----4--	----	001
22	Phlo aur	----------2----	351553152	-2---2-	-153	010
25	Tana san	---2---45-4--2-	555-33254	2-42--4	3153	010
28	Vart mon	-------2--22---	--3--1152	-------	3---	010
2	Alka ori	543224344-5-45-	-5-45--5-	--4--1-	-154	011
5	Arte her	--4-45--5-4--55	5-55-555-	-335--5	---3	011
8	Ball und	453545535555544	5515322--	4555-4-	-154	011
24	Stac aeg	-4-2----5323-22	4-4--3452	224442-	----	011
26	Teuc pol	-------44255445	555525352	2-45522	22-4	011
1	Achi fra	--35---5-3-----	---------	425553-	----	10
12	Echi gla	-------45---3--	-5------4	5455---	---5	10
15	Gali sin	-----445---22--	3-3---252	3455535	--2-	10
21	Orig syr	-------3--2-3--	---42----	-4--45-	2445	10
6	Ball kai	----------2----	--------3	5-52-3-	2---	11
7	Ball sax	----------2----	--1------	2-5351-	4---	11
14	Ficu pal	---------------	---------	-------	5---	11
20	Nepe sep	----------2----	--23-----	424--15	5355	11
		000000000000000	000000000	1111111	1111	
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Environmental variables of stands supporting each vegetation group were subjected to statistical evaluation to test the significance of variation in these factors among the four vegetation groups. Six environmental factors were found to have significant difference between TWINSPAN groups (vegetation groups); organic matter content, soil reaction (pH), texture (*i.e.*, clay, silt and sand fractions), and the altitude (Table 3). For organic matter content, pH, silt, and sand, ANOVA was applied as they met its assumptions (normality and variance homogeneity) while for clay and elevation Kruskal-Wallis was applied, and consequently Steel-Dwass instead of Tukey's pairwise comparisons, as they failed the normality test. The most significantly variable environmental factor was the pH reaction ($P = 0.001$), which had four significant pairwise comparisons out of six. Each of the other significant factors has at least four non-significant differences in pairwise comparisons except for elevation gradient which has no significant comparison out of the six comparisons carried out by Steel-Dwass test although both Kruskal-Wallis and ANOVA resulted in significant variation. Both ANOVA and Kruskal-Wallis tests revealed that gravel percentage, saturation percentage, electric conductivity (EC), slope, and aspect have non-significant variation between different TWINSPAN groups. The four vegetation groups resulted from TWINSPAN are described below.

TABLE 3. Statistical tests for significant differences between TWINSPAN groups. ANOVA and Tukey's pairwise comparisons were used if variable tested has normal distribution (non-significant Anderson-Darling's test) and equal variance or variance homogeneity (non-significant Bartlett's test), otherwise Kruskal-Wallis test and Steel-Dwass pairwise comparisons were used.

Variable	Anderson-Darling departure form Normality Test		Test for equal variance				ANOVA *P*-value	Kruskal-Wallis Test *P*-value	Tukey's or Steel-Dwass pairwise comparisons between TWINSPAN groups					
			Bartlett's test		Levene's test									
	A-Squared	*P*-value	Test statistic	*P*-value	Test statistic	*P*-value			I – II	I - III	I - IV	II – III	II - IV	III – IV
Gravel %	0.138	0.973	8.426	0.038	3.279	0.034	0.186	0.126	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Sat. %	1.210	0.003	2.208	0.530	0.277	0.841	0.284	0.124	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Org. mat. %	0.533	0.161	2.047	0.563	0.174	0.913	0.005	0.019	-4.411 0.414	-3.314 1.923	-7.586^{S} -1.147	-1.580 4.186	-5.806 1.070	-7.257^{S} -0.085
EC	8.538	0.000	56.736	0.000	2.519	0.076	0.082	0.343	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
pH	0.361	0.427	0.816	0.846	0.408	0.748	0.001	0.001	0.0203^{S} 0.5601	-0.3741 0.2120	0.0670^{S} 0.7874	-0.6939^{PS} -0.0487	-0.2477 0.5216	0.1070^{S} 0.9094
Clay %	2.179	0.000	0.303	0.959	0.258	0.855	0.001	0.004	*	N.S.	*	N.S.	N.S.	N.S.
Silt %	0.597	0.112	6.426	0.093	1.085	0.370	0.026	0.020	-7.917 1.559	-6.481 3.806	-13.472^{S} -0.826	-3.821 7.505	-10.772 2.784	-12.855 1.32
Sand %	0.710	0.058	5.850	0.119	0.742	0.535	0.005	0.008	-0.851 11.804	-5.300 8.439	2.738^{S} 19.628	-11.470 3.655	-3.312 14.724	0.207^{S} 19.020
Slope degree	0.952	0.014	6.859	0.077	1.228	0.316	0.293	0.309	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Exp. degree	2.081	0.000	1.648	0.649	0.553	0.650	0.966	0.889	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Elev.	1.893	0.000	6.064	0.109	2.296	0.097	0.022	0.031	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

