Forbs in Lawns of Three University Campuses in Halifax Regional Municipality

by

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This is dedicated to my dad.

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List of Abbreviations

Campuses

DAL: Dalhousie University
MSVU: Mount Saint Vincent University
SMU: Saint Mary's University

Other

ANOSIM: Analysis of Similarities
BIOENV: Biotic-Environmental matching
Ca: Calcium
EC: Electrical Conductivity
HRM: Halifax Regional Municipality
K: Potassium
MDS: Multi-Dimensional Scaling
Mg: Magnesium
P: Phosphorus
U.K.: United Kingdom

ABSTRACT

A ban on the cosmetic use of herbicides and pesticides on turf and gardens in Halifax Regional Municipality (HRM), except on commercial properties, was implemented in 2003. There has been little formal research on forbs (non graminoid, non-woody angiosperms) in the temperate zone turfs of North America, other than on certain problematical weeds, so how the forb composition will change is largely unknown. It is expected that an increase in overall abundance and number of species on turfs previously treated with herbicide will occur. This study, conducted on 3 university campuses in HRM addresses two questions: (i) are there distinct groupings of forb species in lawns of the three campuses? and (ii) can differences in species composition and distribution of individual species be related to environmental and/or management variables? Three campuses (Mount Saint Vincent University, Saint Mary's University, and Dalhousie Univeristy) were chosen for study because each presents a range of site conditions (e.g. shaded/unshaded, shallow/deep soils, disturbed/undisturbed) under a single management regime but the regimes and history of herbicide use differ between campuses. Seventeen sites (discrete turf areas), selected for different degrees of shading, disturbance, and position (edge or contiguous turf) were examined on each campus. Primer E, non-metric multivariate statistical procedures were used to examine the data for species groupings and for the relationship of species composition at different sites to environmental factors. Sites at edges of turfs were characterized by 3 species at which occurred exclusively or predominantly at these sites. Differences between other (contiguous) sites were associated mainly with differences in abundance of globally common species. Multidimensional scaling analysis (MDS) revealed different patterns in the distribution of individual species across sites, but these were not strongly related to the environmental factors examined.

The data permitted a test of the proposal of Tilman et al. (1999) that dandelion (*Taraxacum officinale*) abundance is determined by resource supply rates, in particular by potassium (K) and calcium (Ca). However, there was no correlation between dandelion and soil K or soil Ca.

Acknowledgements

Throughout this project, Dr. David Patriquin has been both a wealth of knowledge and a pillar of support. This year has had many ups and downs, but throughout it all his consistency and drive has been a guide for me to keep focused and enjoy the little things that may pop up...even on the sides of the road! It was a privilege to work and learn from him.

INTRODUCTION

Conventional management of turfs (lawns, playing field, recreational fields, golf courses) involves use of herbicides and other pesticides. The Halifax Regional Municipality (HRM) was the first city in Canada to implement a ban on the cosmetic use of pesticides on turf and gardens, except on commercial properties. The full ban came into effect in 2003. A large increase in abundance and number of forb species on turfs previously treated with herbicide is anticipated. (Forbs are non grassy herbaceous species: Allaby, 1994).

To date, there has been limited research on the botanical composition of turfs maintained without the use of herbicides (Thompson et al., 2004). Papers by Warwick (1980) and Warwick and Briggs (1979; 1980 a,b,c) dealt with the genecology of individual species in U.K lawns. Papers by Wilson and colleagues (1994) used New Zealand lawns to study community assembly rules. Two recent papers are particular relevant to the present study. Thompson et al. (2004) studied the botanical composition of 52 lawns in the region of Sheffield U.K. The species accumulation curves were intermediate between those for semi-natural grasslands on limestone and those on acid soils and lawn species were significantly nested as in semi-natural grasslands. Lawn area was a determinant of species diversity; other local factors such as mowing frequency seemed to have little influence on lawn diversity. They concluded:

> "...lawns are a zone of considerable tension between the desire of gardeners to control the composition of their gardens and the natural processes of colonization and succession. Many species in lawns, and all the abundant ones are typical

> 'lawn' species, well-adapted to frequent mowing by virtue of a creeping habit, basal leaves or basal meristems. Nevertheless, lawns contain an abundance of 'transients', including tall herbs, trees and shrubs, which could rapidly transform the appearance and biomass of the typical lawn if management were relaxed."

Tilman et al. (1999) examined the possibility for controlling an 'undesired plant species', dandelion (*Taraxacum officianale*), by manipulating resource supply rates. Data from the 140 year old Park Grass experiment at Rothamsted suggested that potassium and lime fertilization controlled dandelion abundance at that site. Other data from greenhouse experiments and observations of dandelion and its leaf tissue potassium content in Minnesota lawns suggested a critical role of potassium, with dandelion having a higher potassium requirement than 5 co-occurring grasses. They suggested that use of potassium free fertilizers would keep dandelion out of lawns that occur on low potassium soils.

The purpose of my study was to examine sites in HRM where herbicides have not been used for some time in order to gain an understanding of how botanical composition could be expected to develop after cessation of herbicide use more generally. Three campuses in HRM were selected: Mount Saint Vincent University (MSVU), St. Mary's University (SMU), and Dalhousie University (DAL) where herbicides have not been used for 5, 10, and 15 years respectively. Campuses rather than residential lawns were selected because management was uniform across an individual campus, and each campus provided a variety of site situations associated with differing degrees of shading and disturbance.

Two specific questions were addressed:

(i) Are there distinct groupings of forb species in lawns of the three campuses?

(ii) Can differences in species composition and distribution of individual species be related to environmental and/or management variables?

The forbs alone were examined rather than forbs plus grasses because I was interested in how lawn communities might change after cessation of use of herbicides (which kill forbs but not grasses). Also, except for 1 or 2 species, grass species are not readily identified in mowed lawns.

The terminology for describing plant communities is confused (Gurevitch et al., 2002). In this thesis, the term 'group' is used to talk about sets of co-occurring forbs.

METHODS

Observations were conducted at three university campuses in Halifax, Nova Scotia in 2003. Observations at Dalhousie University were conducted July 5-13, Saint Mary's University July 18-26, and Mount Saint Vincent University July 30-August 14.

Site selection

Seventeen sites on each campus were selected so that approximately the same proportions of disturbed and undisturbed sites, different degrees of shading, and contiguous versus edge sites were represented (Appendix 1). Criteria for classifying sites were as follows:

Exposure to sun was classified as one of the following five categories:

- Open: no shade.
- Morning sun: within seven paces of east side of building (4-10 storeys) or tree line.
- Afternoon sun: within five paces of west side of four storey building or eight paces from the north side of a 4 storey building.
- North: on the north side of a building (max four storey) or tree line.
- Treed: directly under trees, mostly deciduous.

Position: sites were classified as edge or contiguous. Edge sites bordered on a path, road or trail. Contiguous sites were at least three meters from an edge; the precise placement was selected to be in the middle, halfway between an edge and a building.

Disturbance: a site with obvious signs of foot traffic or severe shearing by a mower was classified as disturbed.

Quadrat sampling of forbs

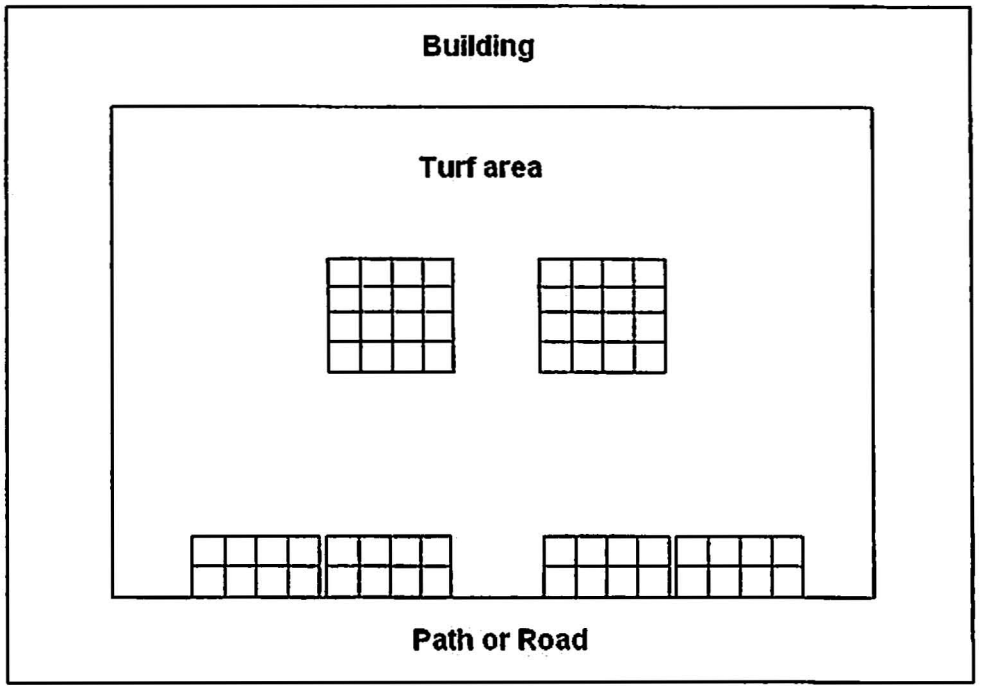
At each contiguous site, a 50 x 50 cm quadrat was placed in the centre of the designated area without reference to species occurrence. A second quadrat was placed three paces to the left or right of the quadrat (randomly choosing left or right) and parallel to the long axis of the turf area (Fig. 1).

At edge sites, two quadrats were placed side by side at the edge; another two were placed side by side at the edge three paces to the right or left of the first set (Fig. 1). Only the halves of these quadrats closest to the edge were used in observations.

The 50 x 50 cm quadrat was subdivided with string or wire into sixteen 12.5 x 12.5 cm squares. For each quadrat, presence or absence of forb species was noted for each square. At edge sites only the eight squares closest to the edge were observed, however the total number of squares observed at each site was the same as the number examined for contiguous sites, i.e. 32 squares. Nomenclature of forb species is that in the Flora of Nova Scotia (Roland & Smith, 1969).

Three megapixel photographs were taken of each area with a digital camera.

Figure 1. Diagram of quadrat placement.


Building
Turf area
Path or Road

Environmental and other observations

At each site, the following observations were made concurrently with quadrat sampling:

Slope was measured with a Silva Ranger Type 15 compass using the clinometer function.

Thatch thickness was measured in millimeters with a ruler at a representative position.

Soil depth and penetrability were measured on September 6 and 7 following 2 days of rain (approximately 70 mm total). Quadrats were placed in their original positions based on notes and photographs. Soil depth was measured by inserting a stiff cylindrical metal probe (3mm diameter) into 5 randomly assigned squares of the quadrat and measuring the depth of penetration. Penetrability (compaction) was measured by using a Soil Test CL-700 pocket penetrometer.

Soil sampling was conducted on October 4 and 5. At each site approximately 750 mL of soil were collected using a standard soil corer (2 cm internal diameter), for tougher soils a toothed corer (24 mm internal diameter). The cores were taken from the same areas in which the quadrats had been placed. A minimum of 5 separate cores were taken from each site.

Soil samples were stored at 5 °C for two weeks then spread out on plastic sheets for rapid air drying. Soil was passed through a 2 mm sieve to remove coarser material.

For measuring pH and EC (electrical conductivity), 50 grams of soil were placed into 125 mL flasks; 50 mL distilled water were added; flasks covered with parafilm, and shaken on a New Brunswick G-24 shaker at 400 rpm for 15 minutes. The parafilm was removed and samples were allowed to stand for 10 minutes with brief agitation to aid equilibration with the atmosphere.

pH was measured with a Fisher Acumet 13-620-97 combination electrode and a Corning Model 610A pH meter, calibrated with pH 7 and pH 4 buffers. After the EC measurement, 1 mL of 0.5 M $CaCl_2$ solution was added and the sample again shaken as above and pH measured again. The electrode was placed just above the sediment.

Electrical conductivity was measured with a Hanna Instruments HI 9033 Multi-range conductivity meter; calibrated with a 1338 µS/cm NaCl solution (0.01M NaCl). The electrode was placed just above the sediment.

Soil texture was determined by the 'texture by feel' method (Brady & Weil, 2002). A sample of soil was moistened with distilled water and kneaded to a putty-like consistency. Several cohesion and malleability tests were performed and the soil classified as one of these categories: sand, loamy sand, sandy loam, silt loam, loam, sandy clay loam, silty

clay loam, sandy clay, and silty clay. These categories were then ranked 1 to 9 according the heaviness (Appendix 2).

Soil darkness was used as a proxy for soil organic matter, the assumption being the darker soil the higher the organic content. Small amounts of soil were placed in 9 cm diameter petri dishes and wetted. Plates were sorted according to darkness and a ranking assigned from 1(darkest), to 51(lightest). Fifteen soil samples were analyzed for organic matter. There was a high correlation between ranking of soil darkness and soil organic matter (Appendix 3).

Fifteen soils were sent to A & L Canada Laboratories Inc. in London, Ontario for standard soil analyses (organic matter, pH, Ca, Mg, K, P). These soils were selected to include 5 levels of darkness with each campus represented once at each level. The soil data are in Appendix 4.

Management information

Employees responsible for maintaining the grounds on each campus were interviewed after the sampling process to determine information such as time since last disturbance and last pesticide application. General information such as age, as well as maintenance practices like mowing heights, periods between mowing, and watering practices were also provided. Mowing heights were confirmed by visiting campuses after they were mowed and recording grass height in centimeters with a ruler (Appendix 5).

Statistical analyses

For each site, frequency values were calculated for the 2 quadrats combined; i.e. number of occurrences of a species in 32 squares. These values were converted to percentages.

Statistical analyses were carried out using PRIMER v5 multivariate software. Rare species that occurred on 2 or fewer sites were removed as advised by Clarke and Warwick (2001).

Non-metric multidimensional scaling (MDS) of sites and species was carried out by constructing a similarity matrix using Bray-Curtis similarity and a square root transformation, followed by performing the MDS analysis with 20 iterations.

Cluster analysis of species was performed on the same similarity matrix using the group average cluster mode and plotted dendrogram.

The ANOSIM procedure was employed using one way design and a maximum of 999 permutations to investigate the significance of the site selection variables.

The BIOENV procedure was carried out to link biotic and other data (pH, depth, etc.). This procedure constructs a large number of (dis)similarity matrices [using normalized Euclidean distances and log (x+1) transformation of the data] for each of the possible

combinations of the specified environmental variables and provides a Spearman rank correlation coefficient relating these matrices with the similarity matrix for sites based on species data (constructed using Bray-Curtis similarities as above).

RESULTS

Seventeen sites were examined on each campus, including 3 edge sites and 14 contiguous sites. There were 3, 5, and 4 treed sites and 9, 7, and 8 open sites (no shade) at MSVU, SMU, and DAL respectively; others received sun only part of the day. The number of sites classified as disturbed was 8, 9, and 6 for MSVU, SMU, and DAL respectively.

A total of 30 forb species were observed for the 51 sites and 102 quadrats, including 27, 16, and 20 species at MSVU, SMU, and DAL respectively (Table 1). Fourteen species were found on all 3 campuses. Eight species were found only at MSVU, 1 only at SMU, and 1 only at DAL.

For the multivariate analyses, species that occurred at only 2 or fewer sites (4% or fewer) were excluded, following the suggestion of Clarke and Warwick (2001) to exclude rarer species. (In their example on page 7-1, they retained only species that accounted for more than 4% total abundance.)

Species clustering and MDS

At a similarity of around 12.5%, the cluster analysis dendrogram (Fig. 2) separates 3 groups. One of these includes a single species (*R. acetosella*). One of the other 2 groups includes species that occurred exclusively (*S. rubra*) or predominantly (*G. uliginosum, M. Matricariodes)* at edge sites (Table 2) from the other species. The third group includes the remaining 16 species.

Table 1. Forb species and their occurrence on the 3 campuses. Species are listed in order of decreasing number of sites at which they were present

Species	No. sites total	No. sites DAL	No. sites SMU	No. sites MSVU
Taraxacum officinale Weber	46	16	14	16
Trifolium repens L.	36	14	14	9
Cerestium vulgatum L.	32	11	8	13
Plantago major L.	27	9	13	5
Veronica Serpyllifolia L.	26	9	6	11
Prunella vulgaris L.	22	13	3	5
Leontodon autumnalis L.	21	8	7	7
Stellaria graminea L.	19	5	2	8
Medicago lupulina L.	15	2	8	9
Polygonum aviculare L.	14	4	7	3
Ranunculus repens L.	12	2	8	2
Hieracium pilosella L.	11	5	1	5
Oxalis stricta L.	10	1	1	8
Achillea millefolium L.	10	7	0	3
Matricaria matricariodes (Less.) Porter	8	2	5	1
Fragaria virginiana Duchesne	6	3	0	3
Veronica officinalis L.	6	0	0	6
Gnaphalium uliginosum L.	4	2	2	0
Rumex acetosella L.	3	2	0	1
Spurgularia rubra (L.) J. & C. Presl.	3	2	0	1
Sonchus oleraceus L.	2	0	0	2
Hieracium caespitosum Dumort.	2	0	0	2
Trifolium procumbens L.	2	0	0	2
Stellaria media (L.) Vill.	1	0	1	0
Equisetum arvense L.	1	0	0	1
Euphrasia americana Wettst	1	0	0	1
Galeopsis tetrahit (L.)	1	0	0	1
Sonchus asper (L.) Hill.	1	0	0	1
Coronopus didymus (L.) Sm.	1	0	0	1
Potentilla spp.	1	1	0	0

Figure 2. Cluster analysis dendrogram for species.

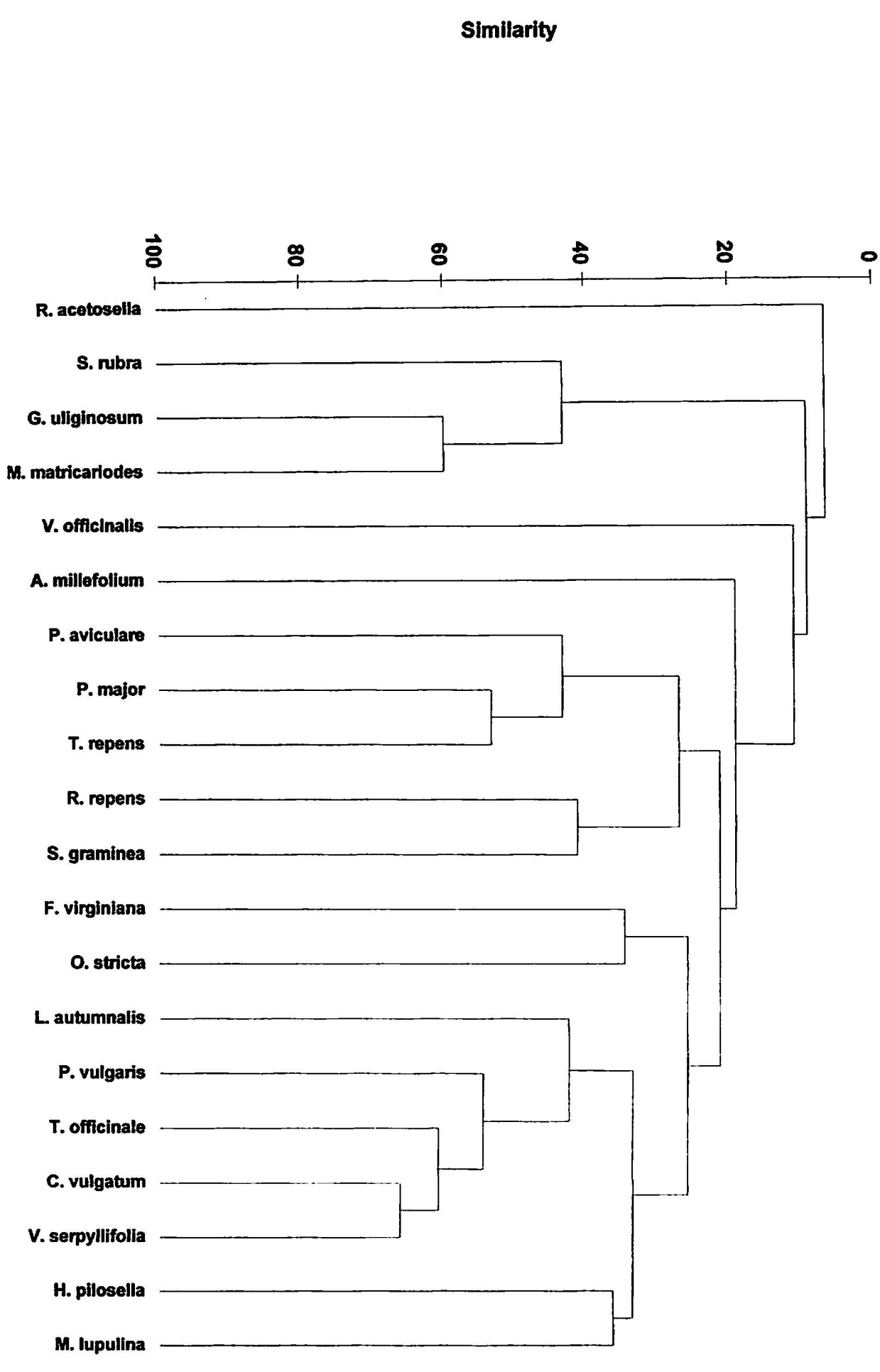

Similarity
100
80
60
40
20
0
R. acetosella
S. rubra
G. uliginosum
M. matricariodes
V. officinalis
A. millefolium
P. aviculare
P. major
T. repens
R. repens
S. graminea
F. virginiana
O. stricta
L. autumnalis
P. vulgaris
T. officinale
C. vulgatum
V. serpyllifolia
H. pilosella
M. lupulina

Table 2. Species at edge sites.

Species at edge sites	No. edge sites n=7	MSVU edge undist. & shade n=1	MSVU edge shade n=1	No. contiguous sites n=42
P. aviculare	7	0	0	7
P. major	7	1	1	18
T. repens	7	0	0	29
M. matricariodes	6	0	0	2
T. officinale	6	1	1	38
G. uliginosum	3	0	0	1
L. autumnalis	3	0	1	17
S. rubra	3	0	0	0
M. lupulina	2	0	1	12
A. millefolium	1	0	0	9
C. vulgatum	1	1	1	29
F. virginiana	1	1	0	4
H. pilosella	1	0	1	9
V. serpyllifolia	1	1	1	23
O. stricta	0	1	1	8
P. vulgaris	0	1	1	20
V. officinalis	0	1	0	5

At a similarity of around 23%, 6 groups are separated, including 3 with only one species. These groups are also separated well by MDS (Fig. 3). The stress value of the MDS was 0.16 for 2 dimensions, and 0.09 for 3 dimensions. The 3 multispecies groups are labeled A (Edge), B (*T. repens* and others) and C (*H. pilosella* and others) for subsequent reference. A stress value of 0.16 provides a useful representation of the multivariate data (Table 3).

MDS ordination of sites

Two-dimensional MDS ordination of sites (Fig. 4) has a stress value of 0.20, the 3-dimensional MDS ordination has a stress value of 0.14.

In Fig. 5, envelopes indicate the boundaries for presence of all species in each of the 3 multispecies groups from Figs. 2 and 3. Group B enclosed group A, and overlapped partially with group C, while there is about 50% overlap between groups A and C.

Plots of individual species abundances on sites show a spectrum of distributions, (Figs. 6-8; Appendix 6). Some species are widely distributed across sites (e.g. *Taraxacum officinale*, Fig. 6), others occur only at a portion and are restricted to 1 region of the MDS ordination.

Figure 3. MDS ordination of the 20 species based on √-transformed frequencies and Bray-Curtis similarities. Envelopes enclose species groups distinguished at a similarity level of 23.5% on the cluster analysis dendrogram (Fig. 2). A, B, and C are the multispecies groups.