Note: * $P \leq 0.05$, N.S. = non-significant, and ^{S} = Tukey's significant pairwise comparison.

Vegetation group I: Ballota undulate: Ballota undulata is the dominant species. *Alkanna orientalis* (80.00%) and *Fagonia mollis* (73.33%) are the most prominent associating species. This vegetation group is found on terraces, slopes, and gorges with a very wide range of both exposure from north eastern (10°) to north western (350°) and slope degree (2°–60°) and a narrow elevation range (mean = 1605.7m a.s.l.). This vegetation group is characterized by having the highest mean sand fraction of the soil (92.51%).

Vegetation group II: Teucrium polium – Phlomis aurea: This vegetation group is codominated by *Teucrium polium* and *Phlomis aurea.* The associating species include; *Tanacetum santolinoides* (88.89%), *Ballota undulata* (77.78%), *Stachys aeygptiaca* (66.67%), and *Artemisia herba-alba* (66.67%). This vegetation group occupies slope, wadi bed, and gorge habitats with a wide range of elevation (1540 to 1920m a.s.l.), and gentle to slightly steep slopes (2.5°–30°). The exposure seems not to affect this vegetation group as it occupies a very wide exposure range from north-eastern (10°) to north (360°). Moderate organic matter content (mean = 5.6%), saturation percent (mean = 25.68%), soil reaction (mean pH = 8.1), sand fraction (mean = 87.03%), and clay fraction (mean = 3.77%) are the prominent characters of this vegetation group.

Vegetation group III: Galium sinaicum: In this vegetation group, *Galium sinaicum* is the dominant species. The associating species includ; *Teucrium polium* (85.71%), *Stachys aegyptiaca* (85.71%), *Achillea fragrantissima* (85.71%), *Ballota undulata* (71.43%), *Ballota saxatilis* (71.43%), *Nepeta septemcrenata* (71.43%), and *Ballota kaiseri* (57.14%). This vegetation group is restricted to gorge habitat and its associated slopes with a narrow medium range of elevation (1580–1770m a.s.l.) and moderate slope degree (mean = 25.9°). The soil of the stands supporting this vegetation group has a relatively low gravel percentage (mean = 40.68), electric conductivity (mean = 280.3 µS/cm), clay fraction (mean = 1.7%), and high sand fraction (mean = 90.94%).

Vegetation group IV: Nepeta septemcrenata – Origanum syriacum: This vegetation group is dominated by *Nepeta septemcrenata* and codominated by *Origanum syriacum* and *Tanacetum santolinoides.* Whereas *Alkanna orientalis* (75.00 %), *Ballota undulata* (75.00%), *Phlomis aurea* (75.00%), and *Teucium polium* (75.00%) represent the most prominent associating species. This vegetation group occurs in the same habitat (gorges and associated slopes) of the previous vegetation group (*Galium sinaicum*) but over a wider elevation range (1590 – 1920m a.s.l.), less exposure range (60° -240°), and lower mean slope (16.5°) with the widest range of gravel percentage (21.9 – 77.3). It's soil is characterized by having the highest mean organic matter content (7.98%), saturation (28.28%), clay (5.5%) and silt fractions (13.17%), and consequently the lowest sand fraction (81.33%). Its soil also has the widest range of electrical conductivity (230 – 6990 µS/cm) and the lowest soil reaction (pH mean = 7.99).

2- Classification of species

Following the TWINSPAN technique, data revealed that all species could be organized into four groups at the second level of classification (Table 2). The first group comprises thirteen species and includes; *Fagonia mollis, Bufonia multiceps, Matthiola arabica,* and *Anarrhinum pubescence.* The second group comprises eight species including *Ballota undulata, Alkanna orientalis, Teucrium polium, Tanacetum santolinoides, Artemisia herba-alba*, and *Stachys aegyptiaca*. The third group contains only four species; *Galium sinaicum, Achillea fragrantissma, Origanum syriacum*, and *Echinops glaberrimus*. The last (fourth) group also comprised upof four species; *Ballota saxatilis, Ballota kaiseri, Nepeta septemcrenata*, and *Ficus palmata*.

3- Compositional gradients

When all the recorded 66 species were used in ordination, a very noisy and unreadable output result was obtained in which most of the species are clumped in the central part of the diagram and few rare species are located at the edge. Thus, rare species were excluded in order to mitigate noise and summarize redundancy (Gauch, 1982). In the first trial, very rare species whose overall densities were less than 0.01 were excluded (24 = 36%), but the output got was still noisy and unreadable. In the second trial, very rare species whose overall densities were less than 0.02 were excluded (37 = 56%), the output was less noisy and somewhat readable. To have more effective display of the ordination analysis, the five environmental factors showed non-significant variation between TWINSPAN groups (gravel %, saturation %, EC, slope degree, and exposure degree) were excluded from CCA analysis. The result is more readable ordination diagrams (Fig. 2 & 3).

Fig. 2. Ordination (CCA) diagram (axis1-axis2 plane) with plant species represented as + and environmental variables as centriod lines.