MDS ***Species***

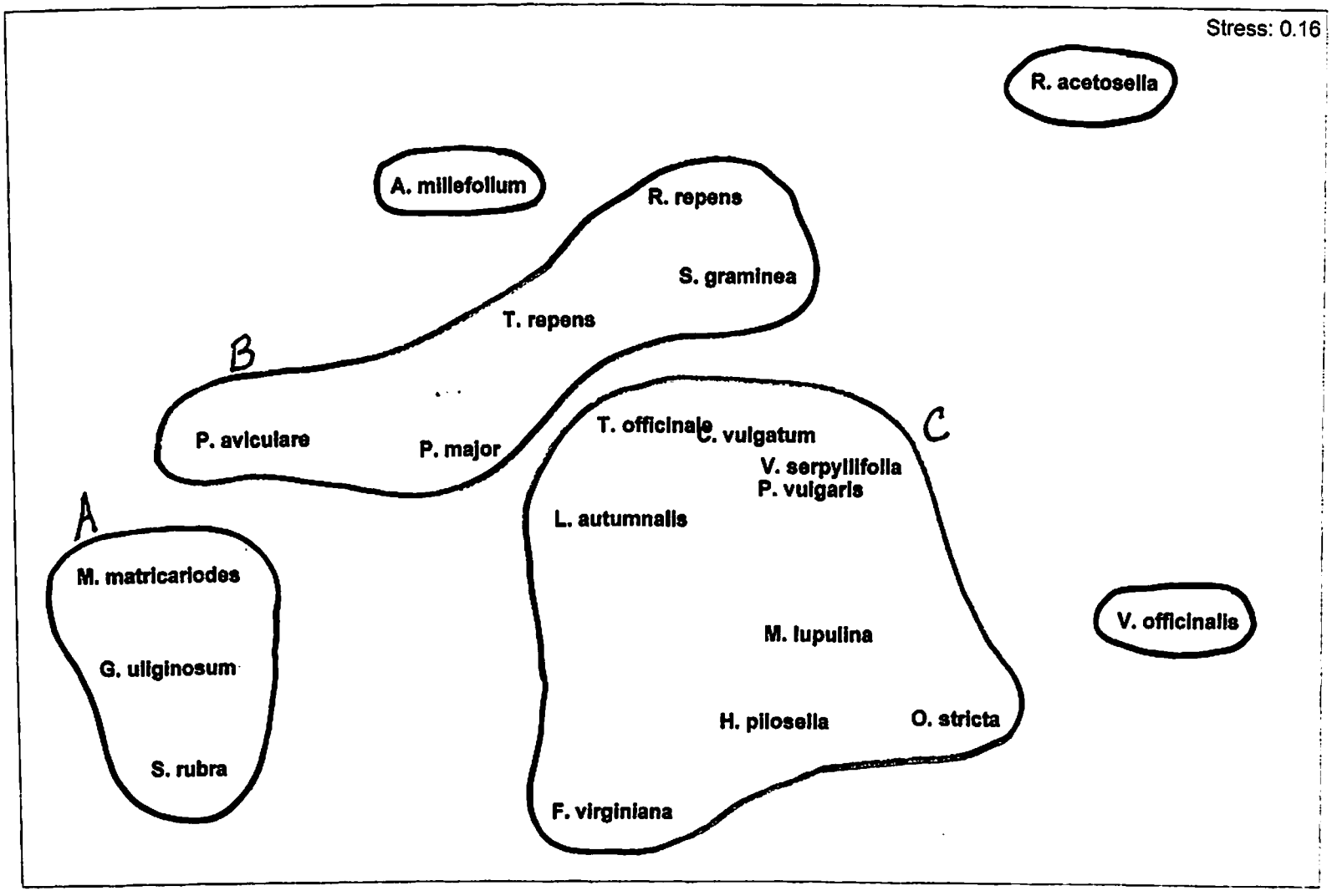

Stress: 0.16
R. acetosella
A. millefolium
R. repens
S. graminea
T. repens
B
P. aviculare
P. major
T. officinale
C. vulgatum
V. serpyllifolia
P. vulgaris
C
L. autumnalis
A
M. matricariodes
G. uliginosum
S. rubra
M. lupulina
V. officinalis
H. pilosella
O. stricta
F. virginiana

Table 3. Interpretation of stress values (Clarke & Warwick, 2001).

Stress	Interpretation
< 0.05	Excellent representation with no prospect of misinterpretation.
< 0.1	Good ordination, no real prospect of a misleading interpretation; 3 or higher dimensional solutions will not add any additional information about the overall structure.
< 0.2	Still gives a potentially useful 2-dimensional picture, though for values at the upper end of this range too much reliance should not be placed on the detail of the plot; a cross check of any conclusions should be made against those alternative technique.
0.2 - 0.3	Points are too close to being arbitrarily placed in the 2-dimensional ordination space. Values in this range should therefore treated with a great deal of skepticism and certainly discarded in the upper half of this range, especially for a small to moderate number of points.

Figure 4. MDS ordination of the 51 sites based on √-transformed frequencies and Bray-Curtis similarities.

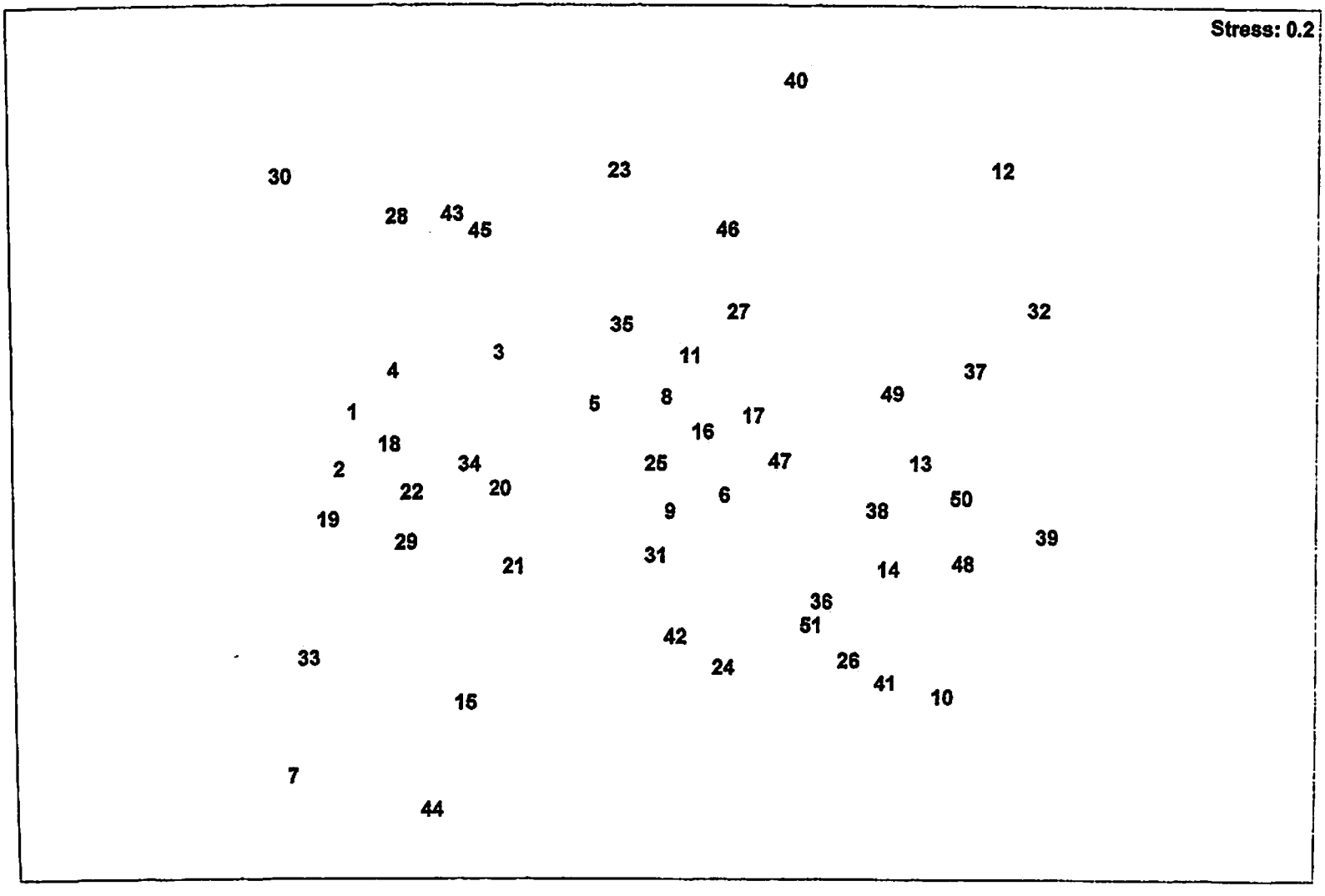
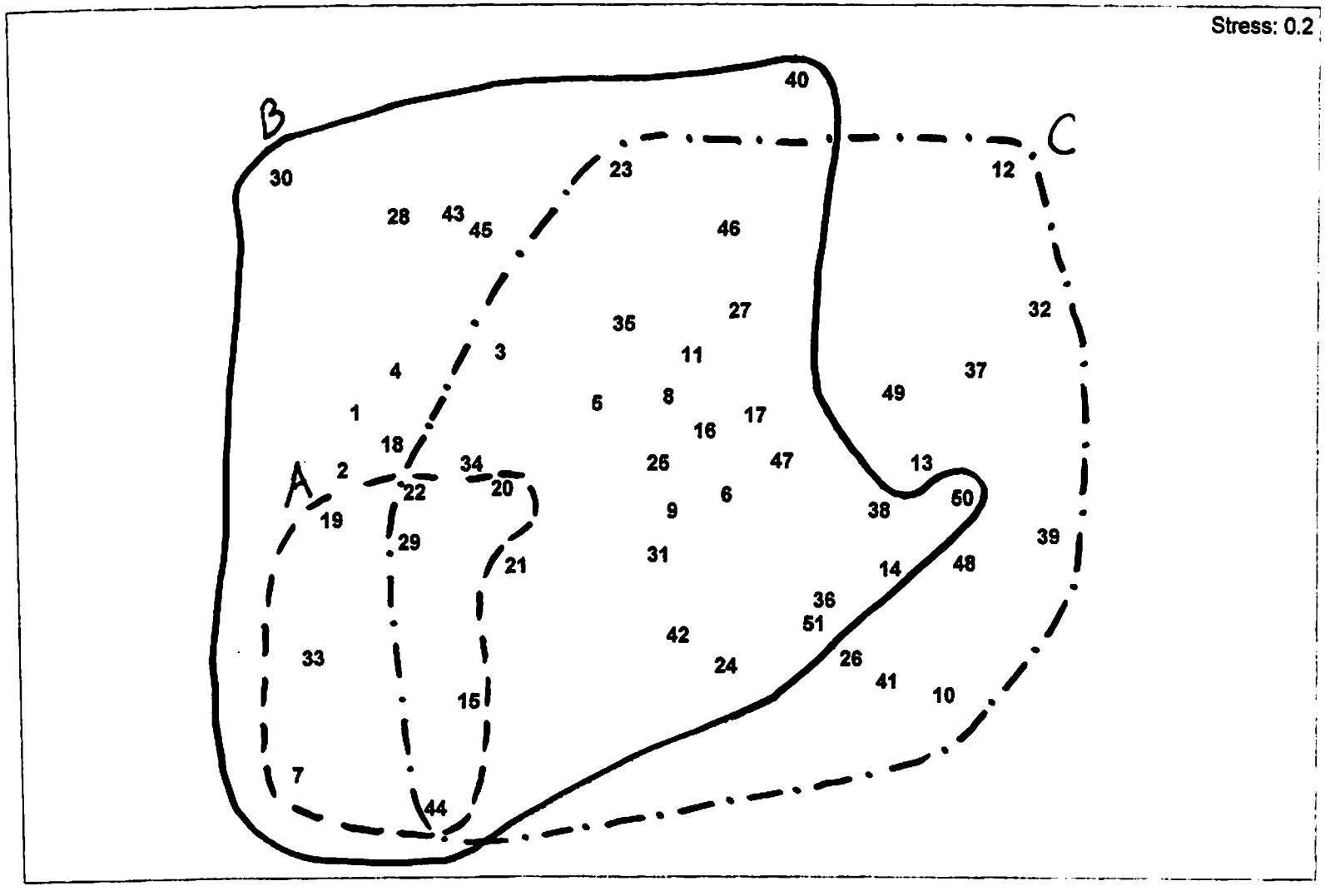

Stress: 0.2
40
30
23
12
28
43
45
46
27
32
35
3
11
4
37
49
1
5
8
17
16
18
2
34
25
47
13
22
20
6
50
19
9
38
29
39
31
21
14
48
36
51
42
33
24
26
41
10
15
7
44

Figure 5. Two-dimensional MDS of the sites similarity matrix. Envelopes enclose all sites at which species from groups A, B, and C (Fig. 3) occurred.

MDS ***Sites***


Stress: 0.2
A
B
C
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
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31
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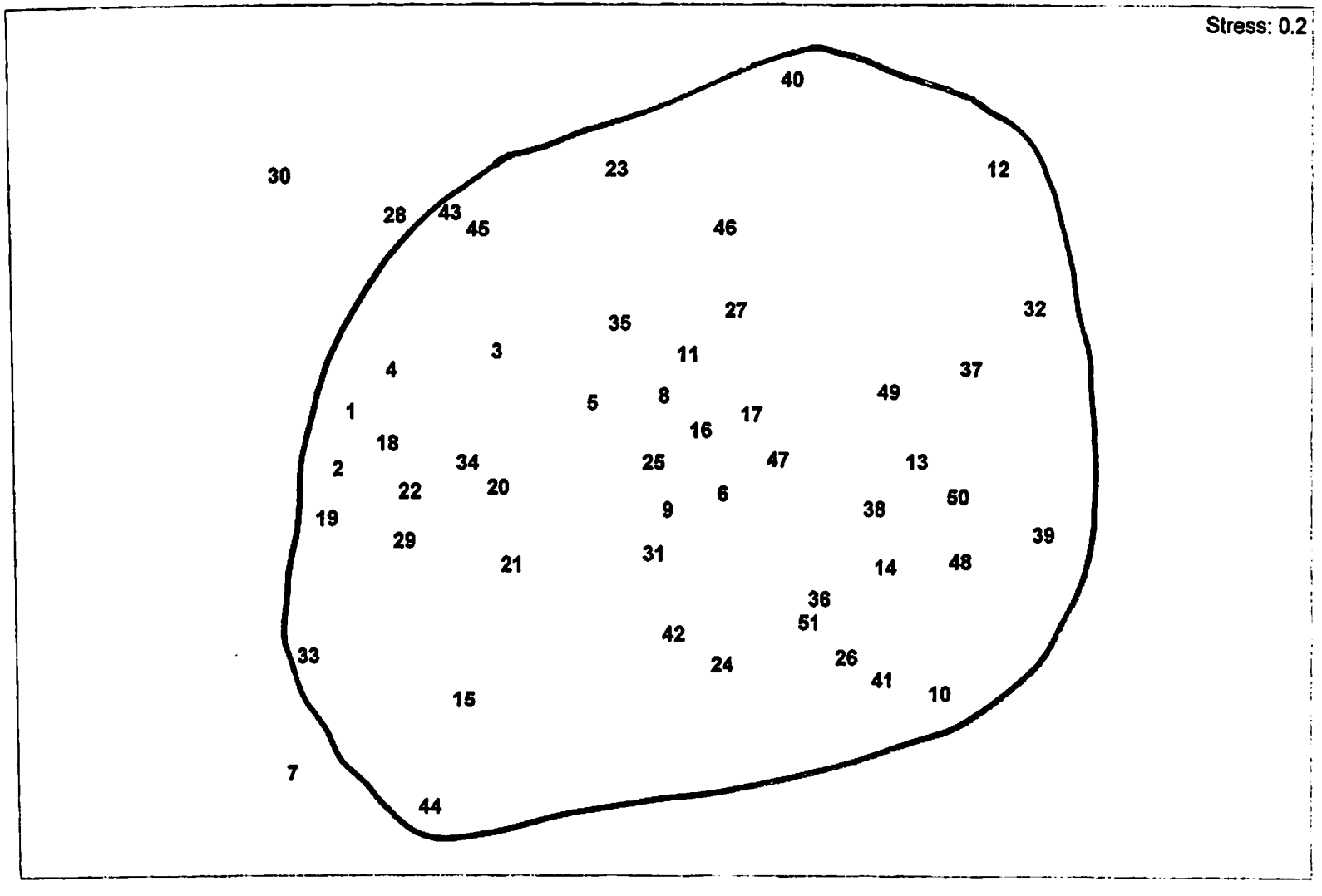
46
47
48
49
50
51

Figure 6. Occurrence of *Taraxacum officinale*. The envelope encloses all sites at which T. officinale occurred; the sites where it did not occur are all outside the envelope.

MDS ***Sites***


Stress: 0.2
40
30
23
12
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43
45
46
27
32
35
3
11
4
37
49
5
8
1
17
16
18
34
25
47
13
2
22
20
6
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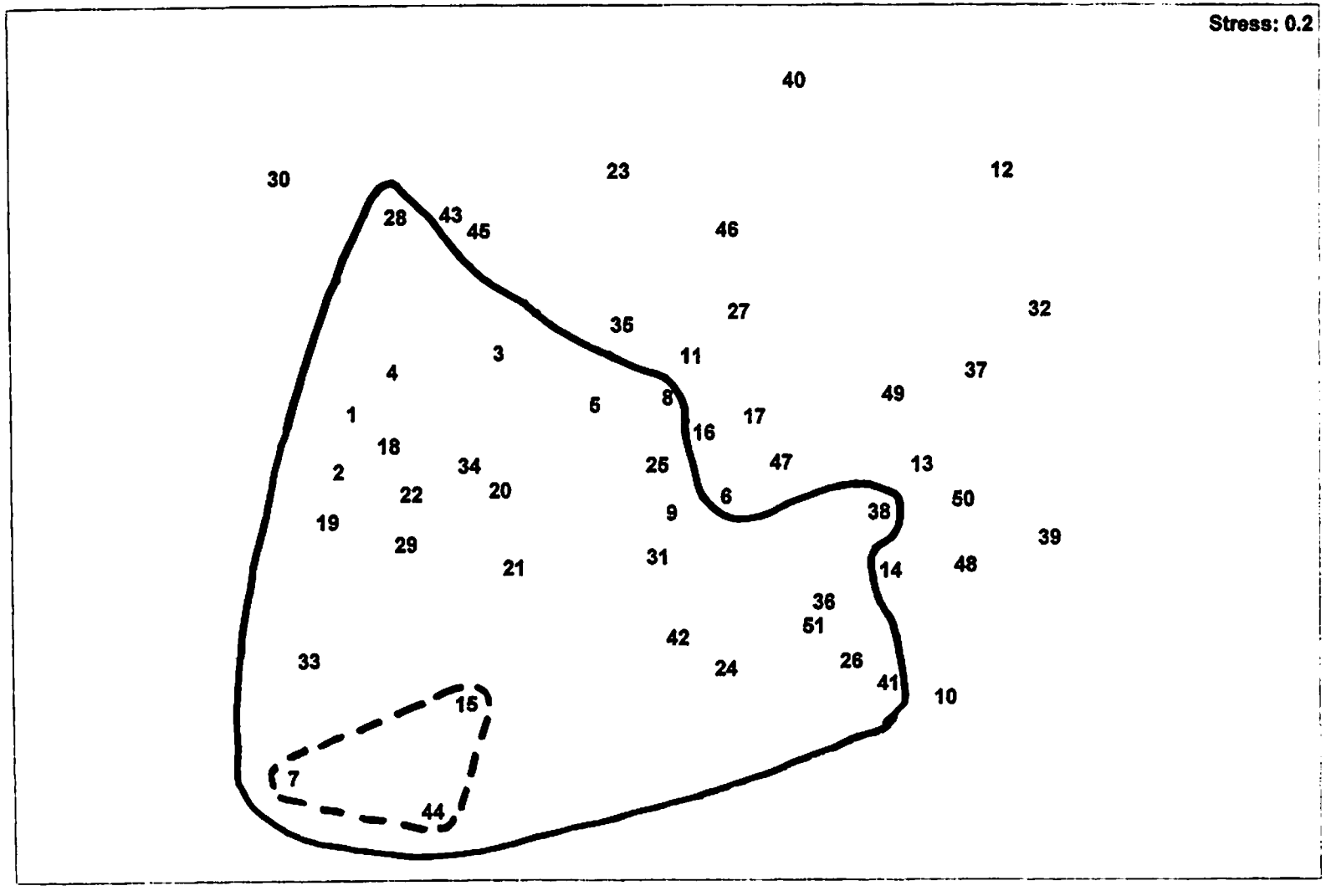
19
9
38
39
29
31
21
14
48
36
51
42
33
24
26
41
15
10
7
44

Figure 7. Occurrence of *Spergularia rubra* and *Plantago major*. The envelope with broken lines encloses all sites at which *S. rubra* occurred, the solid border all sites with *P. major*. Sites where these species did not occur lie outside of their respective envelopes.


Stress: 0.2
40
30
23
12
28
43
45
46
27
32
35
3
11
37
4
49
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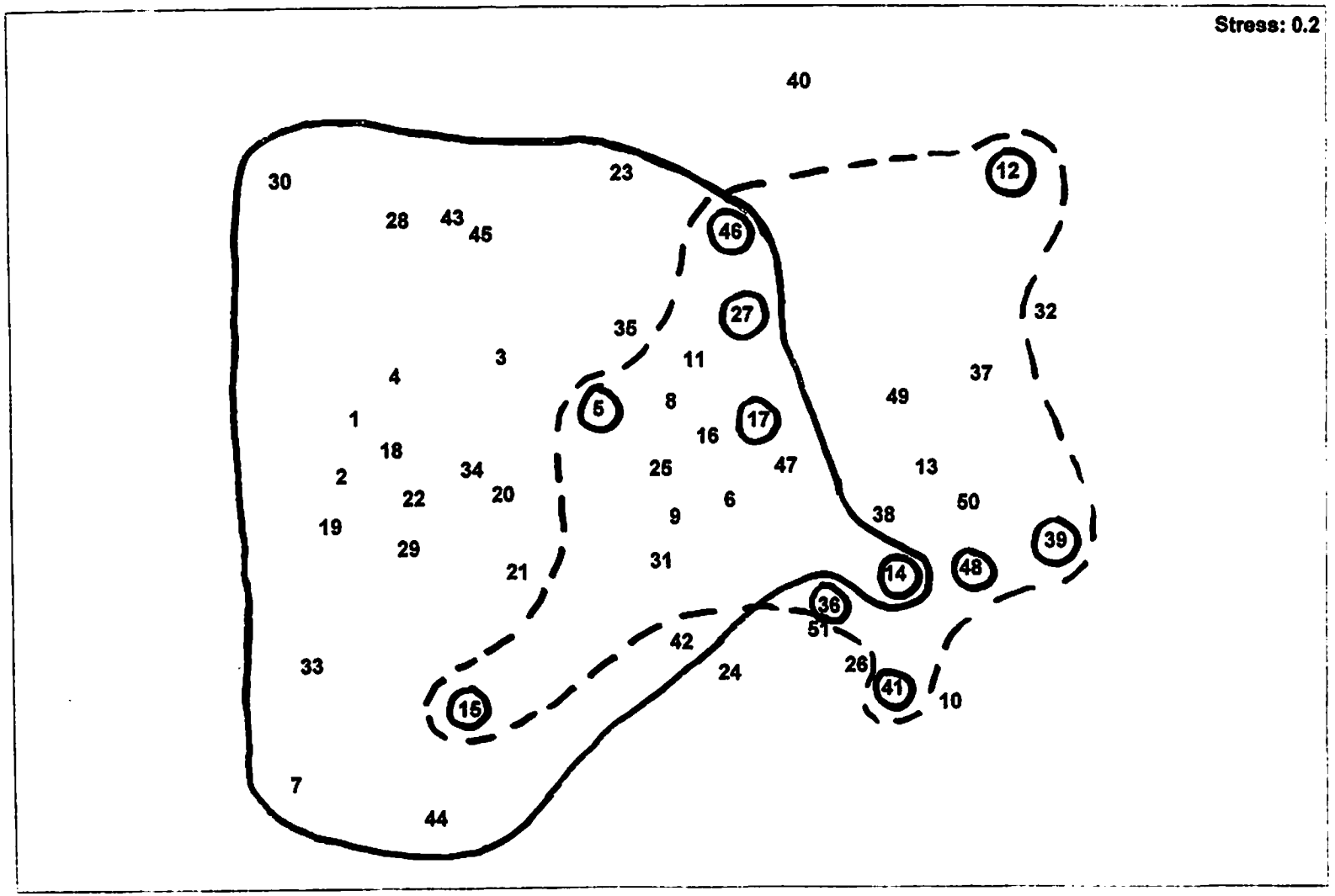
5
1
17
16
18
34
25
47
13
2
22
20
6
50
19
9
38
39
29
31
14
48
21
36
51
42
33
24
26
41
10
15
7
44

Figure 8. Occurrence of *Trifolium repens* and *Hieracium pilosella*. The envelope with a solid border encloses all sites at which *T. repens* occurred. All sites it did not occur lie outside this border. The envelope with a broken border encloses all sites at which *H pilosella* occurred; it was present only at the individually circled sites.


Stress: 0.2
40
30
23
12
28
43
45
46
27
32
35
3
11
37
4
5
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49
17
1
16
18
34
25
47
13
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6
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Significance of site selection variables for forb composition

The ANOSIM procedure was used to assess the significance of the site selection variables (or factors) i.e. campus, position, exposure, disturbance) on the forb composition of the different sites. Each factor was examined separately (Table 4).

These tests give a global statistic for all comparisons and pairwise statistics where more than 1 comparison was involved. An R-value of 1 indicates no overlap of sites for the variable under consideration; a value of 0 indicates complete overlap. Probability values indicate the likelihood of the differences arising by chance.

In regard to campuses (Fig. 9), pairwise R-values are 0.25 or below indicating a high level of overlap, but the differences are significant (Table 4), i.e. there are differences in the composition of the forb ensemble over all pairs of campuses. SMU and DAL have the most overlap; MSVU and SMU the least.

The R-value for position (R=0.284), is the highest recorded for site selection variables. Seven of the edge sites are completely separated from contiguous sites on the 2-dimensional MDS (Fig. 10). The other two sites are separated from these seven, and are not separated from other sites. Five of the first mentioned 7 edge sites are disturbed and under full sun exposure; the other sites (nos. 7, 19) are disturbed sites under afternoon sun. The other 2 sites that do not occur with the first seven in the MDS plots were both at MSVU and both occurred on north sides of buildings (heavily shaded); one was disturbed (no. 36) and one undisturbed (no. 38). These latter two sites do not include the species

Table 4. Results of ANOSIM tests.

Global Variable	Global R	Pairwise Variable	Pairwise R
Campus	R = 0.176 P= 0.001	DAL * SMU DAL * MSVU SMU * MSVU	R = 0.138 P = 0.012 R = 0.143 P = 0.003 R = 0.250 P = 0.001
Position[1]	R = 0.284 P = 0.001		
Position[2]	R = 0.393 P= 0.001		
Exposure[1]	R = 0.044 P = 0.206	O * N O * P O * T O * A N * P N * T N * A P * T P * A T * A	R = 0.066 P = 0.236 R = -0.028 P = 0.624 R = 0.155 P = 0.014 R = -0.121 P = 0.780 R = 0.047 P = 0.310 R = 0.055 P = 0.315 R = -0.026 P = 0.518 R = 0.161 P = 0.044 R = -0.108 P = 0.745 R = 0.025 P = 0.420
Exposure[2]	R = 0.110 P = 0.019		
Disturbance	R = 0.102 P = 0.008		

Figure 9. Site classification by campus superimposed on the site 2-dimensional MDS plot. Envelopes enclose all sites for the respective campuses (solid line MSVU; broken line DAL; broken/dotted line SMU).

Campus

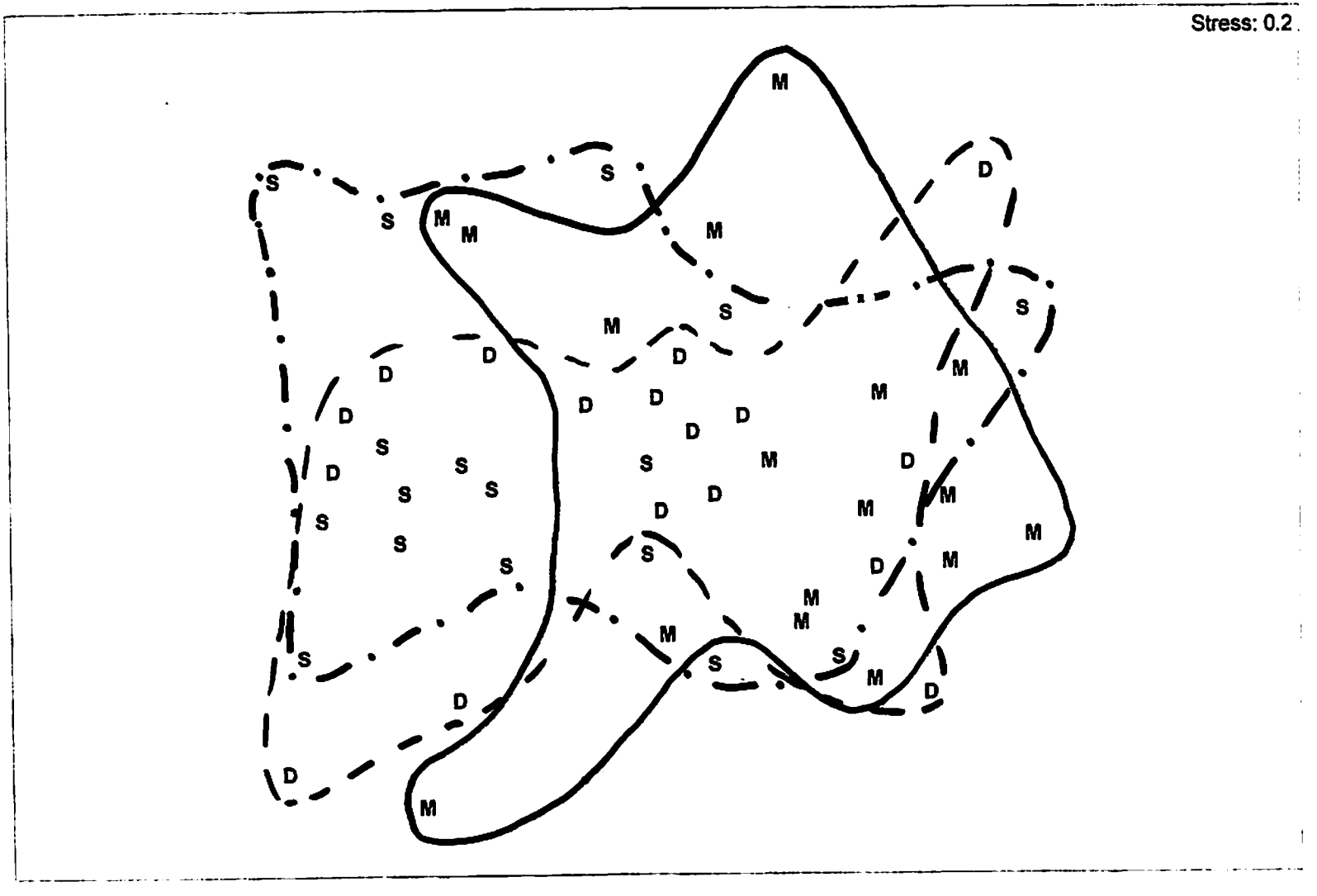
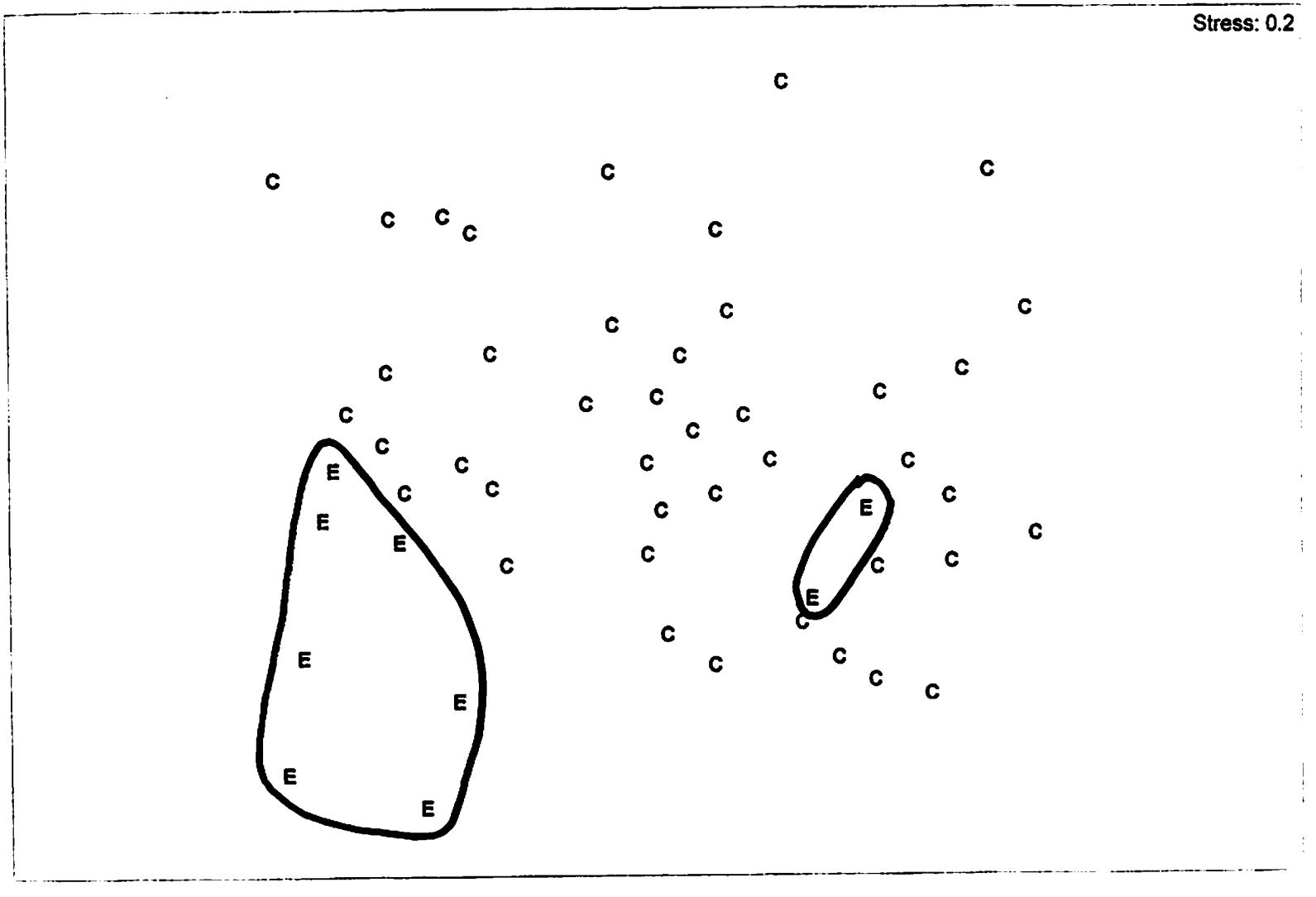


Figure 10. Site classification by position (edge, contiguous) superimposed on the 2-dimensional MDS for sites. Two groups of edge sites are enclosed by envelops.

Edge / Contiguous



that occurred exclusively or predominantly at edge sites (Table 2). When these 2 MSVU edge sites are removed (Position² in Table 4), there is a substantially higher position R-value for position (R = 0.393).

Exposure to sun was classified as open (O in Fig. 11) morning sun (A in Fig. 11), afternoon sun (P in Fig. 11), on the north side of a building or tree line (N in Fig. 11) and under trees (T in Fig. 11). The global R-value for exposure was very low (0.044) and non significant. Higher pairwise R values for P versus T exposure (R = 0.155, P = 0.014), and O versus T exposure (R = 0.161, P = 0.044) were significant. When the N and T classes are combined i.e. the 2 most heavily shaded situations, and compared with the others combined (O, A, P) the R-value is 0.110 (P = 0.019) (Fig 12).

For disturbance, there was a low but significant R-value (R = 0.102, P = 0.008). The 2-dimensional MDS plot (Fig. 13) has a region of mostly disturbed sites which correspond to the edge sites; i.e. most of the difference between disturbed and undisturbed sites is probably associated with the peculiarities of the edge sites.

Significance of other environmental variables

The possible significance of the eight site variables that were measured after selecting sites (rather than being used to select sites) were investigated using the BIOENV procedure (Clarke & Warwick, 2001). A combination of 5 individual variables produced the highest correlation coefficient (0.307). Three variables (soil depth, penetrability, and

Figure 11. Site classification by exposure to sun superimposed on the 2-dimensional MDS for sites. O = open, A = morning sun, P = afternoon sun, N = north side of building or tree line, T = under trees. Solid envelops enclose all open sites, broken envelops all treed sites.

Exposure (1)

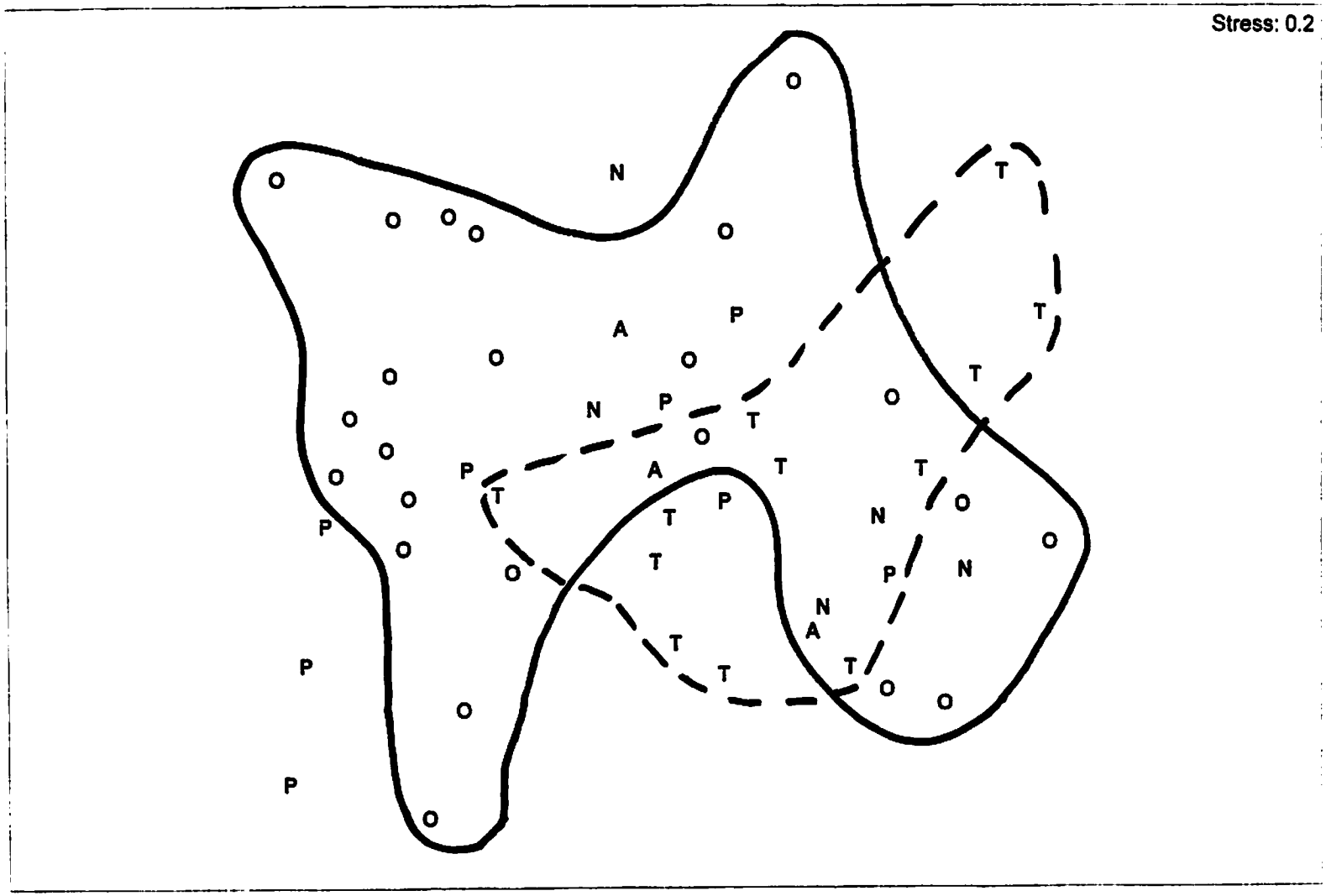


Figure 12. Site classification by exposure to sun superimposed on the 2-dimensional MDS for sites. The heavily shaded classes (T, N) are combined (S) and enclosed by a broken envelope, the more open classes (O, A, P) are combined (O) and enclosed by a solid envelope.

Exposure (2)

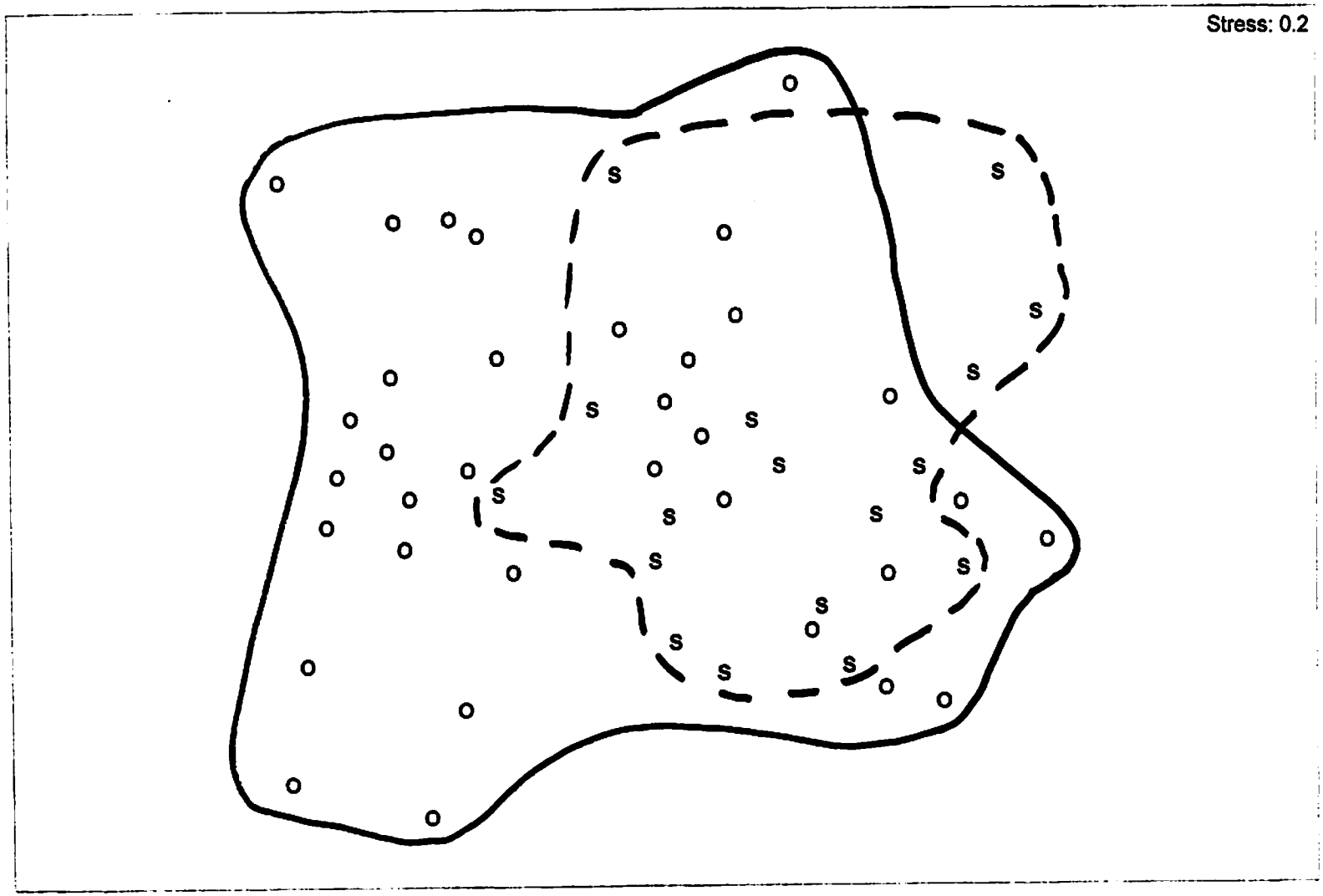
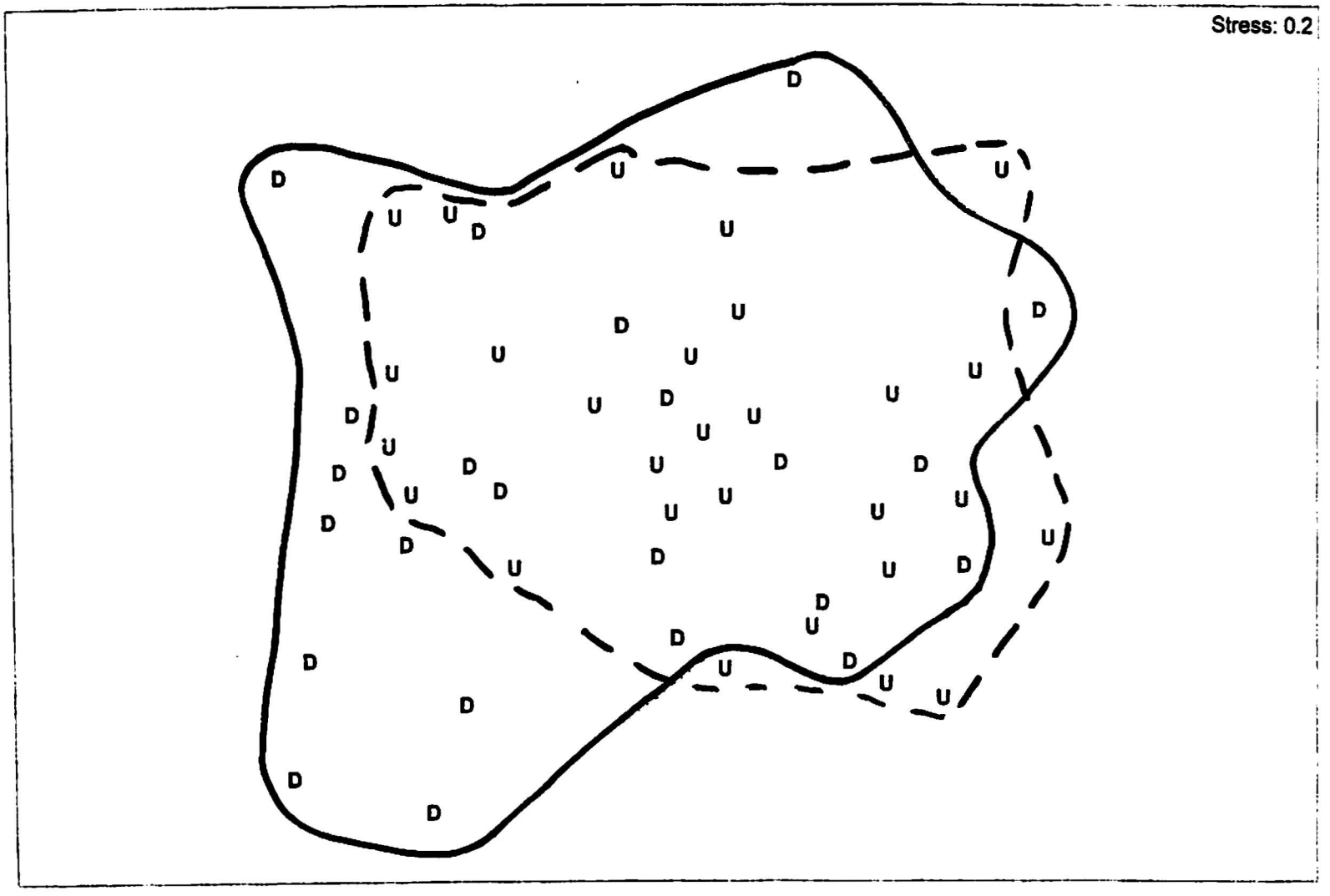


Figure 13. Site classification by disturbance superimposed on the 2-dimensional MDS for sites. D = sites that are disturbed, U = sites that are undisturbed. A solid border encloses all sites that are disturbed, a broken border all those that are undisturbed.

Disturbance

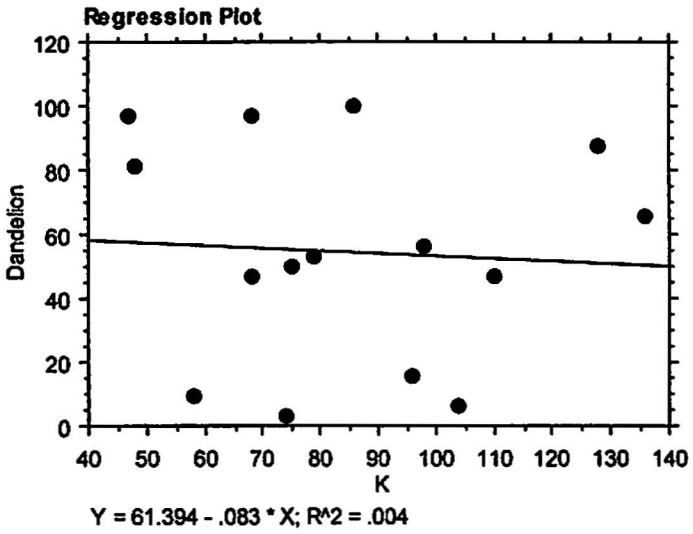


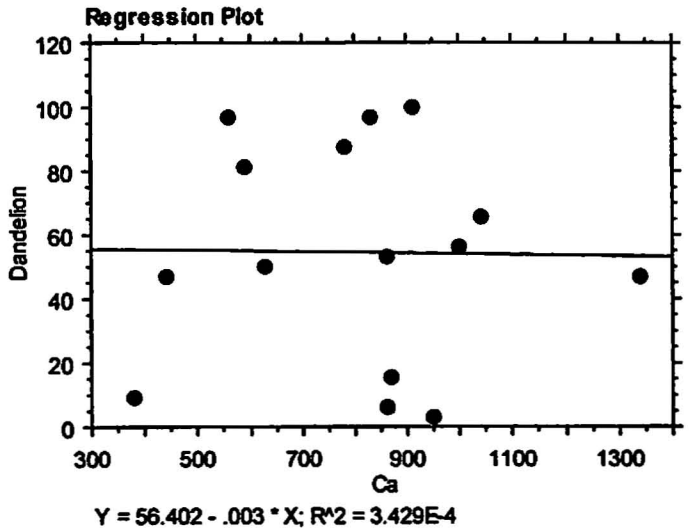
pH) gave an R-value of 0.289. Examination of the bubble plots for each of those variables do not show any clear trends of gradients in the values (Appendix 7).

Dandelion

Tilman et al.(1999) produced a variety of evidence to suggest dandelion abundance is controlled by potassium and lime (calcium). Dandelion was the most abundant forb on our sites. There was no correlation however, of dandelion with soil K or soil Ca (Fig. 14).

Figure 14. Relationship of dandelion frequency to soil potassium (K) and soil calcium (Ca).


Regression Plot
Dandelion
K
120
100
80
60
40
20
0
40
50
60
70
80
90
100
110
120
130
140
Y = 61.394 - .083 * X; R^2 = .004


Regression Plot
Dandelion
Ca
120
100
80
60
40
20
0
300
500
700
900
1100
1300
Y = 56.402 - .003 * X; R^2 = 3.429E-4

DISCUSSION

The two questions I wished to address were:

(i) Are there distinct groupings of forb species in lawns of the three campuses?

(ii) Can differences in species composition and distribution of individual species be related to environmental and/or management variables?