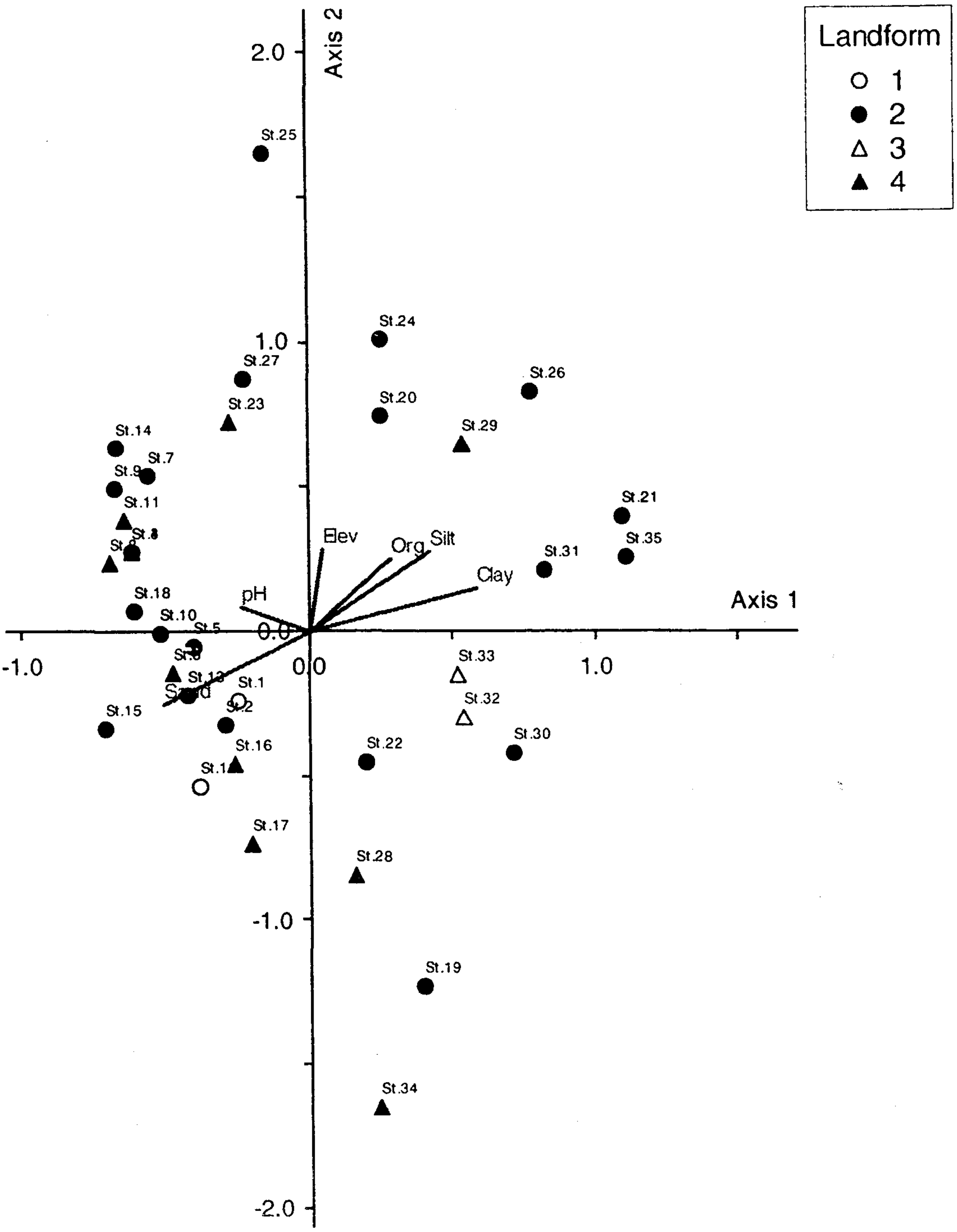

Fig. 3. **Ordination (CCA) diagram (axis1-axis 2 plane) with stands represented with different sympols according to landform and environmental variables as centriod lines.**

Eigenvalues and species-environment correlation coefficients for the three axes for all ordinations were carried out and are shown in Table 4. The eigenvalue represents the variance in the community matrix that is attributed to a particular axis. The Pearson species-environment correlation is a standard correlation coefficient between sample scores for an axis derived from the species data (the WA scores) and the sample scores that are linear combinations of the environmental variables (the

LC scores) and it is a measure of how well the extracted variation in community composition can be explained by the environmental variables (McCune & Mefford, 1999 and Ter Braak, 1986). The significance of the eigenvalue and species-environment correlation coefficient for the three axes was tested by Monte Carlo permutation test. The total variance (or "inertia" in the terminology of ter Braak, 1990) in the species data is a statement of the total variability in the community matrix that could potentially be "explained".

TABLE 4. Comparison of the axes summary statistics resulted from ordination of (A) all species with all the eleven factors, (B) species with density > 0.01 with all the eleven factors, (C) species with density > 0.02 with all the eleven factors, and (D) species with density > 0.02 with the six TWINSPAN significant factors.

Ordination	Eigenvalue			% of variance explained			Cumulative % of variance explained			Pearson Correlation, Spp-Envt‡		
	X1	X2	X3	X1	X2	X3	X1	X2	X3	X1	X2	X3
A	0.497	0.438	0.410*	7.9	7.0	6.5	7.9	14.9	21.4	0.950	0.896	0.903
B	0.475	0.436	0.400*	8.2	7.5	6.9	8.2	15.7	22.6	0.934	0.892	0.898
C	0.475	0.436	0.392*	8.9	8.2	7.4	8.9	17.1	24.5	0.919	0.882	0.883
D	0.393	0.333	0.318*	7.4	6.3	6.0	7.4	13.6	19.6	0.878	0.747	0.849*

‡Correlation between sample scores for an axis derived from the species data and the sample scores that are linear combinations of the environmental variables. * Significant ($P \leq 0.05$) value based on Monte Carlo permutation test.

Species – Environment relationship

In the ordination diagram (Fig. 2), six environmental factors (organic matter content, sand, silt, and clay fractions, soil pH, and elevation) are represented as vectors and twenty-nine species as pluses (+). According to the TWINSPAN classification, the species are grouped into four groups. The first one includes *Fagonia mollis*, *Buffonia multiceps*, *Matthiola arabica*, and *Anarrhinum pubescence*, and occupies the central position in axes 1 & 2 plane and axes 1 & 3 plane, while it is V-shaped occurs almost in the left half of the diagram in axes 2 & 3 plane. This group is most significantly and positively affected by the sand fraction, and negatively by elevation, pH, and silt fraction. The second group, which includes *Ballota undulata*, also occupies a central position along axis 1 and axis 3. This group is most affected positively by elevation and negatively by soil reaction (pH). The third group comprises of four species; *Galium siniacum*, *Achillea fragrantissima*, *Origanum syriacum*, and *Echinops glaberrimus*, and is located at the upper left corner of both axes 1 & 2 and axes 1 & 3 planes, and in the upper right corner of axes 2 & 3 plane. This group is affected positively by soil reaction (pH) and negatively by elevation. The fourth group also comprised of four species; *Ballota saxatilis*, *Ballota kaiseri*, *Nepeta septemcrenata*, and *Ficus palmate*. This group is located along the first and third axis at the edge of axis 2 and mostly affected by elevation, clay fraction, silt fraction, and organic matter positively, and by sand fraction negatively.

Finally, if one can consider the *Ballota* species as standing by itself in the ordination without considering the group in which it occurs, we can conclude that

Ballota saxatilis and *Ballota kaiseri* are significantly and positively affected by soil reaction and elevation, while *Ballota undulata* is mostly affected by soil reaction and sand fraction. The remaining edaphic factors have little effect on them either positively or negatively.

Stands – Environment relationship

The 35 stands were classified by TWINSPAN technique at the second level into four vegetation groups. The ordination diagram (Fig. 3) shows the position of these vegetation groups and their interrelation with environmental factors. The first vegetation group (*Ballota undulata*) occurs along axis 1 and axis 2 and so it occupies the lower left-hand corner in axes 1 & 2 plane of the diagram. This vegetation group is mostly affected by soil sand fraction positively and elevation, soil organic matter content, and silt & clay fractions negatively. *Teucrium polium – Phlomis aurea* is the second vegetation group and is located at the central part of both axis 1 and axis 2, and along the lower (-ve) part of axis 3. This vegetation group is most affected positively by elevation gradient and negatively by soil reaction (pH). *Galium sinaicum* vegetation group (III) is separated along axis 1 and axis 3, and is found at the upper half of axis 3 at the corner between axis 2 and axis 3. This vegetation group is most positively affected by soil reaction (pH) and silt fraction, and negatively by soil sand fraction.

Vegetation group IV (*Nepeta septemcrenata–Origanum syriacum*) is separated along axis 2 at the lower (-ve) part of axis 3 and right (+ve) part of axis 1, and it stands in the lower right-hand corner of axes 1 & 3 plane. This vegetation group is affected mostly by elevation and soil clay fraction, positively, and soil reaction (pH), negatively.

Environmental variables and ordination axes

CCA generates two sets of sites scores: (1) the WA scores obtained by weighting averages of the species scores and (2) the LC scores obtained by regressing the WA scores on the environmental variables then calculating fitted values from the regression equation. ter Braak (1986) calls correlations of environmental variables with the WA scores the "interest correlations" and correlations with the LC scores "intraset correlations". For consistency in interpretation, it is reasonable to use the intraset correlations if the LC scores were used as the final scores (our case), and to use the intraset correlations if the WA scores were used as the final scores (McCune and Mefford, 1999).