Species groups

Both the MDS and cluster analysis of species clearly identify a group of 3 species that occurred exclusively or predominantly at edge sites and separated those from all other species at a similarity level of 12.5%.

Three multispecies groups were evident at a similarity level of 23.5% in the cluster analysis diagram. On the MDS plots of sites, envelops of these 3 groups distinguish them from each other, but with some overlap. Bubble plots of individual species show clear patterns of occurrence on the 2-dimensional MDS of sites. Thus the 2-dimensional MDS representation of sites corresponds to real differences in species composition across sites.

The edge sites, excluding the 2 MSVU university sites that occurred in the shade, are characterized by a fairly distinct group of 4 species (*M. matricariodes*, *G. uliginosum*, and *S. rubra*). These species are all annuals or short-lived perennials (USDA). Also occurring on the edge sites are 3 species (*T. repens, T. officinale, R. repens*) that are shared with the contiguous sites and are typically perennials. However at the edge sites,

most do not survive the winter and thus must be dependant on persistent seed banks (*T. repens, P. major*) or annual colonization (*T. officinale*). The edge sites are a very harsh habitat due to heavy salting, high foot traffic, and sun exposure and therefore a high level of species selection probably occurs.

Except for edge versus other sites, there were not well defined groups of species. Rather individual species exhibit different patterns of distribution across the sites, and variation between the sets of species (e.g. treed versus open sites, different campuses) are more related to differences in abundances of globally common species than to differences in occurrence of particular species (Table 5, Appendix 8).

Some points of interest:

- *T. repens* is ranked in the top seven of all groupings (Table 5) except for MSVU. This could be related to the high fertilizer use of MSVU and low fertilizer use on the other 2 campuses (Appendix 5). T. repens is a legume and will be inhibited by high fertilizer (VanDommelen, 2003).
- *T. officinale* is abundant at all sites except on the edge sites.
- *P. major* is common except for areas where *H. pilosella* and *V. serpyllifolia* are common i.e. *P. major* and *H. pilosella/V. serpyllifolia* are mutually exclusive to some extent.

Table 5. Seven most abundant species in different sets of sites, based on average quadrat frequencies. T. offi = *T. officinale*, P. majo = *P. major*, T. repe = *T. repens* H. pilo = *H. pilosella*, V. serpy = *V. serpyllifolia*.

	All	T. offi	P. majo	T. repe	H. pilo	V. serp
T. repens	1	1	1	1	4	4
T. officinale	2	2	2	2	3	1
P. major	3	5	3	3		
C. vulgatum	4	3	4	4	1	2
V. serpyllifolia	5	4	5	5	6	3
S. graminea	6	6	6	6		
H. pilosella					2	7
P. vulgaris	7	7			5	6
M. lupulina						5
L. autumnalis			7	7	7	
P. aviculare						
M. matricariodes						
S. rubra						
A. millefolium						
R. repens						
O. stricta						
G. uligonosum						

MSVU	SMU	DAL
	1	1
1	4	2
	2	
2	5	4
3	7	5
4	3	
5		
		6
		3
		7
7	6	

Open	Treed
1	5
2	1
5	3
6	2
7	4
3	
4	
	6
	7

Edge
4
7
1
2
3
5
6

- The treed sites are distinguished from open sites mainly by lower abundances in T. repens, S. graminea, M. lupulina, and a greater abundance of L. autumnalis and R. repens.

Site/environmental factors

Position (edge vs. contiguous) was clearly identified as an important environmental factor influencing species composition of sites.

A priori it was expected that exposure, disturbance and campus (management history) would be important influences on species composition. The ANOSIM procedure confirms influence of some of these factors. Position has the strongest influence as discussed above.

None of the other environmental variables (ph, EC, depth, penetrability, slope, age, texture, darkness) by themselves had a strong influence and even in combination, the BIOENV correlation was not high (Table 6).

Conclusion

In conclusion, the multivariate analysis seems to have been very effective in representing differences in species composition over different sites but except for the edge versus other sites, the driving forces were not readily discernable.

Table 6. Spearman correlations for the relationship of the site similarity matrix with Euclidean distance matrices of environmental variables.

A

Variable	R-value for 1 variable
Depth	0.168
Penetrability	0.185
Slope	0.131
Age	0.116
pH	0.153
Electrical Conductivity (EC)	0.188
Texture	0.008
Darkness	0.026

B

No. of variables	Variables giving highest R-value	R-value
1	Penetrability	0.185
2	Depth, pH	0.249
3	Penetrability, Depth, pH	0.289
4	Penetrability, Depth, pH, Slope	0.298
5	Penetrability, Depth, pH, Slope, EC	0.307

Although not planned as part of the original study, the data allowed a test of the Tilman proposal that potassium and calcium are the critical resources for dandelion (*Taraxacum officinale*) (Tilman et al. 1999). Overall, this species was the most common species in this study. Examination of the relationship of quadrat frequencies of dandelion at different sites with soil calcium and potassium showed no evidence of dependence of dandelion frequency on soil Ca or soil K.

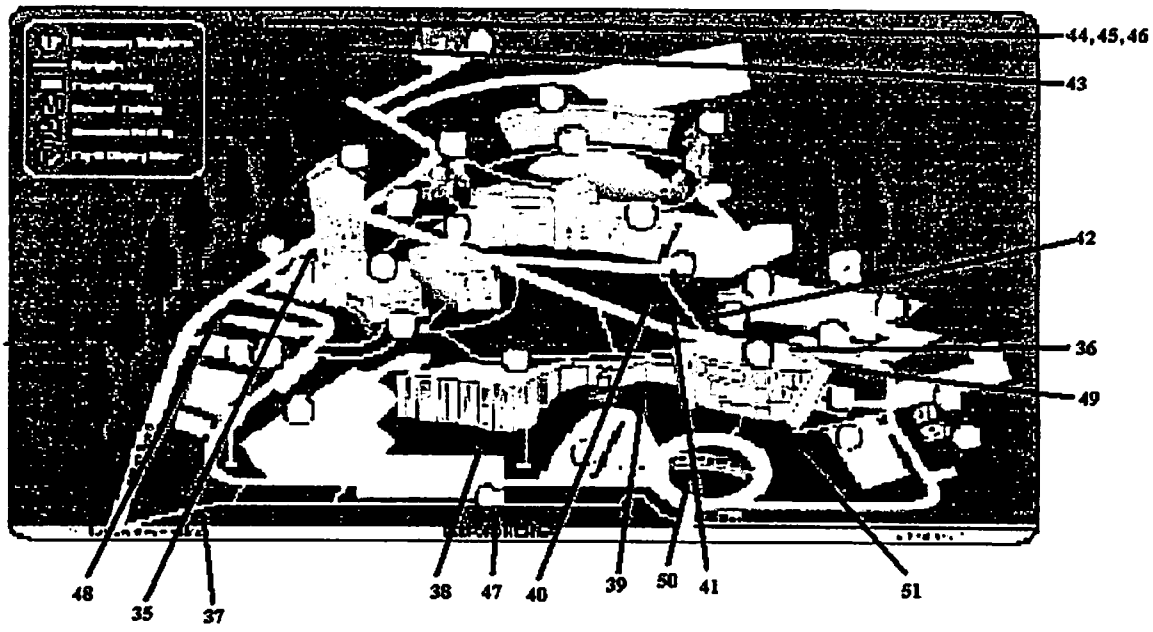
Appendix 1. Site selection classification and site locations.

Under Campus D = Dalhousie, S = Saint Mary's, M = Mount Saint Vincent's
Under Edge/Contiguous E = edge, C = contiguous
Under Disturbance D = disturbed, U = undisturbed
Under Exposue O = Open, N = North side of a building or tree line, P = pm sun, A = am sun, T = treed area

Sites	Campus	Location	Edge/Contiguous	Disturbance	Exposure
1	D	A&A East	C	D	O
2	D	AA East Path bisecting disturbed area	E	D	O
3	D	Across from soccer pitch by chair	C	U	O
4	D	AA East across fr. Chem and bench	C	U	O
5	D	AA North btw building and path	C	U	N
6	D	AA North btw wall and path	C	U	P
7	D	AA North pathway	E	D	P
8	D	AA West	C	D	P
9	D	LSC North by Biology door in trees	C	U	T
10	D	LSC Blower	C	U	O
11	D	Next to East side of Tennis court	C	U	O
12	D	Tree area adjacent oxford street (OCEA)	C	U	T
13	S	Psych West, tree area	C	D	T
14	S	Psych West btw building and path	C	U	P
15	S	AAE btw rosehips and path	E	D	O
16	S	Rosehip enclosure	C	U	O
17	S	Btw NRCC and OCEA, tree area	C	U	T
18	S	Blower McN E	C	U	O
19	S	Burke Building West path	E	D	P
20	S	Burke Building West, tree area	C	D	T
21	S	Burke Building North	C	U	O
22	S	Across from Gorsebrook Lng entrance	C	U	O
23	S	Side of parking lot closest Inglis and Robie	C	U	N
24	S	Side of parking lot closest Inglis and Tower	C	U	T
25	S	McN E btw stairs & library	C	U	A
26	S	Across from McN E stairs, shaded trees	C	D	T
27	S	McN Main, by building	C	U	P

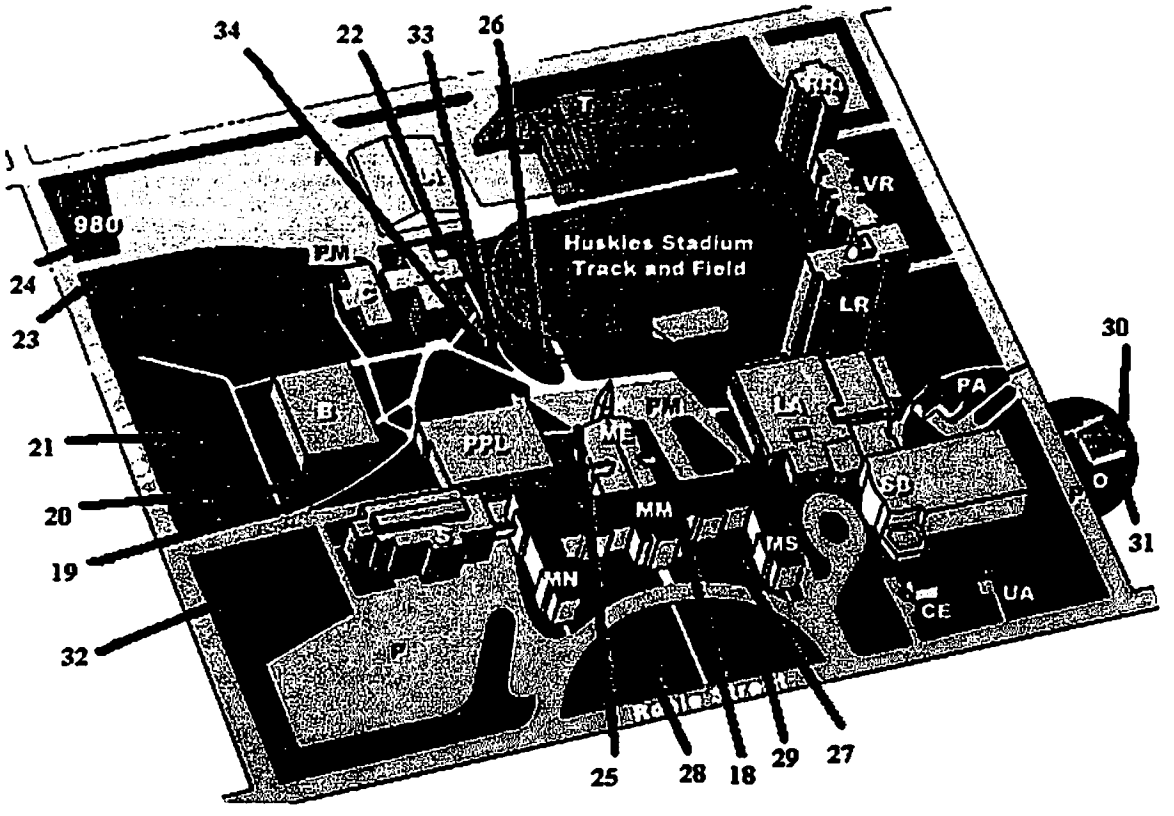
Sites	Campus	Location	Edge/Contiguous	Disturbance	Exposure
28	S	McN North, circular area by road	C	U	O
29	S	McN main, path	E	D	O
30	M	Oaks South	C	D	O
31	M	Oaks West	C	D	T
32	M	Science building North, tree area	C	D	T
33	M	Between café and track, path	E	D	O
34	M	Between café and track triangle	C	D	P
35	M	Assissi flat	C	D	A
36	M	Blower	E	D	N
37	M	Edge of MSVU closest to Hfx, sign	C	U	T
38	M	EMFCC front	E	U	N
39	M	Btw EMFCC and Seton annex	C	U	O
40	M	Bottom of evaristus mono area	C	D	O
41	M	Evaristus slight slope	C	U	O
42	M	Evaristus tree area	C	D	T
43	M	Meadows	C	U	O
44	M	Mother house edge of road	E	D	O
45	M	Mother house flat	C	D	O
46	M	Motherhouse slope	C	U	O
47	M	Front of Communication Ctr	C	D	T
48	M	Beside Rosaria SC sign	C	D	N
49	M	Seton Academic South	C	U	O
50	M	Front of Seton Academic circular area	C	U	O
51	M	Across from Seton Annex entrance	C	U	A

Mount Saint Vincent University Sampling Map



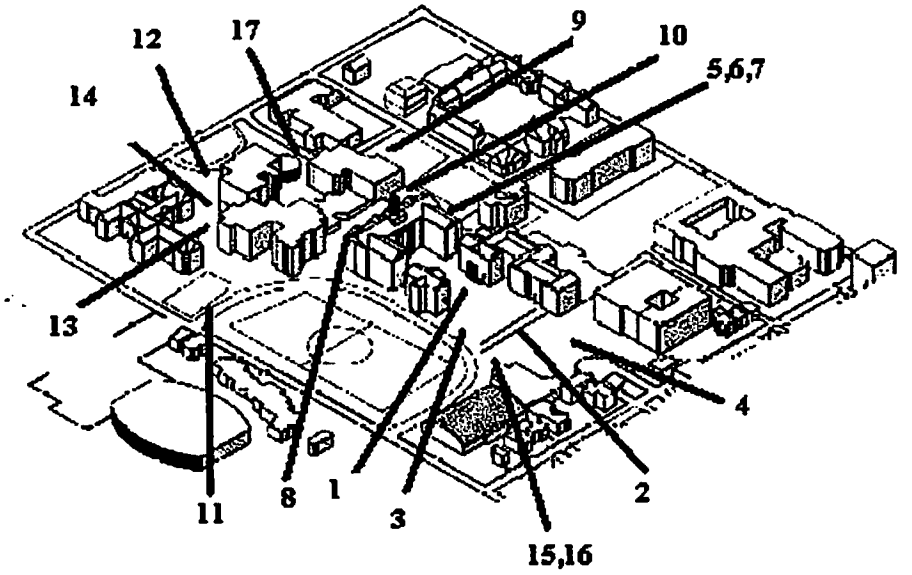
35. Assissi flat area.
36. Blower area behind Seton building, edge.
37. Edge of MSVU closest to Hfx, near sign under trees.
38. Front of EMFCC building, edge.
39. Between EMFCC and Seton building.
40. Bottom of Evaristus hill in monoculture looking area (sodded?).
41. Bottom of Evaristus less slope.
42. Bottom of Evaristus tree area.
43. Meadows open area.
44. Motherhouse edge of road (edge).
45. Motherhouse flat area.
46. Motherhouse sloping area.
47. Front of EMFCC off of road under trees.
48. Beside Rosaria student centre sign North of tree line.
49. South of Seton Academic.
50. Front of Seton Academic circular area.
51. Across from Seton Academic entrance slightly south east.

Saint Mary's Sampling Map



18. McN East blower.
19. Burke Building West path edge.
20. Burke Building West tree area.
21. Burke Building North in front of sign.
22. Across from Gorsebrook Lounge entrance.
23. Tree area on side of Inglis parking entrance on Robie Street side.
24. Tree area on side of Inglis parking entrance on Tower Road side.
25. McNally East building between the stairs and the library.
26. Across from last area, beside entrance to sports field, tree area.
27. McNally Main by building.
28. McNally North in circular grass area.
29. McNally Main on circular area edge.
30. The Oaks South facing in open area.
31. The Oaks West facing in tree area.
32. Science building North in tree picnic area.
33. Between the café and sports field path edge.
34. Between the café and sports field triangular area.

Dalhousie Sampling Map

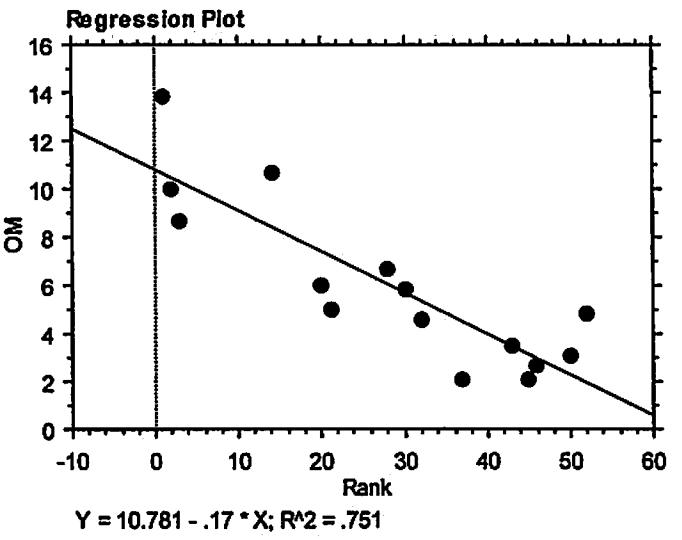


1. A & A East disturbed area.
2. A & A East bisecting pathway (btw dist. & undist.) edge.
3. Across from the soccer pitch in front of the chair.
4. A & A East diagonal from Chem building, undisturbed area.
5. A & A North between building and path.
6. A & A North between wall and path.
7. A & A North path edge.
8. A & A West
9. LSC North by Biology entrance in trees.
10. LSC Northeast by blower.
11. Tennis court East.
12. Off Oxford St. tree area Psych & Ocea West.
13. Psych West tree area.
14. Psych West between building and path.
15. A & A East between rosehips and path.
16. Rosehip enclosure.
17. Between Ocea W and NRCC, tree area.

Appendix 2. Soil texture categories. Verbal descriptions are those of Brady et al. (2002). Rankings are in order of increasing clay content.

Rank	Texture
1	loamy sand
2	sandy loam
3	silt loam
4	loamy sand
5	sandy clay loam
6	clay loam
7	silty clay loam
8	sandy clay loam
9	silty clay loam

Appendix 3. Soil darkness and soil organic matter. The figure shows the relationship between percent soil organic matter and soil darkness (1 highest, 51 lowest).


Regression Plot
16
14
12
10
8
6
4
2
0
OM
-10
0
10
20
30
40
50
60
Rank
Y = 10.781 - .17 * X; R^2 = .751

Appendix 4. Soil analysis results (A & L Labs, Ontario)

Report Number: C04196-009
Account Number: 20002

A & L Canada Laboratories Inc.

2136 Jetstream Road, London, Ontario, N5V 3P5
Telephone: (519) 457-2575 Fax: (519) 457-2664

To: DALHOUSIE UNIVERSITY
BIOLOGY DEPARTMENT
HALIFAX, NS B3H 4J1

For:

Attn: DR. DAVID PATRIQUIN
902-949-3736
Report Date: 7/16/04

SOIL TEST REPORT

Sample Number	Lab Number	Organic Matter	Phosphorus - P ppm Bicarb	Phosphorus - P ppm Bray-P1	Potassium K ppm	Magnesium Mg ppm	Calcium Ca ppm	Sodium Na ppm	pH pH	pH Buffer	CEC meq/100g	Percent Base Saturations % K	% Mg	% Ca	% H	% N
A1	9133	13.8		22 *M*	104 *M*	70 *VL*	860 *VL*	121 *VH*	5.7	6.0	17.7	1.5	3.3	24.3	67.9	3.0
A2	9134	10.0		175 *VH*	110 *M*	275 *H*	1340 *L*	49 *H*	6.0	6.7	13.1	2.2	17.5	51.2	27.5	1.6
A3	9136	8.7		10 *L*	68 *L*	55 *VL*	440 *VL*	30 *M*	5.0	5.8	17.4	1.0	2.6	12.7	82.9	0.8
B1	9137	10.7		44 *H*	86 *M*	85 *VL*	910 *VL*	30 *M*	5.5	5.9	18.8	1.2	3.8	24.2	70.2	0.7

Sample Number	Sulfur S ppm	Zinc Zn ppm	Manganese Mn ppm	Iron Fe ppm	Copper Cu ppm	Boron B ppm	Soluble Salts ms/cm	Saturation P %	Aluminum Al ppm	Nitrate Nitrogen NO3-N ppm	K/Mg Ratio	ENR	Field ID
								2 VL	1481		0.45	112	
								20 VH	1120		0.13	112	
								1 VL	1313		0.38	100	
								4 M	1314		0.32	112	

OE

VL = VERY LOW *L* = LOW *M* = MEDIUM *H* = HIGH *VH* = VERY HIGH

Report Number: C04196-009
Account Number: 20002

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Attn: DR. DAVID PATRIQUIN
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SOIL TEST REPORT

Sample Number	Lab Number	Organic Matter	Phosphorus - P ppm Bicarb	Phosphorus - P ppm Bray-P1	Potassium K ppm	Magnesium Mg ppm	Calcium Ca ppm	Sodium Na ppm	pH	Buffer	CEC meq/100g	Percent Base Saturations % K	% Mg	% Ca	% H	% N
B2	9138	6.0		46 *H*	136 *M*	100 *L*	1040 *VL*	127 *VH*	5.8	6.6	11.7	3.0	7.1	44.3	40.9	4.7
B3	9139	5.8		26 *M*	79 *M*	35 *VL*	860 *VL*	345 *VH*	5.4	6.6	11.1	1.8	2.6	38.8	43.3	13.5
C1	9140	5.0		50 *VH*	96 *M*	115 *L*	870 *VL*	63 *VH*	5.8	6.6	10.6	2.3	9.0	40.9	45.2	2.6
C2	9141	6.7		15 *L*	75 *L*	85 *L*	830 *VL*	19 *L*	5.7	6.2	13.7	1.4	5.2	22.9	69.9	0.6

Sample Number	Sulfur S ppm	Zinc Zn ppm	Manganese Mn ppm	Iron Fe ppm	Copper Cu ppm	Boron B ppm	Soluble Salts ms/cm	Saturation P %	Aluminum Al ppm	Nitrate Nitrogen NO3-N ppm	K/Mg Ratio	ENR	Field ID
								7 M	884		0.42	73	
								4 L	876		0.69	71	
								8 M	803		0.26	63	
								1 VL	1488		0.27	80	

OE

VL = VERY LOW *L* = LOW *M* = MEDIUM *H* = HIGH *VH* = VERY HIGH

Report Number: C04196-009
Account Number: 20002

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SOIL TEST REPORT

Sample Number	Lab Number	Organic Matter	Phosphorus - P ppm Bicarb	Phosphorus - P ppm Brey-P1	Potassium K ppm	Magnesium Mg ppm	Calcium Ca ppm	Sodium Na ppm	pH pH	pH Buffer	CEC meq/100g	Percent Base Saturations % K	% Mg	% Ca	% H	% N
C3	9142	2.1		70 *VH*	45 *L*	35 *VL*	830 *M*	19 *H*	6.3	6.9	5.8	2.0	5.0	71.1	20.5	1.4
D1	9143	4.6		55 *VH*	68 *L*	45 *VL*	560 *VL*	73 *VH*	5.7	6.5	9.7	1.8	3.9	29.0	62.1	3.3
D2	9144	4.8		76 *VH*	128 *M*	115 *M*	780 *M*	43 *VH*	5.8	6.9	6.6	5.0	14.6	59.3	18.3	2.8
D3	9145	3.5		14 *L*	58 *L*	65 *VL*	380 *VL*	24 *M*	5.2	6.3	11.1	1.3	4.9	17.1	75.7	0.9

Sample Number	Sulfur S ppm	Zinc Zn ppm	Manganese Mn ppm	Iron Fe ppm	Copper Cu ppm	Boron B ppm	Soluble Salts ms/cm	Saturation P %	Aluminum Al ppm	Nitrate Nitrogen NO3-N ppm	K/Mg Ratio	ENR	Field ID
								8 L	1115		0.40	33	
								5 L	1333		0.46	59	
								9 L	1062		0.34	61	
								2 VL	922		0.27	47	

oe

VL = VERY LOW *L* = LOW *M* = MEDIUM *H* = HIGH *VH* = VERY HIGH

Report Number: C04186-009
Account Number: 20002

A & L Canada Laboratories Inc.