The intraset correlation between environmental variables and the ordination axes was assessed (Table 5) to interpret the ordination axes. From intraset correlation, one can notice that soil clay and silt fractions are the most correlated factors with the first axis, while elevation gradient and soil silt fraction are the most correlated with second axis. Soil reaction (pH) and silt fraction are the most correlated factors with the third axis. In other words, soil silt fraction is the second most correlated factors with the three axes.

TABLE 5. Intraset correlations of environmental factors with the ordination axes.

Variable	Correlations		
	Axis 1	Axis 2	Axis 3
Organic matter content	0.453	0.434	0.029
pH	-0.377	0.141	0.489
Clay %	0.924	0.253	-0.256
Silt %	0.668	0.478	0.171
Sand %	-0.807	-0.437	-0.037
Elevation	0.074	0.491	-0.792

Discussion

Species must ultimately exist in natural settings, within functioning communities and ecosystems, interacting with other species and the abiotic environment. Therefore, conservation efforts must also focus on species interactions and the systems within which these interactions occur (Meffe and Carrol, 1994). So, the protection of ecosystems is the easiest, safest, most natural and economic way to protect individual species of plants, and should therefore be considered as the definitive form of defensive action (Anonymous, 1973 and Greuter, 1979). Conservation of plants within their natural ecosystems falls within the framework of conservation of the ecosystems themselves. Fundamental to the conservation of ecosystems is the maintenance of their definitive physical and biological conditions. One of the first priorities is to begin a careful study of the conditions existing in the ecosystem. In short, the autoecology of each taxon of interest should be sufficiently known to deal with its conservation under optimal conditions (Ruiz de la Torre, 1985).

In the ongoing multi-pronged efforts to halt species extinction and to promote conservation, evaluation, and sustainable use of plant natural resources in the St. Catherine Protectorate, this study was carried out to understand the behavior of three threatened species of *Ballota* in their natural habitats.

Although El-Husseiny (1989) recorded four *Ballota* species (*B. damascene, B. undulata, B. saxatilis,* and *B. kaiseri*) based on herbarium specimens collected from the Sinai in the period from 1928 to 1959 for *B. undulata*, from 1877 to 1944 for *B. damascene*, from 1924 to 1981 for *B. saxatilis*, and in 1926 for *B. kaiseri*, only three species (*B. undulata, B. saxatilis,* and *B. kaiseri*) were recorded in this study as well as other ecological and floristic studies done in the area in the last 2 decads. These three species are threatened by human impact through unmanaged severe grazing by goats and sheep.

Ballota species are grazed in the spring when it has new soft green branches and before it is capable of producing reproductive organs. The effect of grazing is aggravated by the general aridity prevailing in the area where the rainfall is below 50mm on average (Zaghloul, 1997). While the drought itself has effects on sparse vegetation in arid and extremely arid ecosystems, it also aggravates any other threat especially human-induced ones. The natural enemies of *Ballota* include mice and pest insects. Mice have been noticed during field visits to cut ripe seed-bearing (ready to be shed) branches. They collect these dry branches in any cave-like space under the nearest rock and start to open the dried capsule-like calyx (tubular campanulate) through pressing on the base and pushing out the seed and then eating it. Since the seeds are tiny (≅1*2 mm), the whole seed set on one plant may not be satisfactory as a daily diet for the mouse and it may search for a supplementary meal, perhaps another *Ballota* plant.

Insect samples have been collected from calyx and identified by Dr. Allen L. Norrbom, Department of Entomology, Smithsonian Institution as a fruit fly (*Katonaia aida* Hering). This insect was previously reared from *Ballota saxatilis* C. Presland *B. undulata* (Fresen.) Benth. from the area (Freidberg & Kugler, 1989). About 70 species of fruit flies are considered important agricultural pests, and many others are minor or potential pests (White & Elson-Harris, 1992).