2136 Jetstream Road, London, Ontario, N5V 3P5
Telephone: (519) 457-2575 Fax: (519) 457-2664

To: DALHOUSIE UNIVERSITY
BIOLOGY DEPARTMENT
HALIFAX, NS B3H 4J1

For:

Attn: DR. DAVID PATRIQUIN
902-949-3736

Report Date: 7/16/04

SOIL TEST REPORT

Sample Number	Lab Number	Organic Matter	Phosphorus - P ppm Bicarb	Phosphorus - P ppm Bray-P1	Potassium K ppm	Magnesium Mg ppm	Calcium Ca ppm	Sodium Na ppm	pH	pH Buffer	CEC meq/100g	Percent Base Saturations % K	% Mg	% Ca	% H	% N
E1	9146	2.7		16 *L*	48 *L*	100 *H*	590 *M*	20 *H*	5.5	6.9	5.2	2.4	16.0	56.8	23.1	1.7
E2	9147	3.1		64 *VH*	98 *M*	140 *H*	1000 *M*	20 *H*	6.9	6.9	7.7	3.3	15.1	64.9	16.6	1.1
E3	9148	2.1		88 *VH*	74 *M*	35 *VL*	950 *M*	43 *VH*	6.3	6.9	6.6	2.9	4.4	71.8	18.1	2.8

Sample Number	Sulfur S ppm	Zinc Zn ppm	Manganese Mn ppm	Iron Fe ppm	Copper Cu ppm	Boron B ppm	Soluble Salts ms/cm	Saturation P %	Aluminum Al ppm	Nitrate Nitrogen NO3-N ppm	K/Mg Ratio	ENR	Field ID
								4 VL	582		0.15	39	
								8 L	1029		0.22	43	
								17 VH	656		0.66	33	

OE

VL = VERY LOW *L* = LOW *M* = MEDIUM *H* = HIGH *VH* = VERY HIGH

Appendix 5. Notes on management.

MSVU – Mowed at 2 ½", 3-3 ½" through hot periods in the summer. Mixed fertilizers applied 1 to 2 times a year.

SMU – Maintenance is contracted out to Edmonds Landscaping. They mow at 2" – 3" through the summer, shorter in the fall. Lime and Potassium are applied when very get very low, to support clover. Other fertilizers not applied regularly.

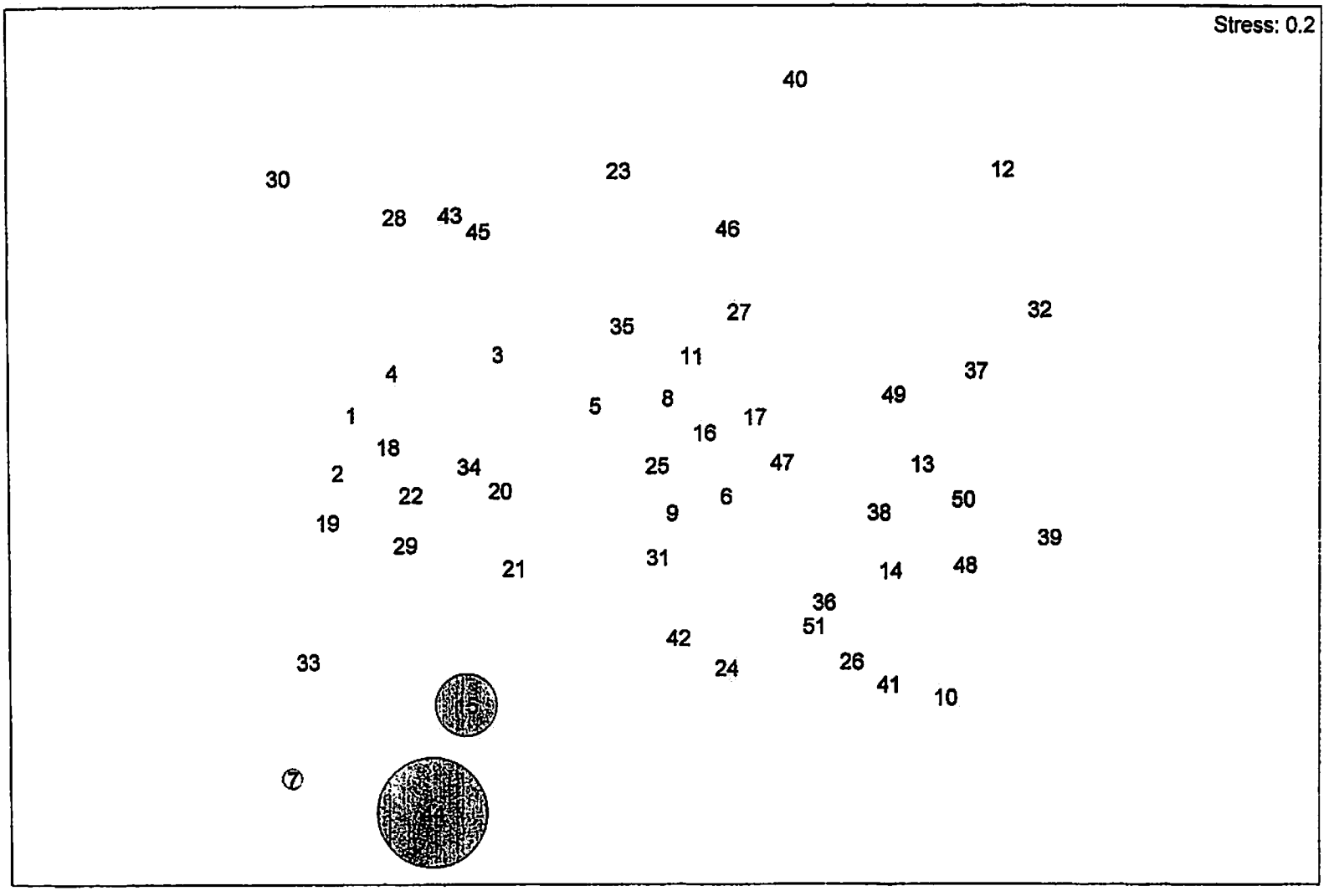
DAL – Mow 10-14 days at maximum 3", mid summer 3 ½" with some watering. Edges are seeded (clover and grass seed). Fertilizers and lime not used regularly. Some 'weed & feed' was used in the rosehips area about 10 years ago, but otherwise no herbicides used for 15 years. I noted that the lawns were mowed weekly; and much shorter than 3".

Mowing heights measured at 7 locations on each campus in mid-September.

Campus	Avg. Mowing Height (cm)	Actual mowing heights (cm)
MSVU	6.3	7.0
		7.0
		6.0
		5.5
		5.0
		7.0
		6.5
SMU	5.8	5.5
		5.5
		6.0
		6.5
		6.0
		6.0
		5.0
DAL	3.6	4.5
		3.0
		4.0
		3.5
		4.0
		3.5
		3.0

Appendix 6. Bubble plots for all species. The frequency of occurrence is proportional to the size of the bubbles.

S. rubra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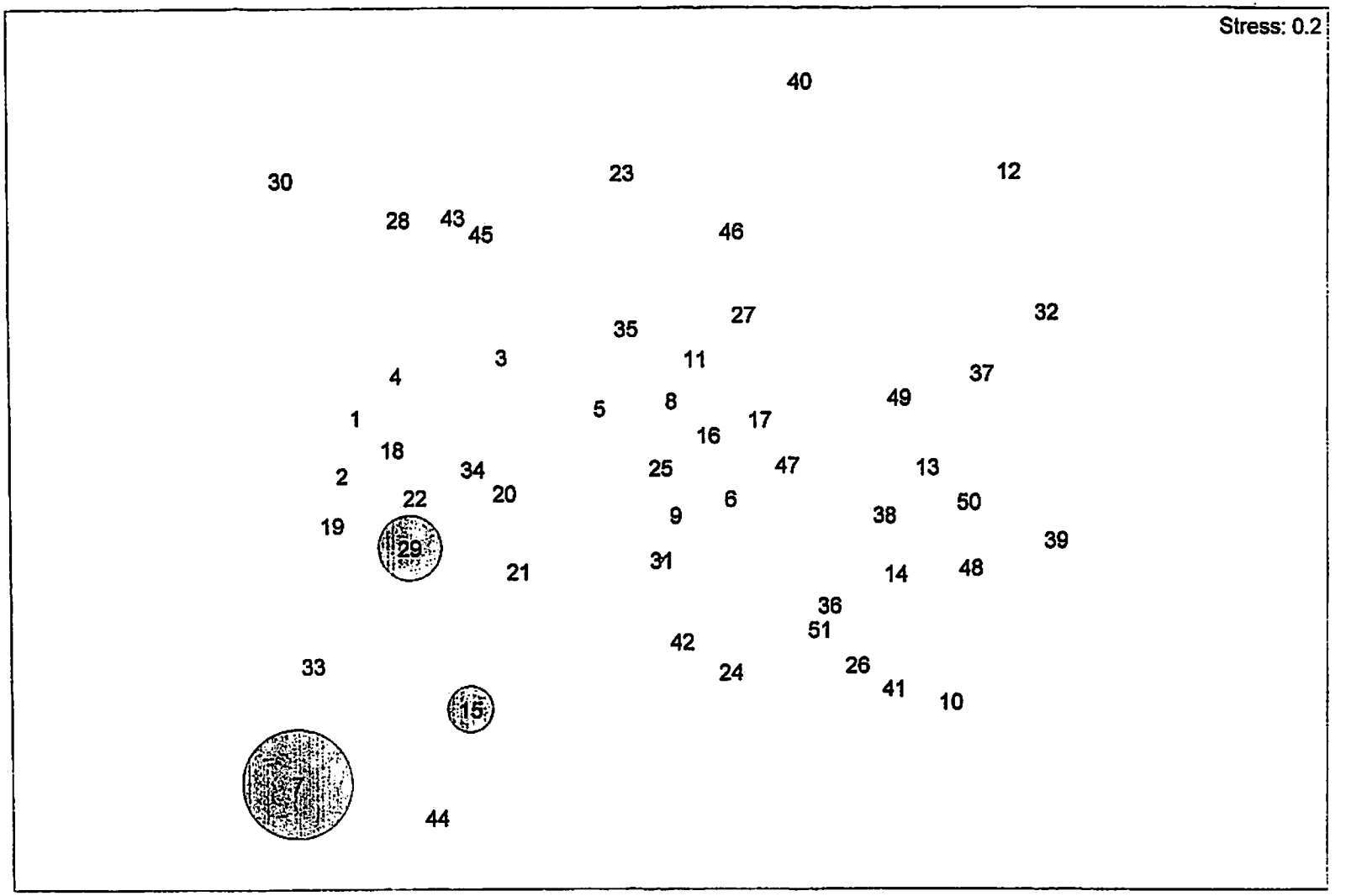
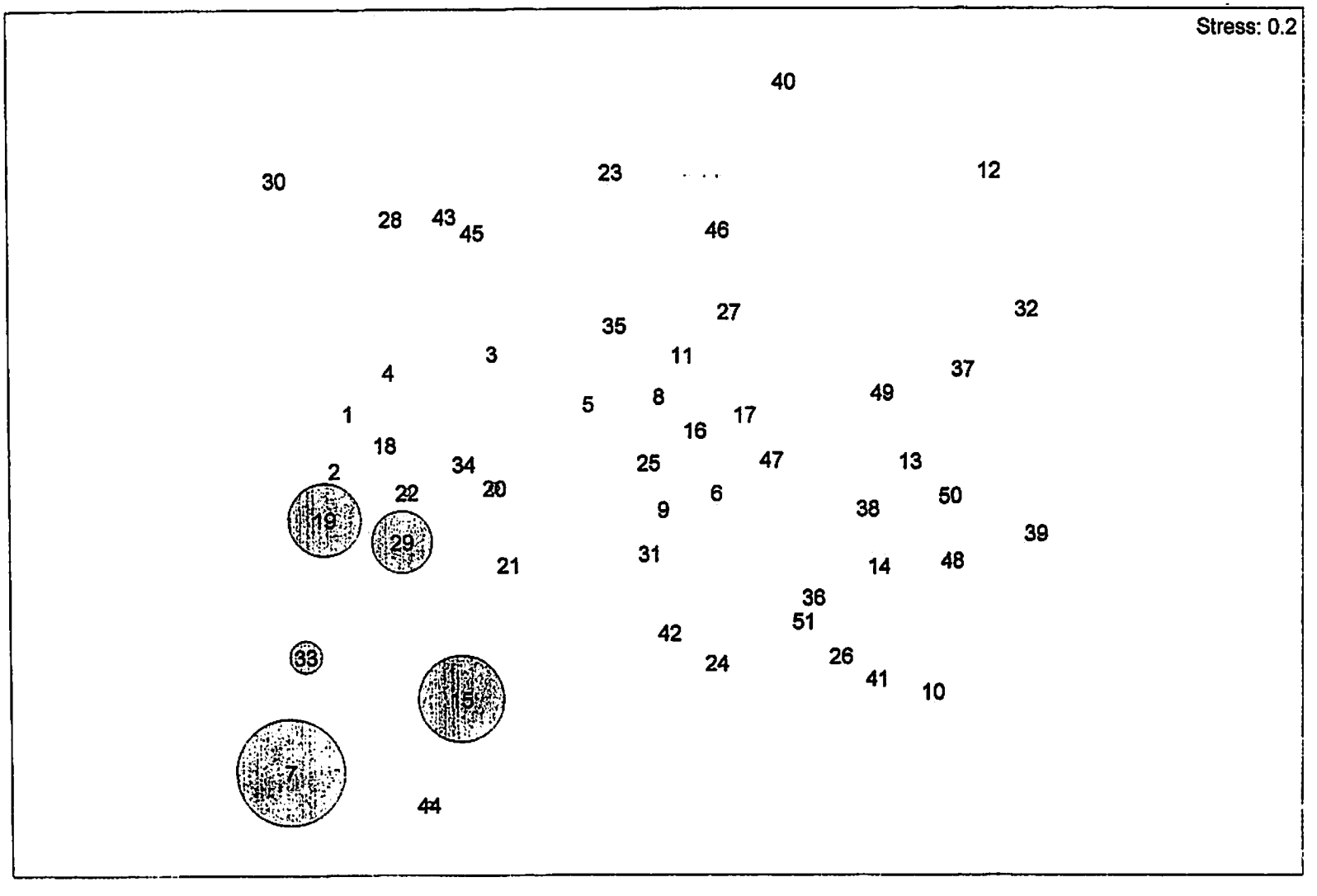
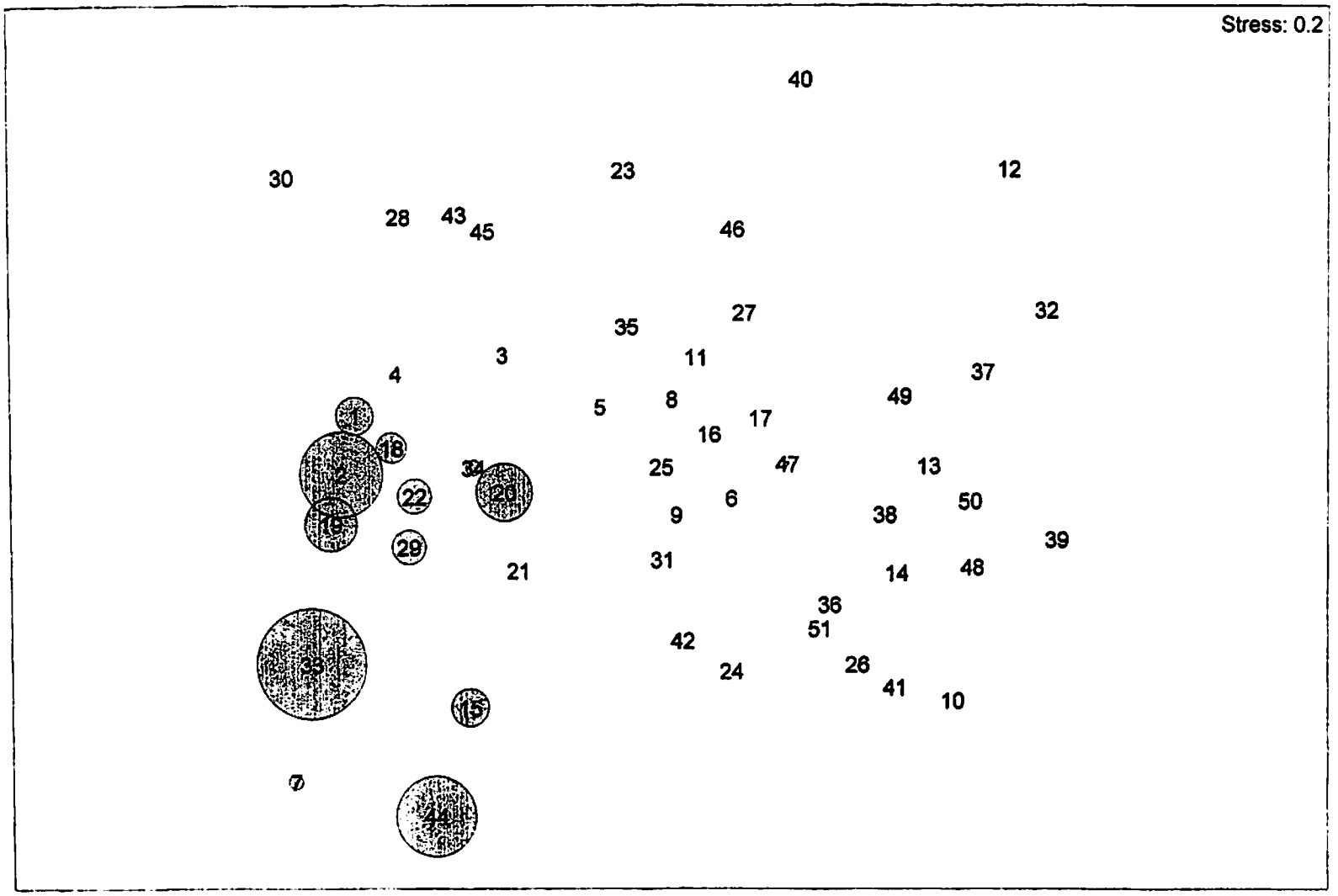
G. uliginosum



M. matricariodes



P. aviculare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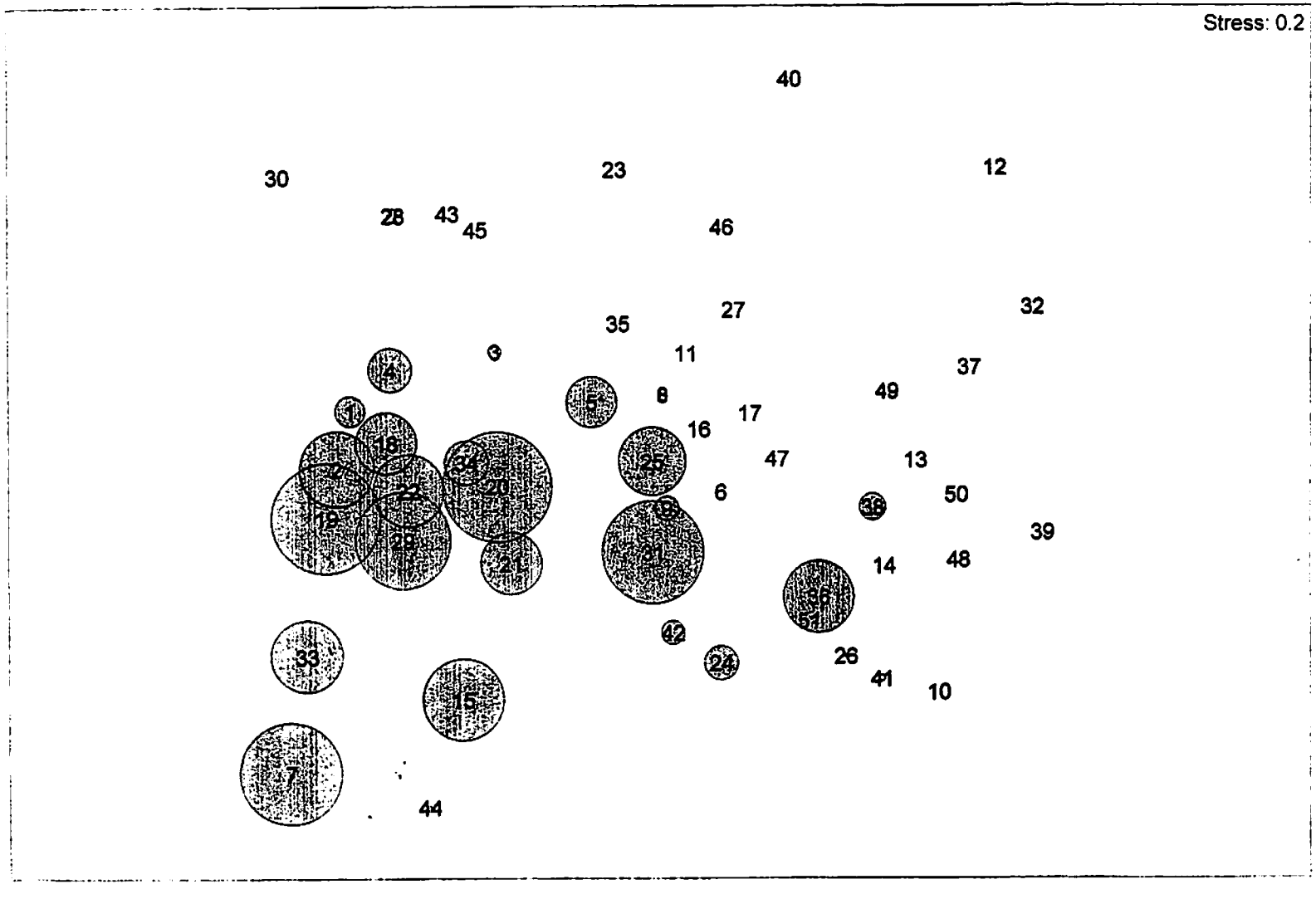
P. major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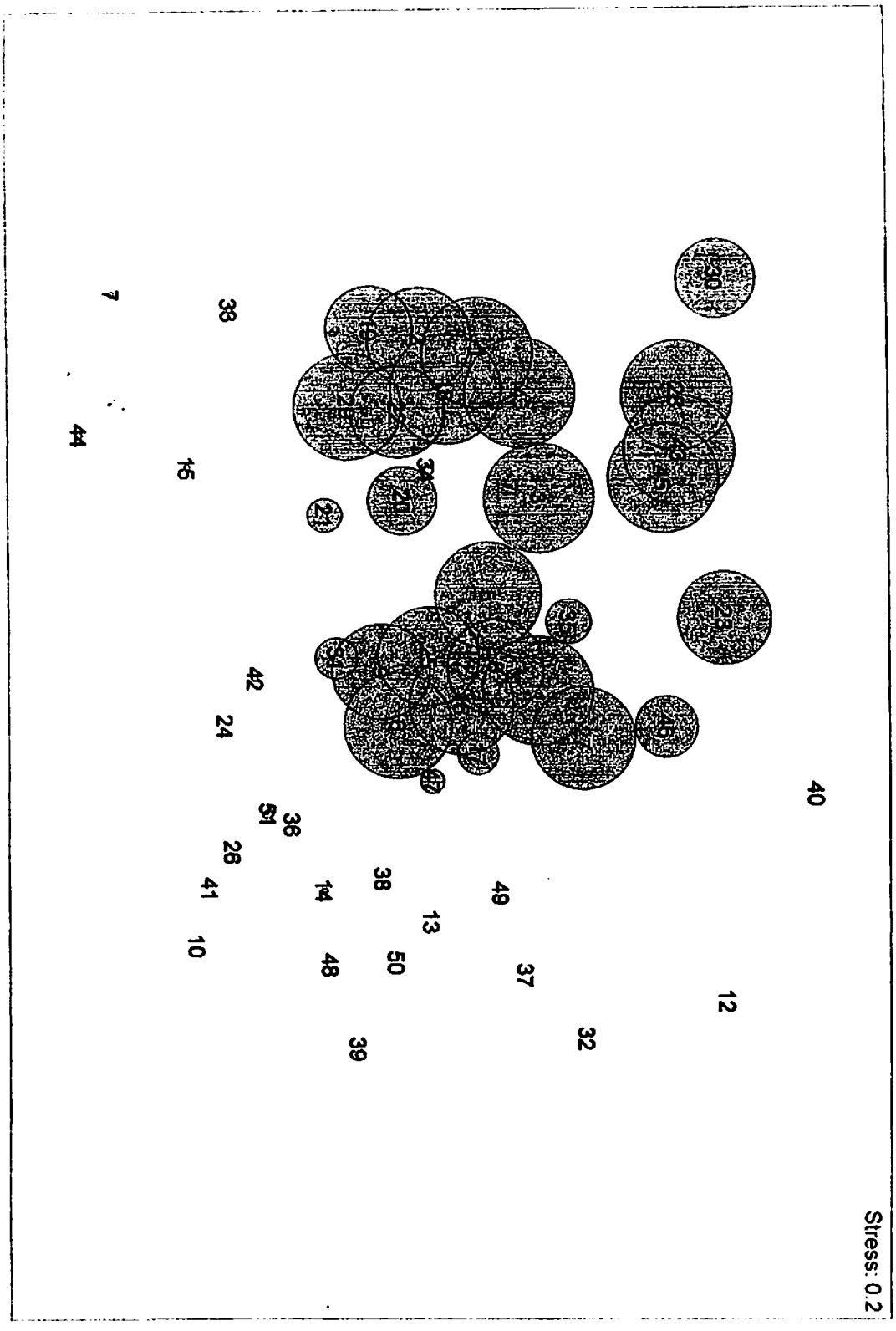
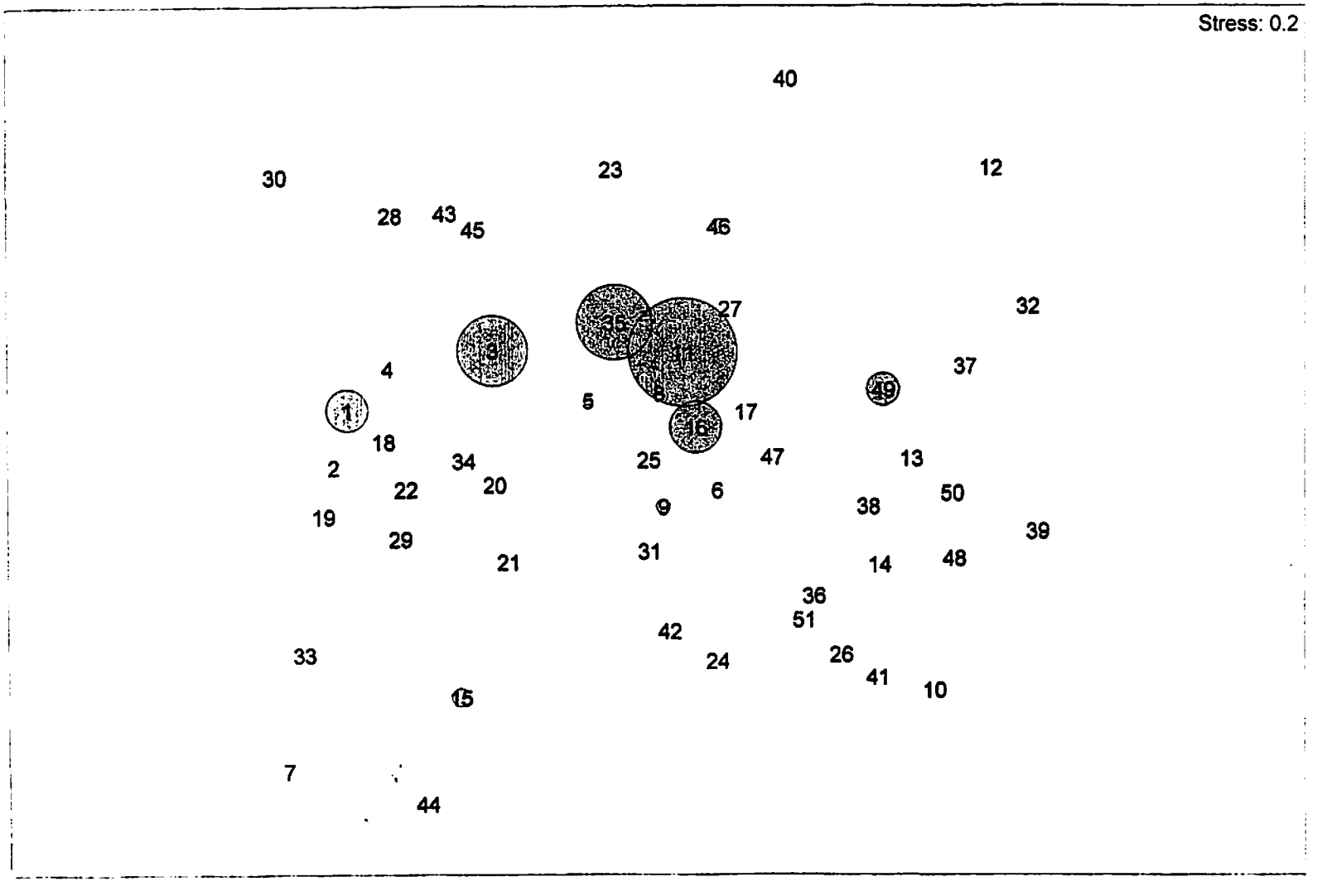
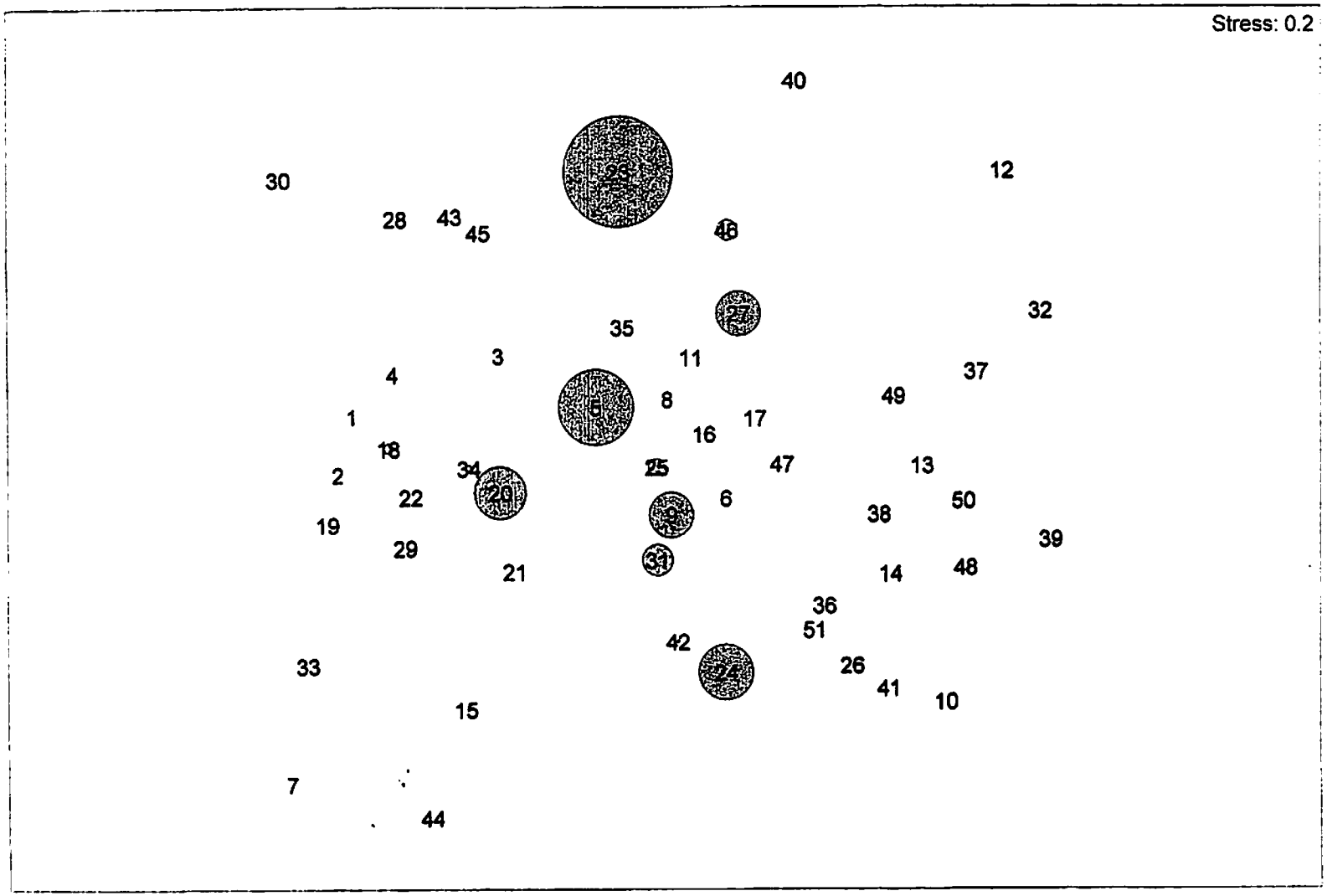


T. repens

A. millefolium



R. repens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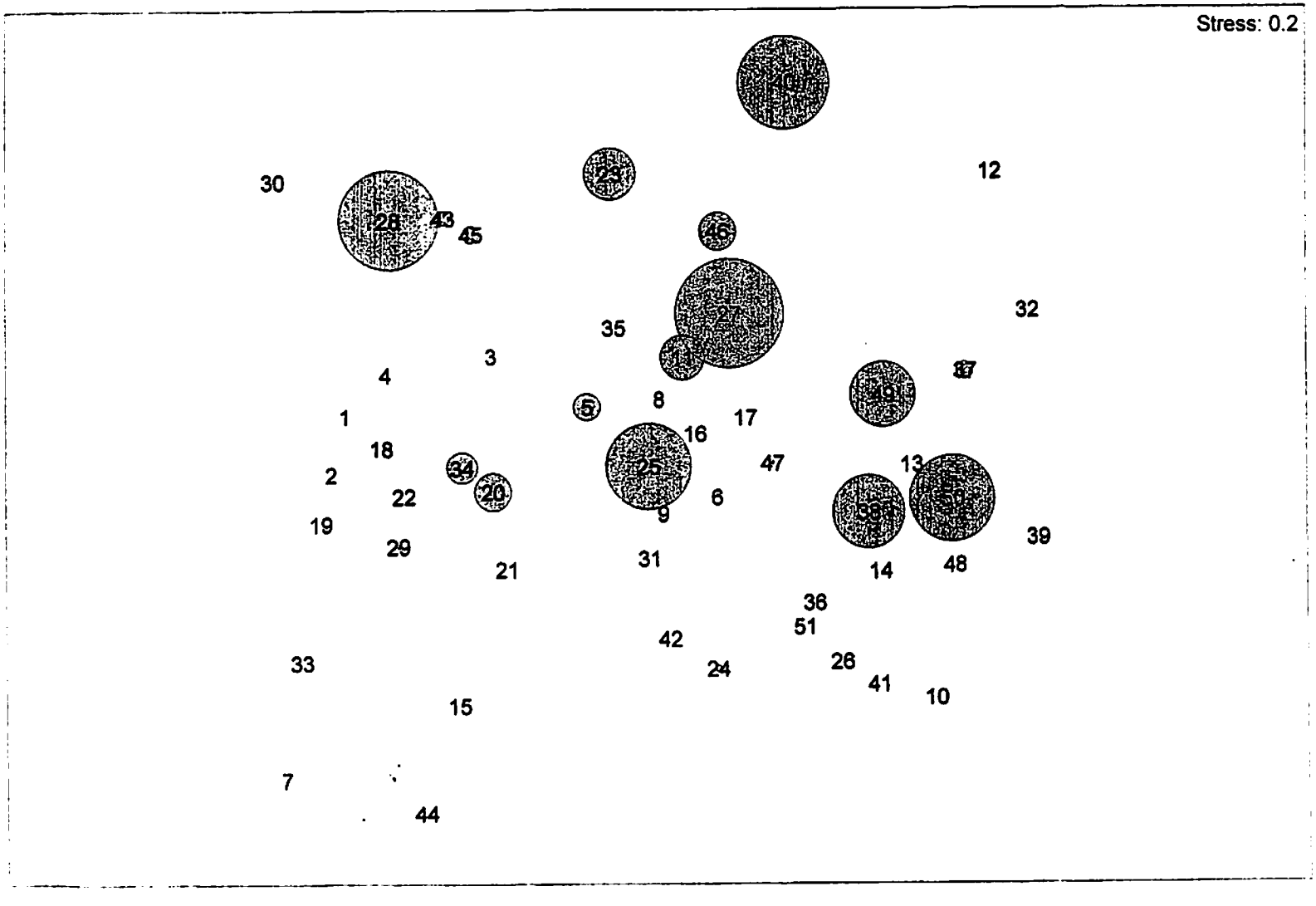
S. graminea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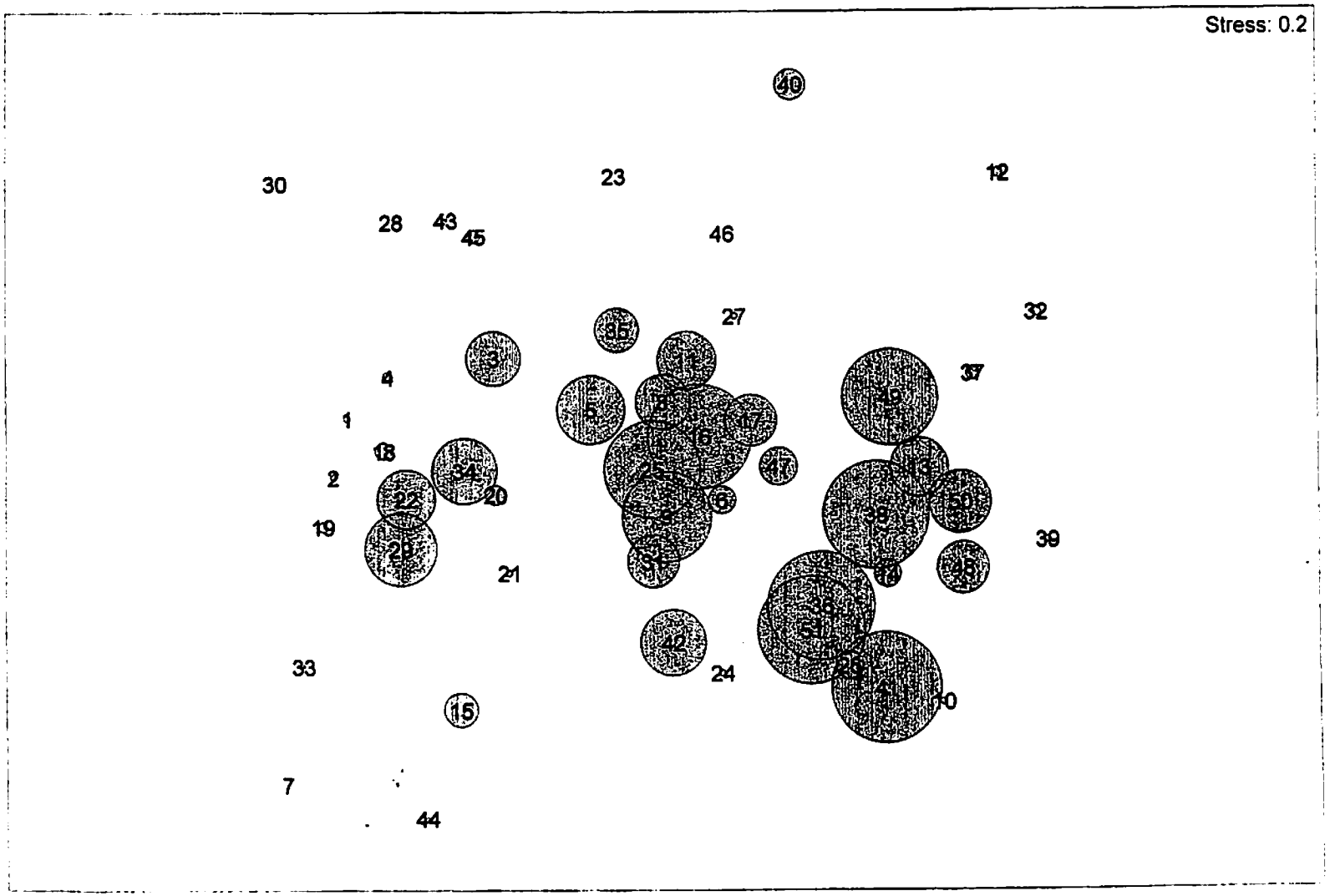
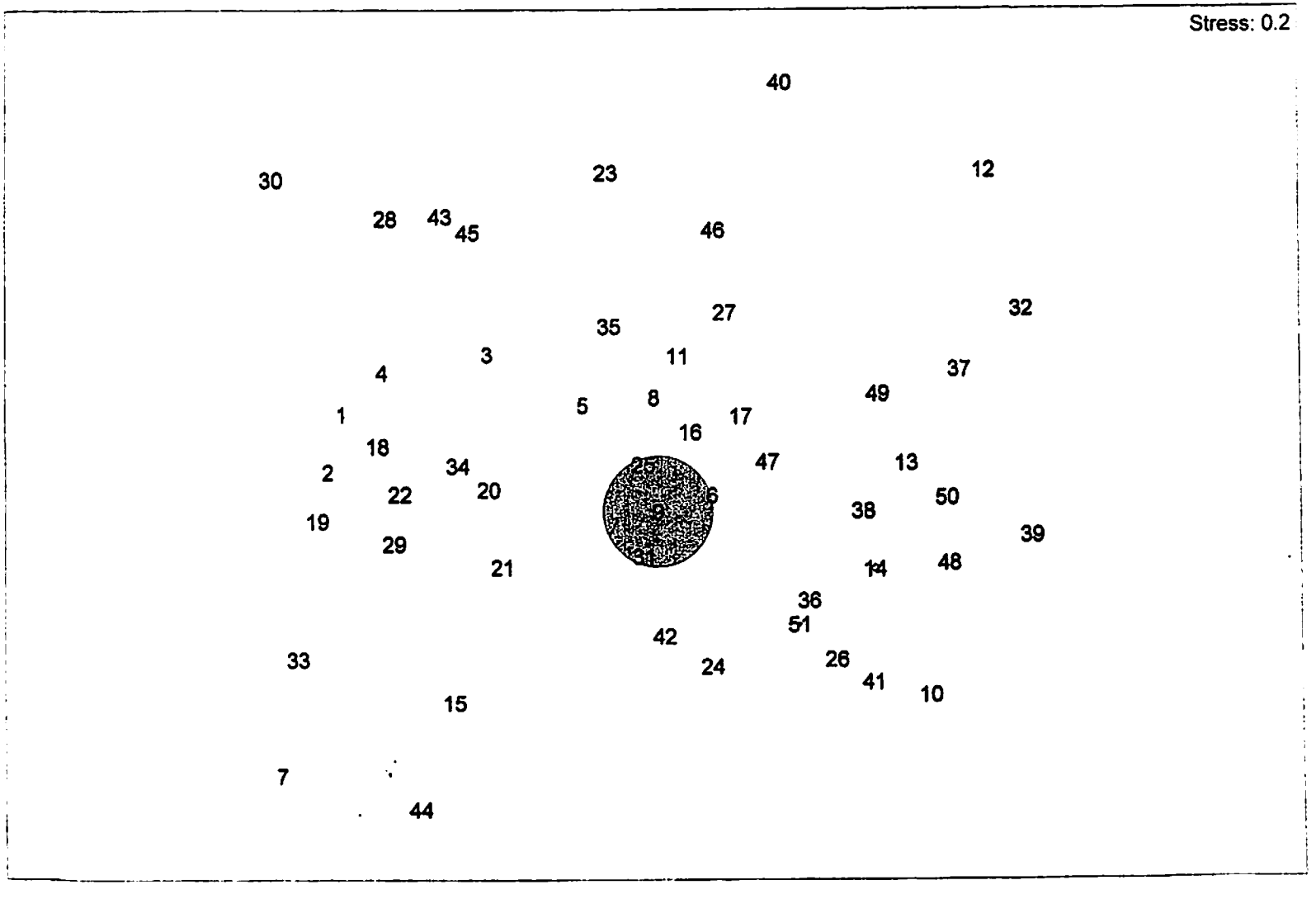
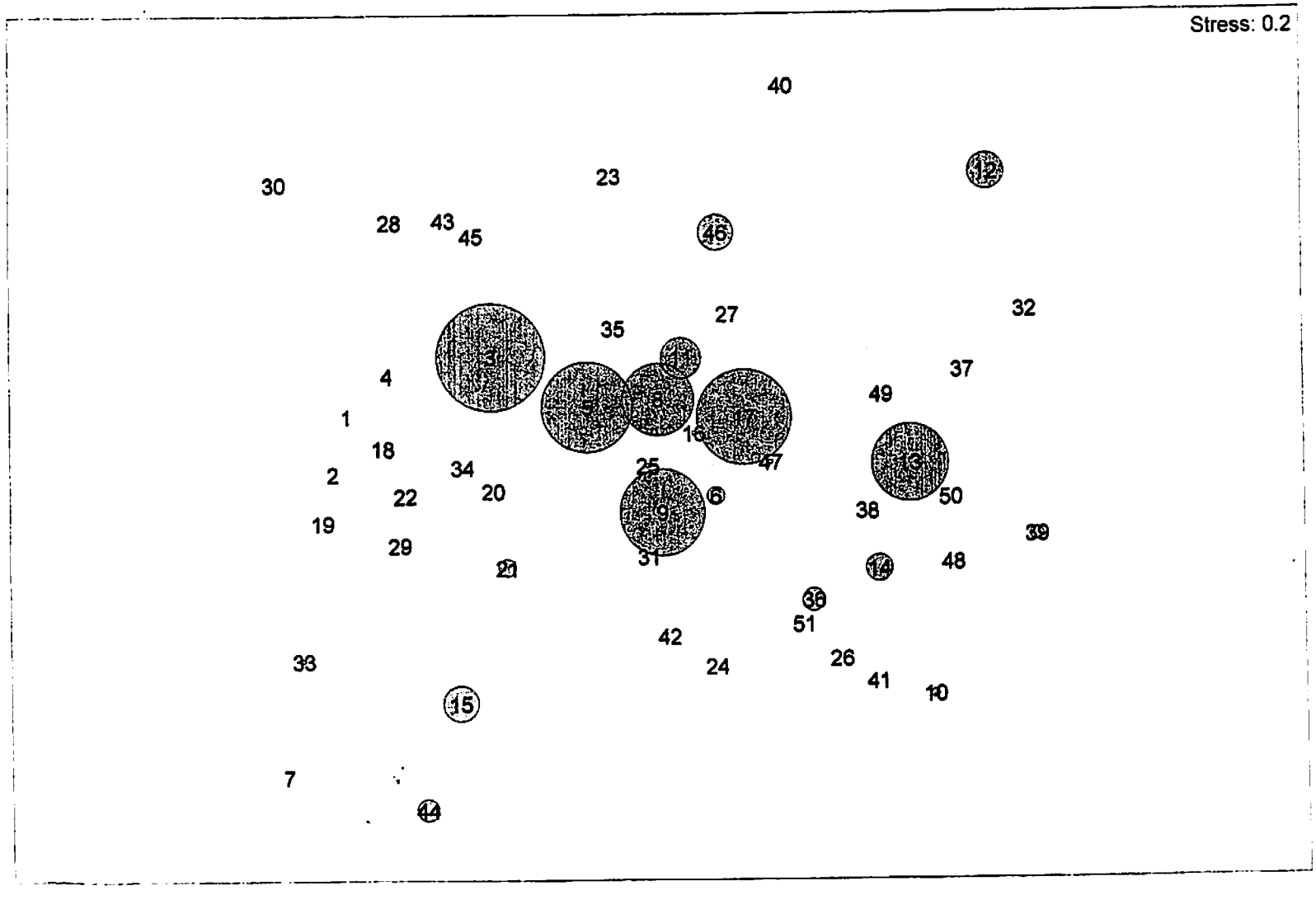
T. officinale