The impact of abiotic and biotic threats was reflected in the rareness of *B. undulata* and extremely rareness and limited distribution of both *B. kaiseri* and *B. saxatilis*. This distribution was well pronounced in this study that although *Ballota* have been targeted and its presence was the main factor in choosing the study stands, *B. kaiseri* and *B. saxatilis* were represented only as associated species in the *Galium sinaicum* vegetation group with 57.14% and 71.43% presence, respectively, while *B. undulata* was recorded as an associating species in the *Teucrium polium – Phlomis aurea* (77.78%), *Nepeta septemcrenata – Origanum syriacum* (75%) and *Galium sinaicum* (71.43%) vegetation groups beside its own vegetation group (I) where it is the dominant species.

Any endemic plant species may be threatened by its limited distribution, as local catastrophes can destroy large portions of its total population (Menges, 1991). Danin (1986) stated that *Ballota kaiseri* is a rare endemic species restricted to crevices in outcrops of smooth-faced granite, to elongated gaps, and to narrow ravines in such rocky terrain. *B. saxatilis* has a discontinuous distribution and may be recorded as a relict of Mediterranean origin. *B. undulata* is also Mediterranean but has a more continuous distribution in a wider range of relatively wet microhabitats.

Based on CCA, the present study revealed, that *Ballota* species distribution is affected positively by elevation. While *B. undulata* prefer lower pH values (-ve relation), *B. kaiseri* and *B. saxatilis* share the same microhabitats favoring high soil clay and silt percent and organic matter content and consequently low sand percent (-ve relation) which means a low pH also and high soil moisture content. In fact, the distribution of species is determined by the integrated influence of these environmental factors rather than by their independent effects (Gorham, 1954; Waring & Major, 1964; Went, 1948 and Whittaker, 1975). This result is in agreement with the achivements recorded by many other researchers (Ayyad *et al.*, 2000; Moustafa, 2002 and Moustafa & Zaghloul, 1993; 1996).

The effect of moisture regime on the distribution of plants in arid ecosystems has been emphasized by many studies very long ago (Ayyad & Dix, 1964; Marks & Harcombe, 1981; Noy-Meir, 1973 and Whittaker & Neiring, 1965). Moisture is the most decisive factor controlling life-form in arid lands (Danin & Orshan, 1990; Kassas & Girgis, 1965 and Zohary, 1973), therefore chamaephytes represented the most common (56.6%) life-form in this study followed by hemicryptophytes (27.4%) and therophytes (8.1%), although the latter was underestimated in this study as the field work was not carried out in the favorable season.

The precipitation type, intensity and annual variation, soil deposits, topography (especially micro-), and vegetation physiognomy influence the availability of moisture furnished by precipitation to the plants (e.g. Ayyad & Ammar, 1974; El-Sharkawi & Ramadan, 1984; Kassas & Batanouny, 1984 and Kassas & Imam, 1954). The effect of slope degree lies in the fact that more gentle slopes have lower run-off rates and more adequate moisture availability to plants cover. The effect of nature and roughness of soil surface on moisture availability is related to its water holding capacity, which depends not only on the volume of water resources, but also on the depth of surface deposits; the shallower the deposits the lower the capacity for moisture storage (Hillel & Tadmor, 1962). Moisture availability also increases with increasing coarseness of surface cover that besides the natural stony mulch on slopes retards run-off, it prevents the formation of continuous crust and slows the rate of evaporation (Hillel & Tadmor, 1962). Geomorphological studies in arid areas indicated that coarse-grained surface material provides maximum soil water penetration and minimum runoff (Yair & Klein, 1973). Also the spatial distribution of soil moisture had been demonstrated to be controlled by surface properties of rock and soil as main factors (Olsvig-Whittaker *et al.*, 1983 and Yair *et al.*, 1980). Soil texture is one of the most important factors affecting moisture availability and subsequently the distribution of plants in arid lands. Sandy and gravelly soils usually have more favorable moisture conditions and support denser and taller vegetation than silty and clayey soils (Hillel & Tadmor, 1962 and Noy-Meir, 1973).

Elevation as a physical factor affects the amount of precipitation, which increases with elevation in a linear relation (Lull & Ellison, 1950). There is also an inverse relation between elevation and temperature gradient or lapse rate, whereby there is usually a decrease of about 6.5° C/1000m elevation (Lowry, 1969). Ecological conditions differ on the opposing north and south facing slopes due to differences in solar radiation (e.g. Barbour *et al.*, 1987; Daubenmire, 1959; Whittaker, 1960 and Whittaker & Niering, 1965).

This study has revealed that sites supporting *Ballota* species have sixty-two species belonging to twenty-six families, nineteen of them (73%) are represented by only one species. Most of these recorded species (56%) could be considered as extremely rare having a density lower than 0.02, which means that sites supporting *Ballota* species are supporting rare and threatened species in general, and consequently a proper conservation plan for *Ballota* species would probably include other threatened species. Endemic species represent 14.5% (9 species), 55.6% of them (5 species) belonging to the Labiatae. This reflects the particular taxonomic profile of the area where endemic species are unequally divided among plant families and are over-represented among the Labiatae (Ayyad *et al.*, 2000).

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التوزيع المحلى لثلاثة أنواع مهددة من جنس الغصة (*Ballota*) فى محمية سانت كاترين، جنوب سيناء، مصر

محمد سعد زغلول عبده عبدربه[1] ، عبدالرؤوف عبدالرحمن مصطفى[1] ، وفاء محمد كامل[1] ، جيمس لويس هامريك[2] ورفيق الغريب محمود[3]
[1]قسم النبات – كلية العلوم – جامعة قناة السويس – الاسماعيلية – مصر ، [2]قسم بيولوجية النبات – جامعة چورچيا– الولايات المتحدة الأمريكية و[3]قسم النبات – كلية العلوم – جامعة الإسكندرية – الإسكندرية – مصر.

يتعرض جنس نبات البالوتا *Ballota* بأنواعه الثلاثة : الغصة *B. udulata* والشيرما *B. kaiseri* (نبات متوطن) والمسيسة *B. saxatilis* النامية فى محمية سانت كاترين بمنطقة جنوب سيناء لضغوط عديدة أدت الى إنخفاض عدد وحجم عشائر هذا الجنس الى درجة تهدده بالإنقراض. تشمل هذه الضغوط الجفاف والسيول والأعداء الطبيعية (الفئران والحشرات) والضغوط البشرية والتى تشمل الرعى والتقطيع الجائرين.

فى هذه الدراسة تم إختيار خمسة وثلاثون موقعاً لدراسة التوزيع الطبيعى لهذه الأنواع والتى تغطى معظم الإختلافات البيئية المصاحبة لإنتشار عشائر جنس البالوتا. فى كل موقع تم قياس العوامل البيئية المختلفة المميزة للموقع والتى أشتملت على الإرتفاع عن سطح البحر elevation ودرجة الإنحدار slope والتعرض exposure وتضاريس الأرض landform بالإضافة إلى خصائص التربة. تم تحليل هذه البيانات إحصائياً وبواسطة التحاليل متعددة المتغيرات multivariate analysis والتى شملت التوينسبان TWINSPN والكانوكو CANOCO والتى ساعدت فى توضيح العوامل البيئية المؤثرة فى توزيع الأنواع الثلاثة من البالوتا المعنية بالدراسة.

أوضحت الدراسة أن نبات الغصة *B. undulata* يتواجد فى مجتمع قائم بذاته (مجتمع الغصة) بجانب وجوده كنبات مصاحب فى مجتمع الجعدة – العورور *Teucrium polium – Phlomis aurea* بنسبة تواجد ٧٥٪ ومجتمع *Galium sinaicum* بنسبة تواجد ٧١,٤٪ ، بينما تتواجد نباتات الشيرما *B. kaiseri* والمسيسة *B. saxatilis* كنباتات مصاحبة لمجتمع البسيسة *Galium siniacum* بنسبة تواجد ٥٧,١٪ و ٧١,٤٪ فقط . أيضا أوضحت هذه التحاليل أن نباتات البالوتا تتواجد فى ظروف بيئية محدودة ويتأثر تواجدها إيجابياً بالإرتفاع عن سطح البحر elevation.