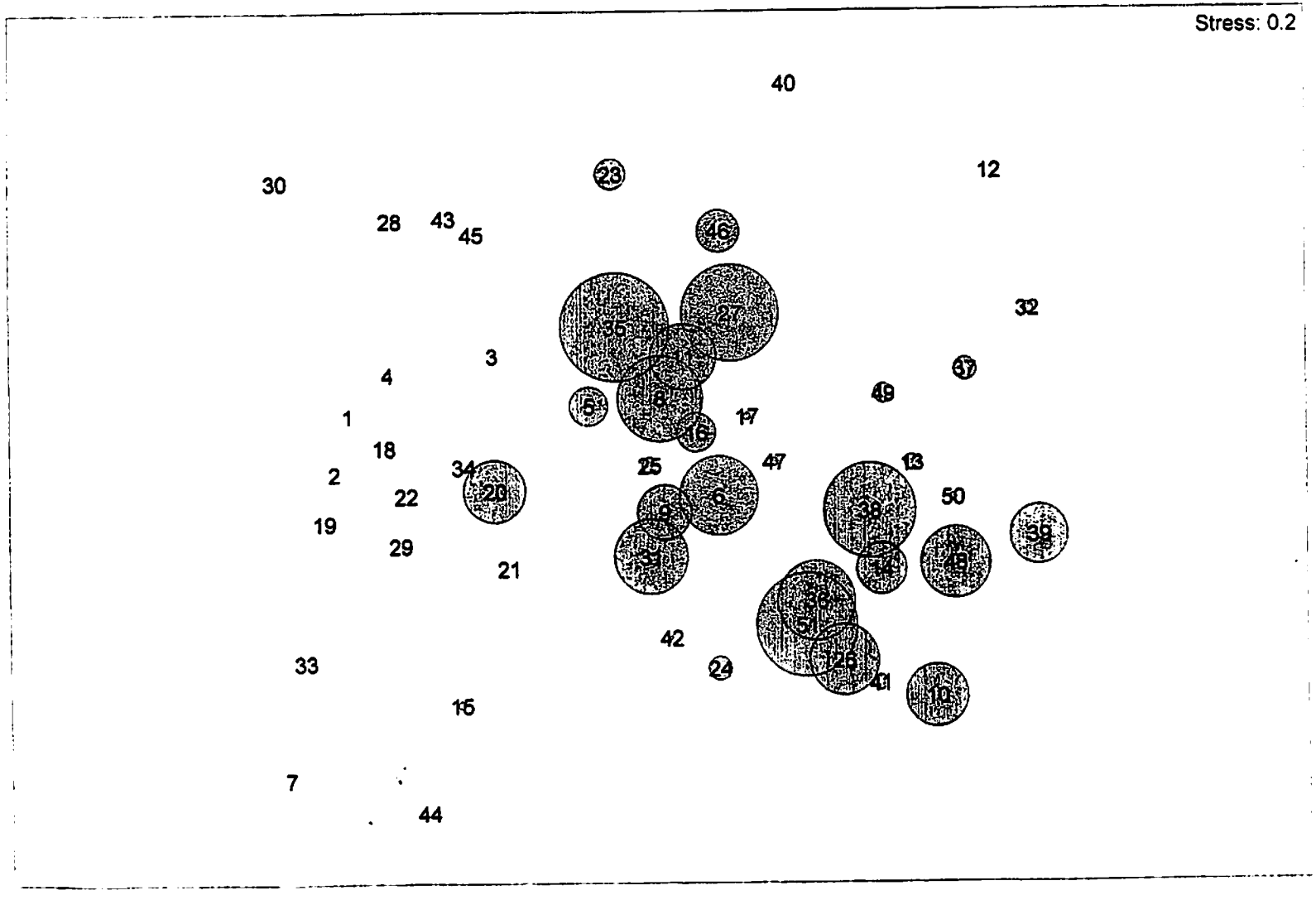
R. acetosella



L. autumnalis



C.vulgatum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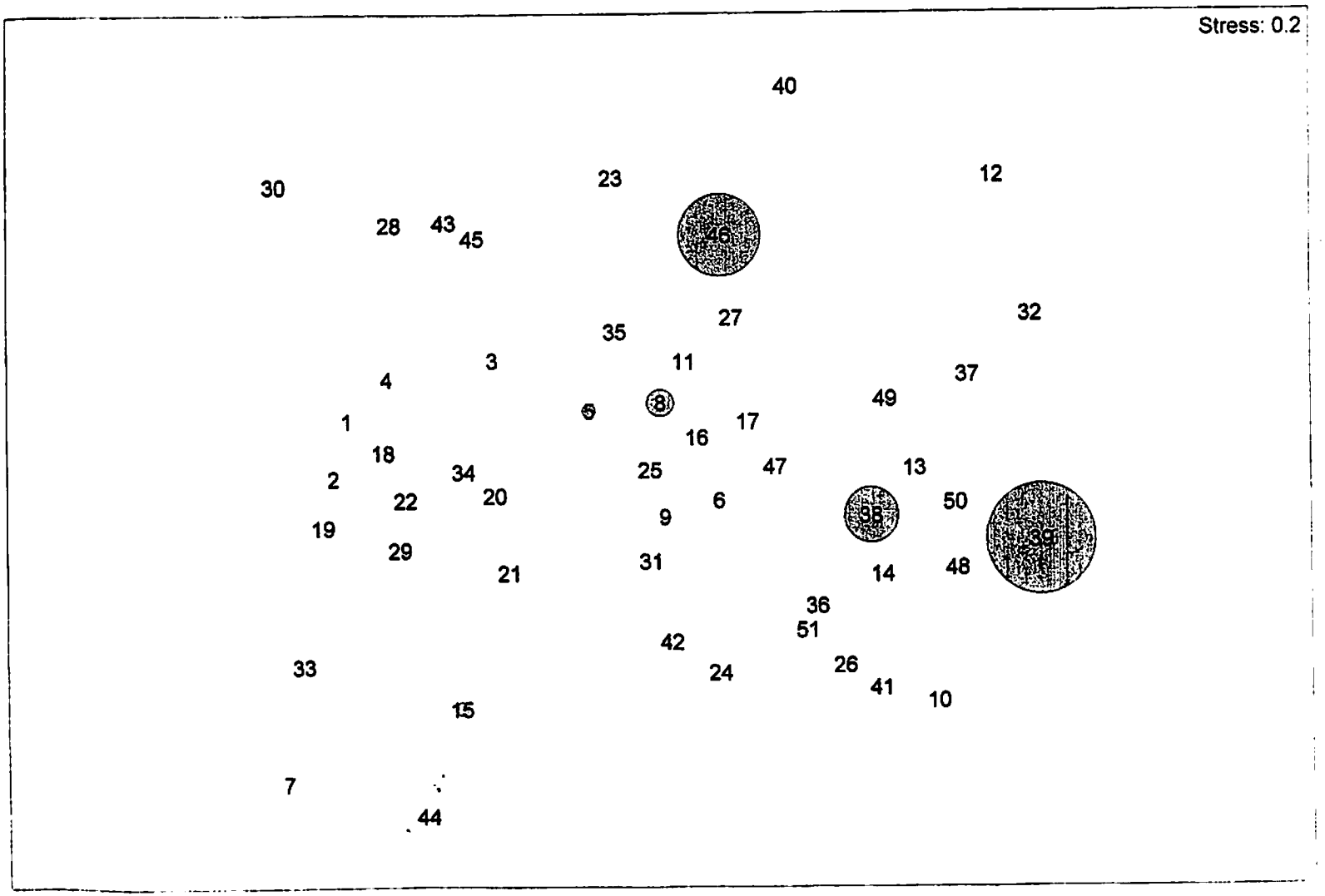
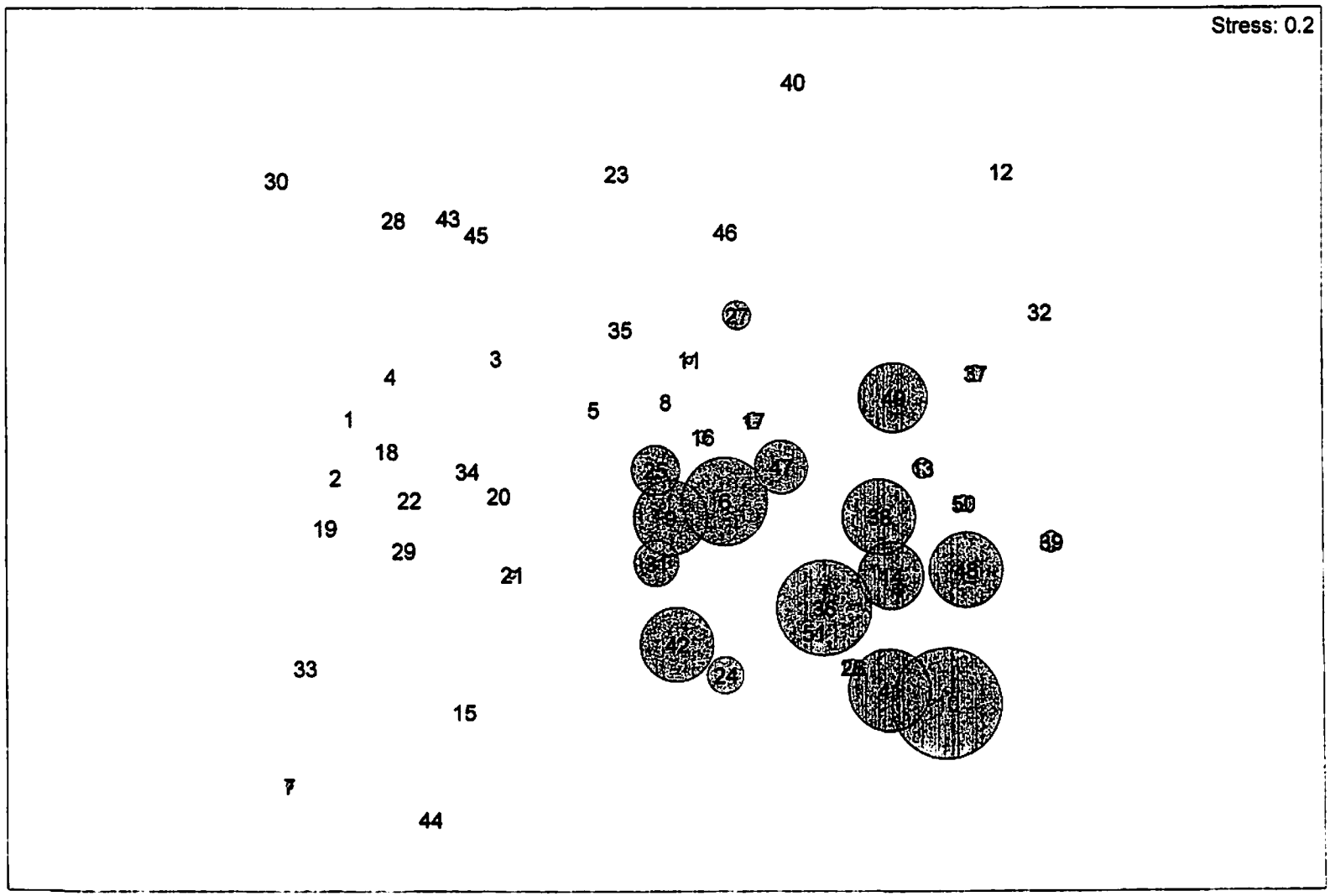
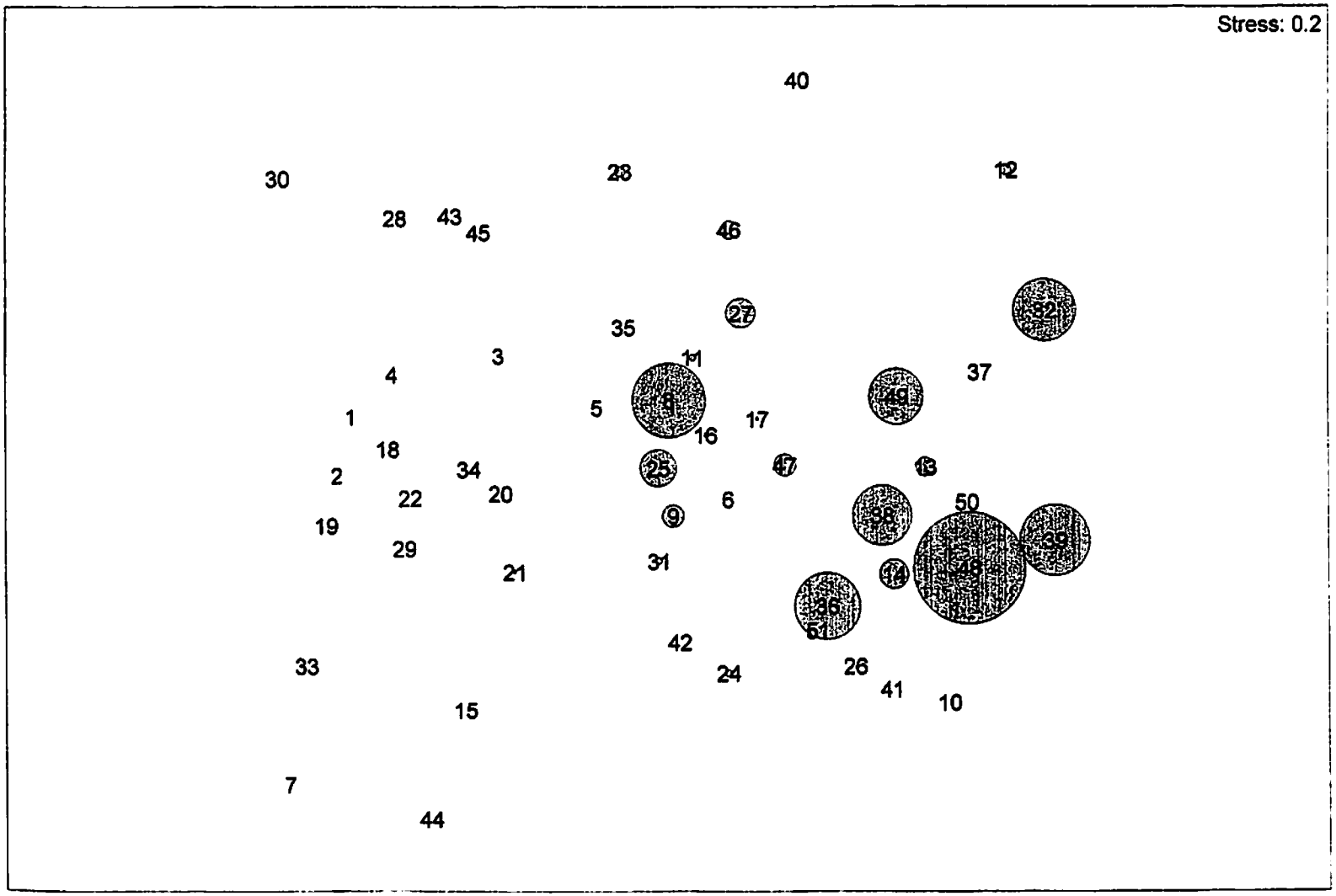
F.virginiana



V. serpyllifolia



P. vulgaris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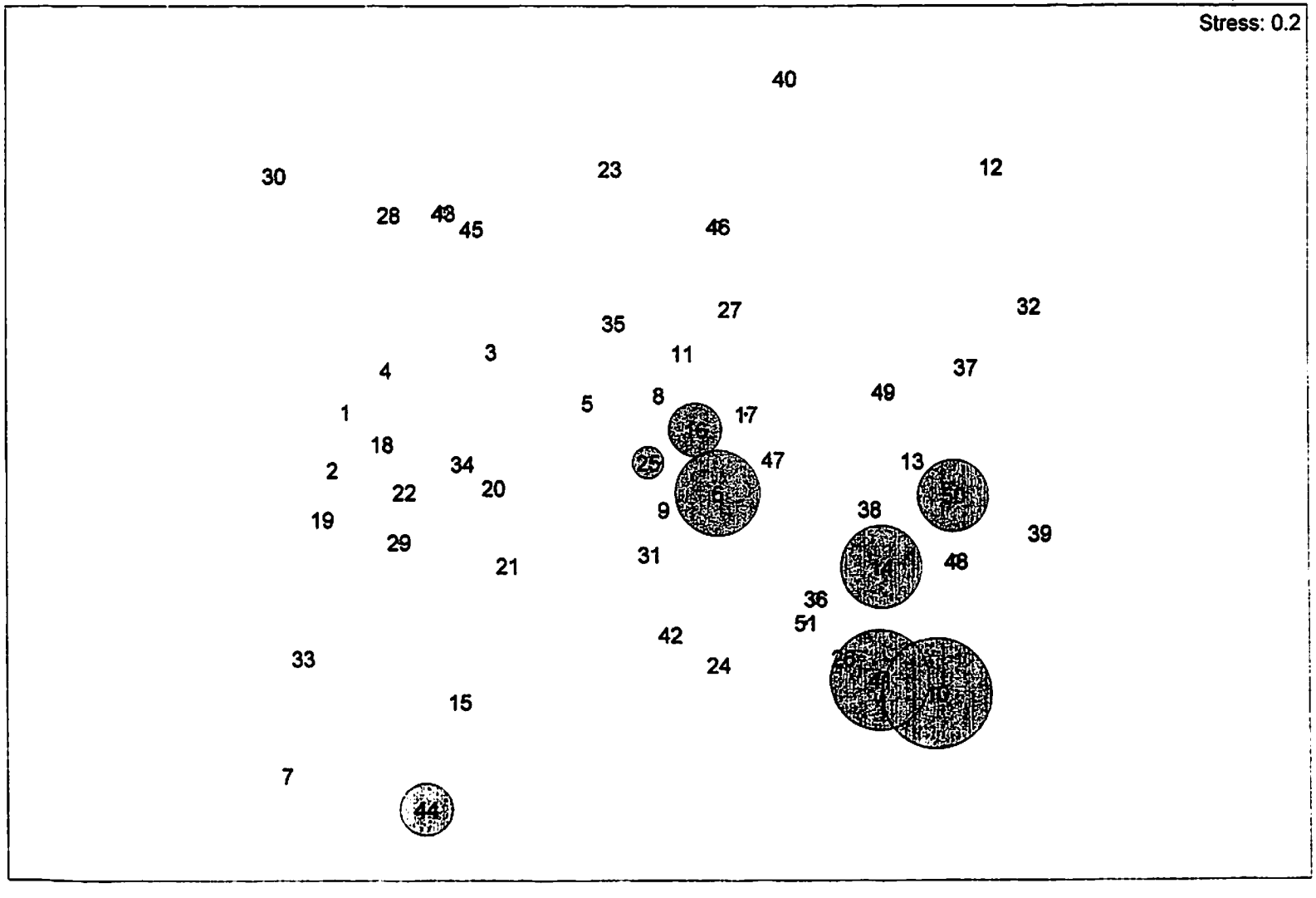
M. lupulina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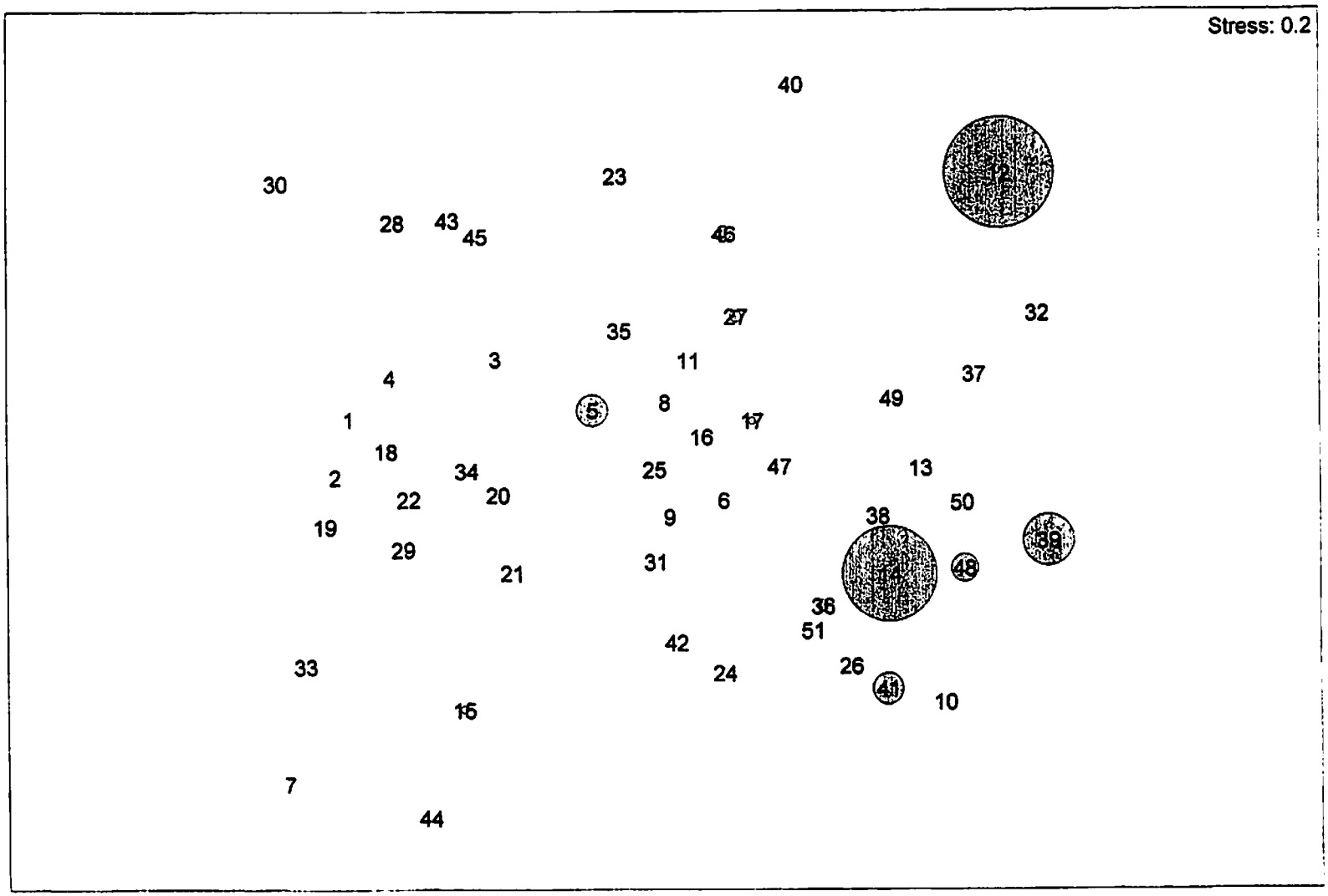
H. pilosella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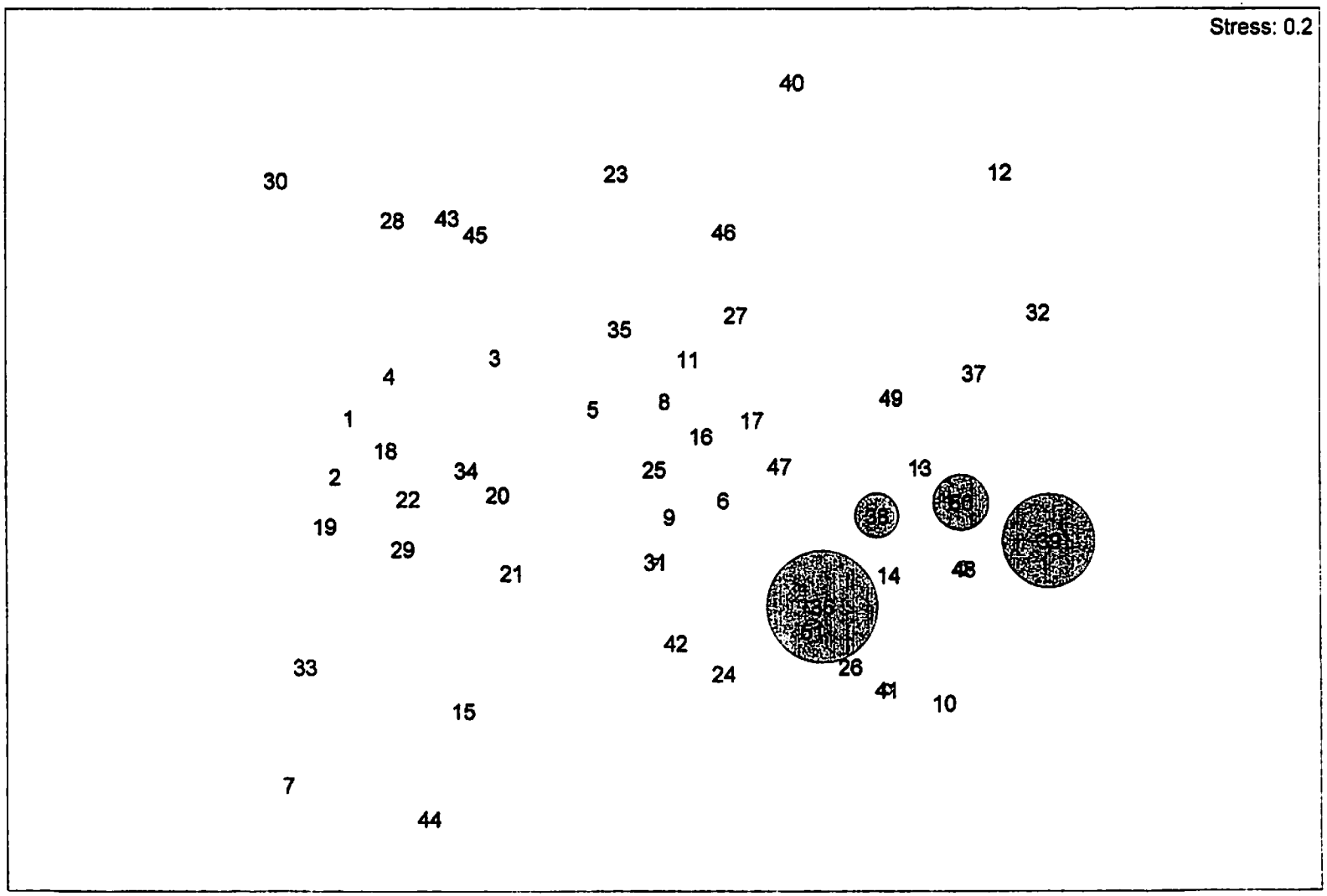
O. stricta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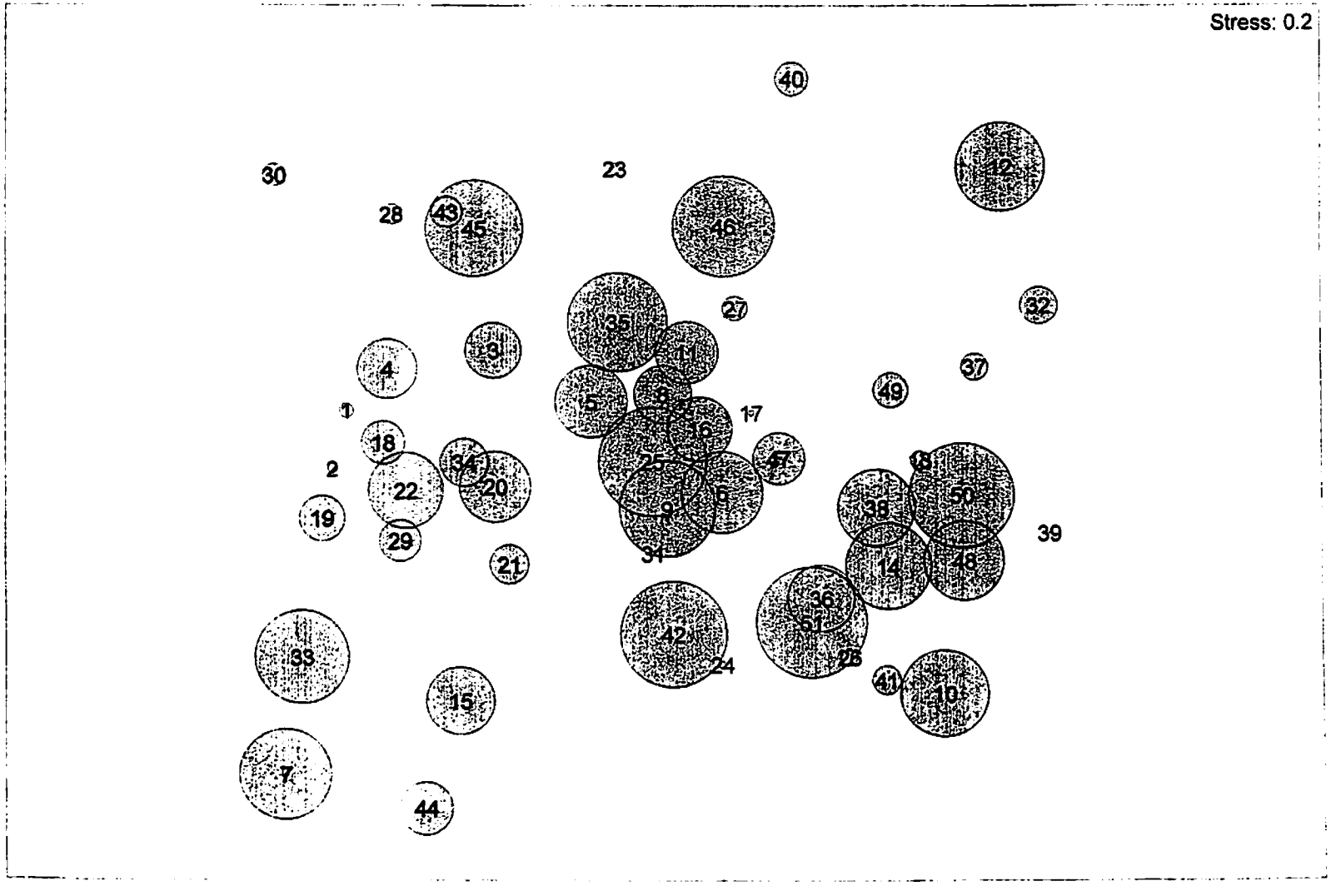
V. officinalis

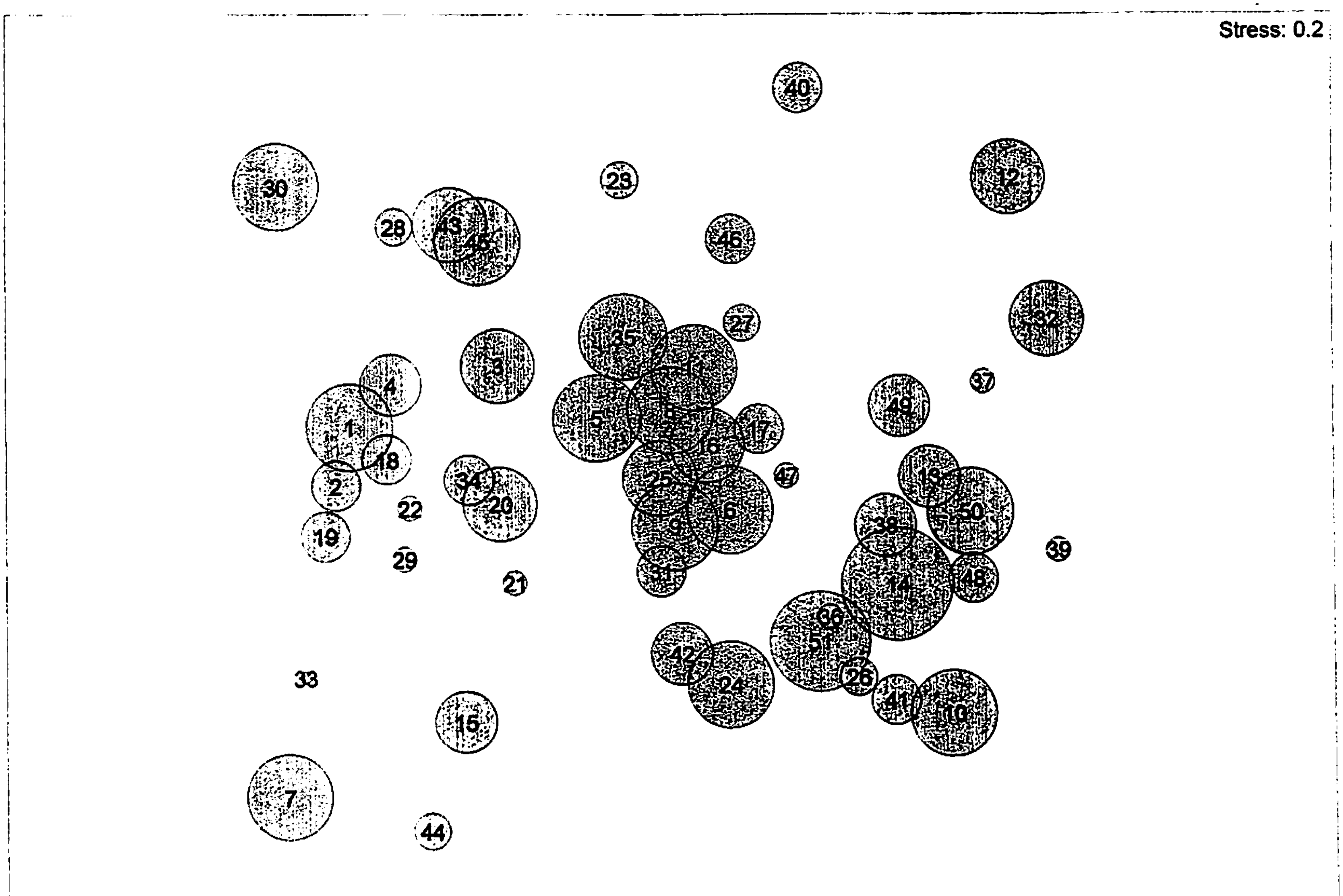
Appendix 7. Bubble plots for environmental variables. The measurement is proportional to the size of the bubbles.

Penetrability

Colour Ranking



Texture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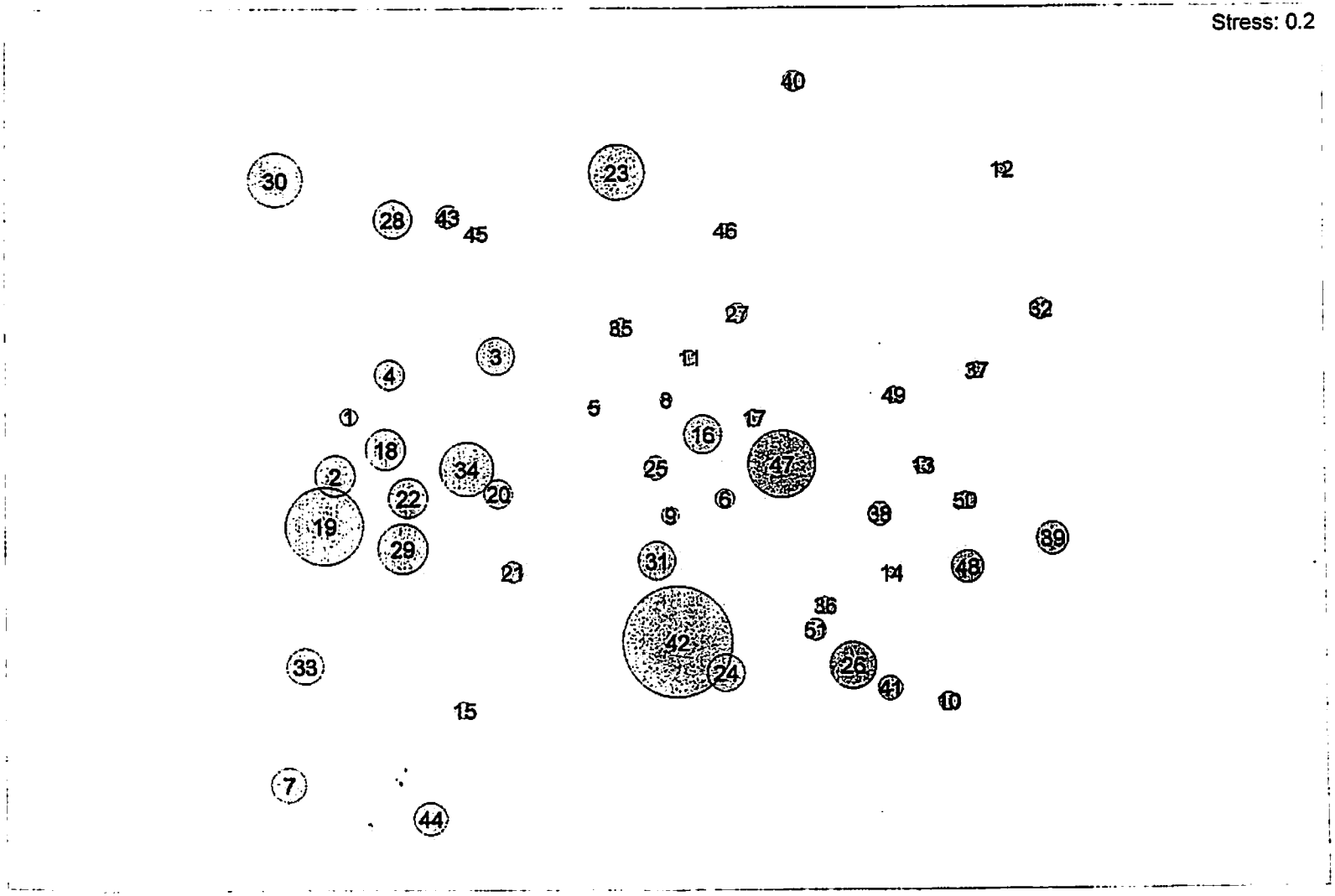
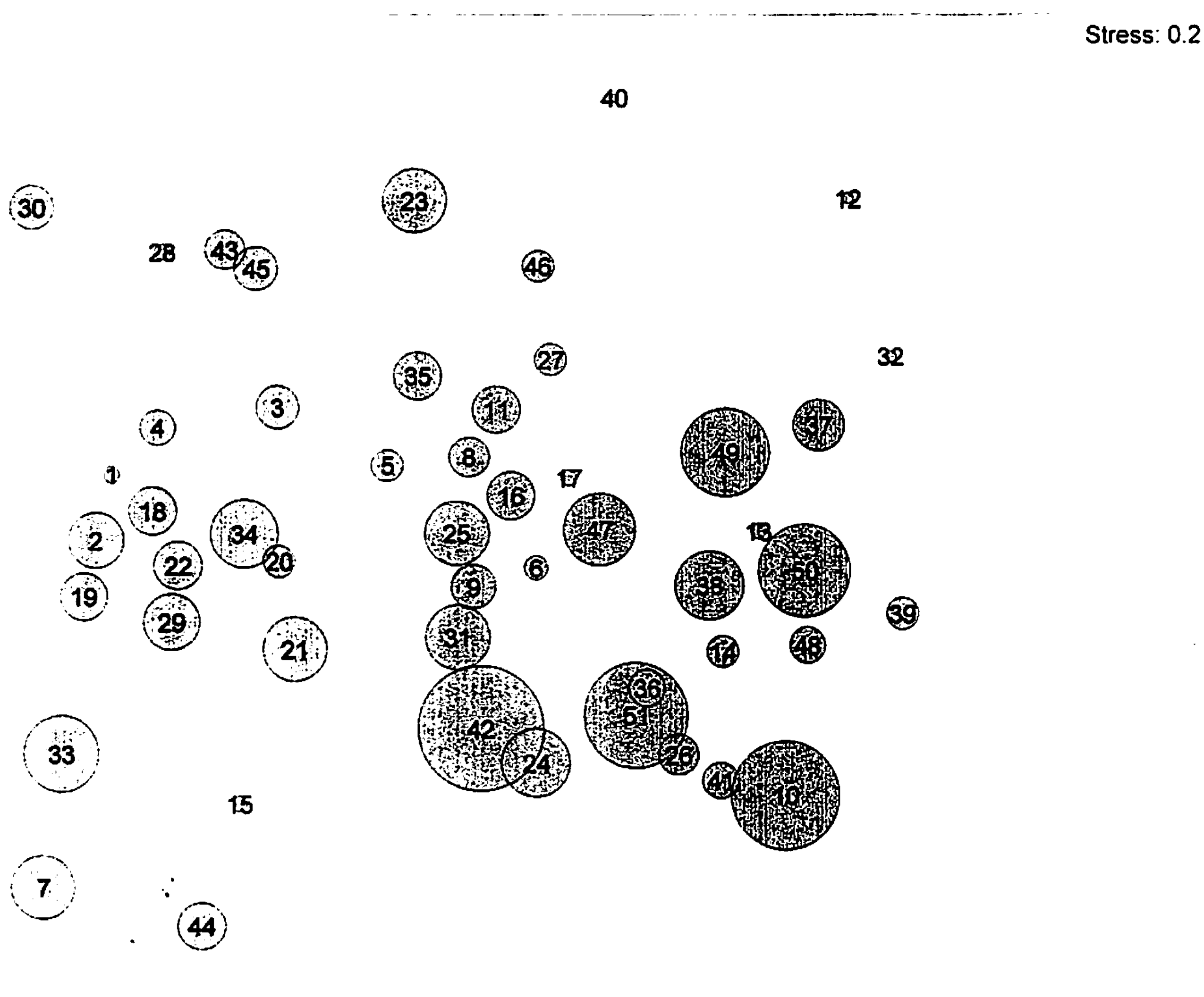
Electroconductivity



pH+CaCl2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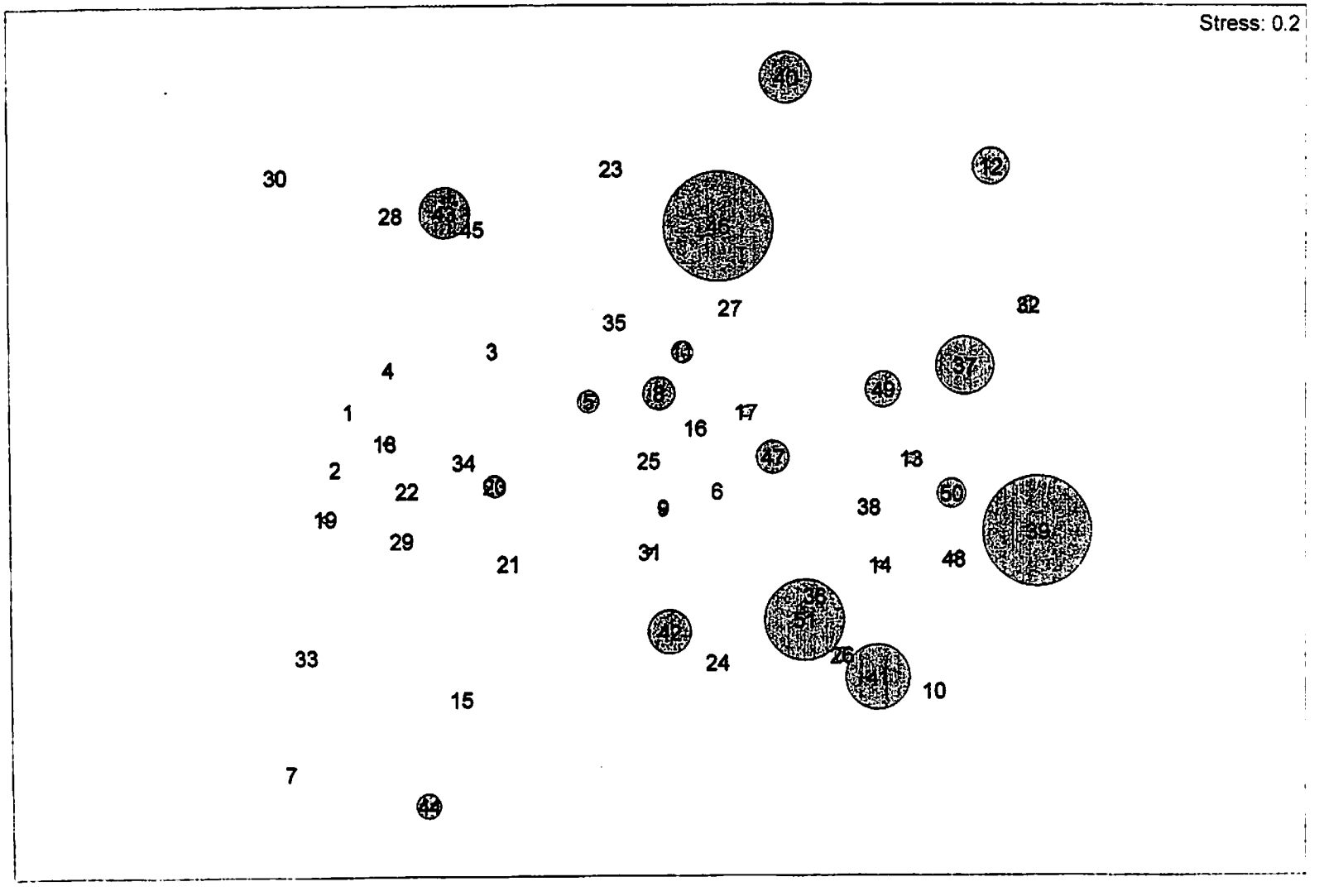
Slope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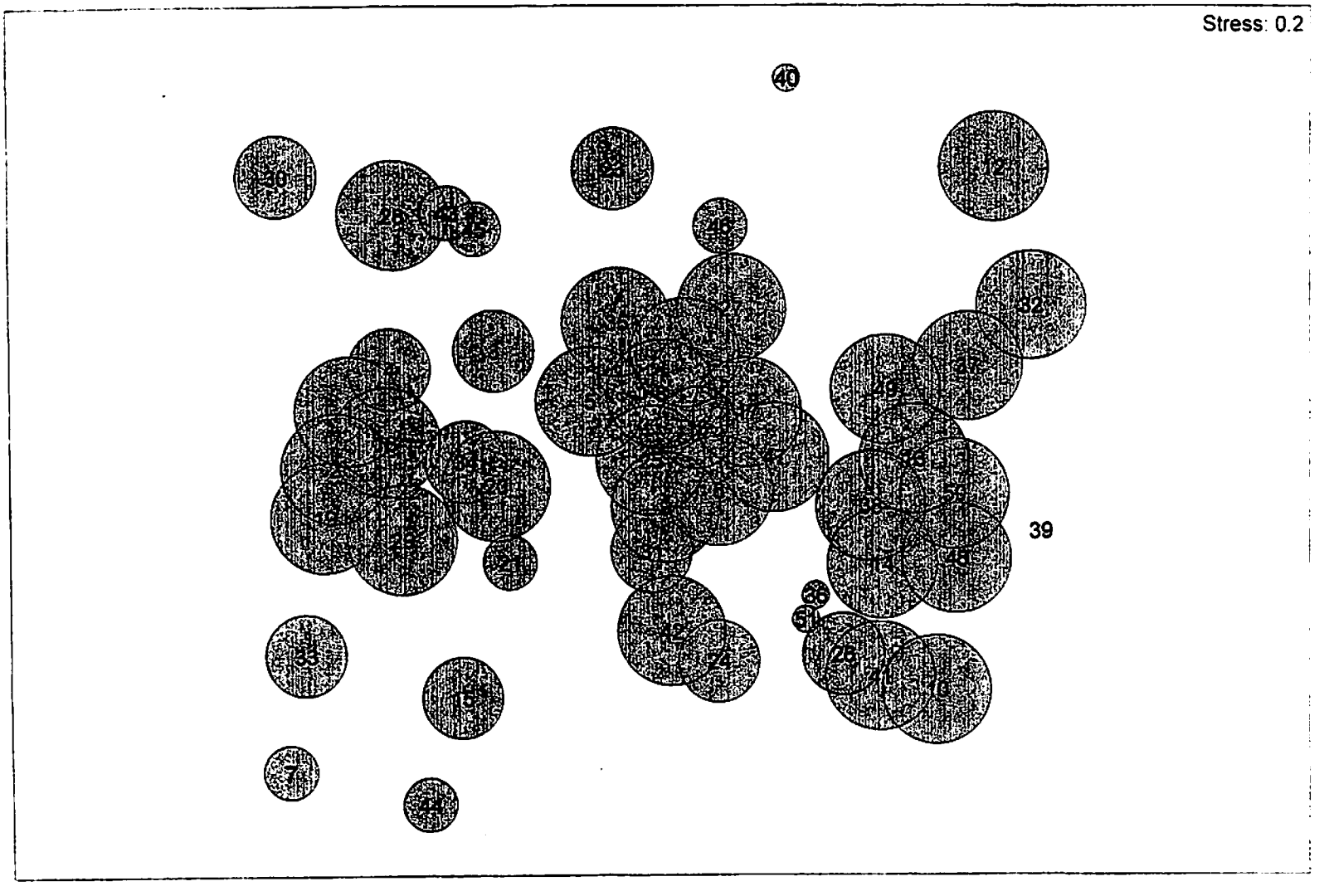
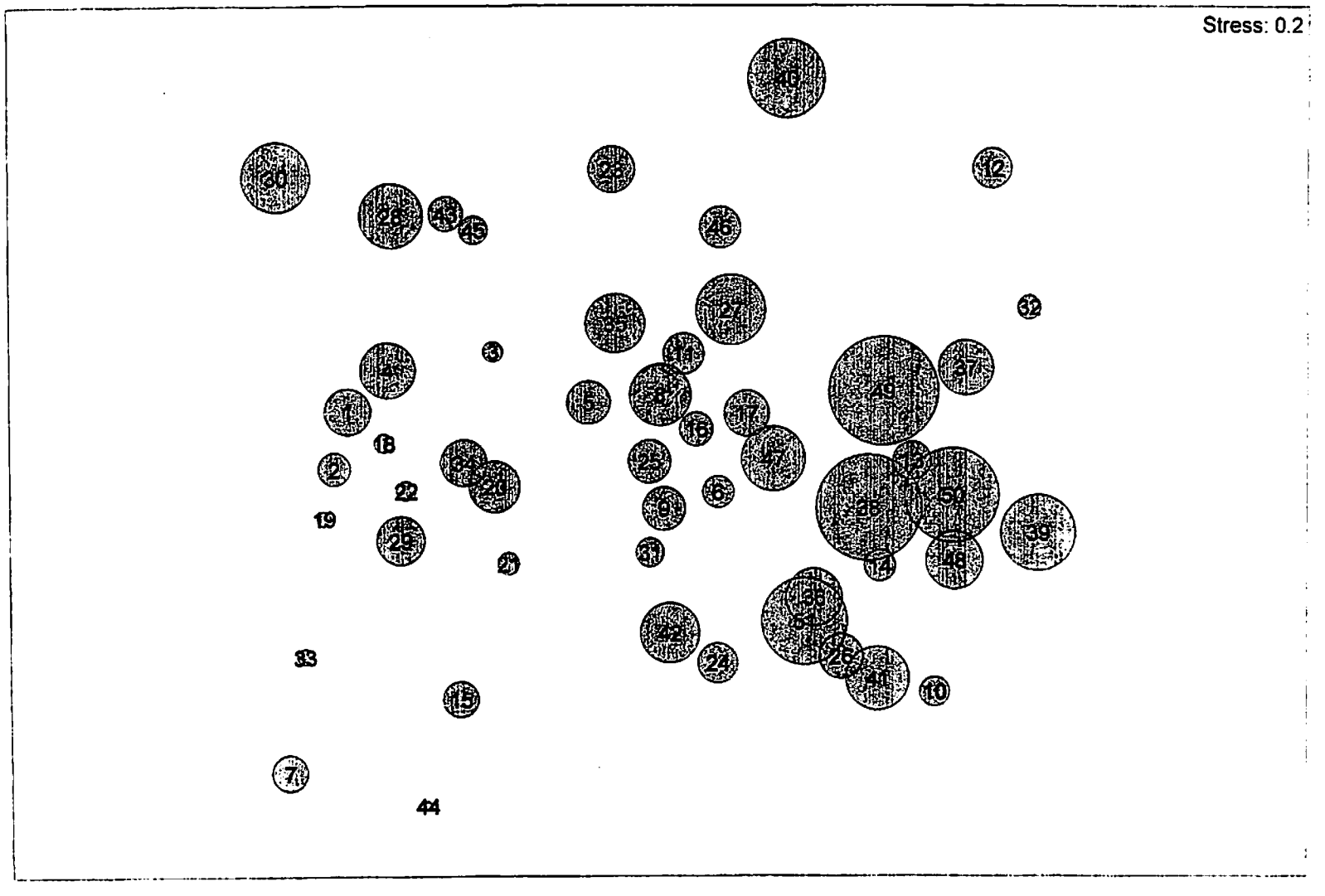
Age



Depth



Appendix 8. Frequency of species sets. Species are broken down into frequency across the set, average quadrat frequency within the set, and average quadrat frequency on sites where the species occurred.

All

	Occur	QF_1	QF_2
T. repens	36	45.16	63.98
T. officinale	46	35.36	39.20
P. major	27	25.37	47.92
C. vulgatum	32	23.96	38.18
V. serpyllifolia	26	17.39	34.12
S. graminea	19	16.11	43.25
P. vulgatum	22	12.13	28.13
L. autumnalis	21	11.21	27.23
M. lupulina	15	11.03	37.50
P. aviculare	14	9.62	35.04
R. repens	12	8.39	35.68
M. matricariodes	8	6.56	41.80
H. piloselia	11	6.25	28.98
O stricta	10	6.07	30.94
A. millefolium	10	5.70	29.06
F. virginiana	6	5.39	45.83
S. rubra	3	3.43	58.33
G. uligomosum	4	3.00	38.28
R. acetosella	3	2.02	34.38
V. officinalis	6	1.53	13.02

T.repens

	Occur	QF_1	QF_2
T. repens	36	63.98	69.29
T. officinale	31	32.29	41.75
P. major	22	32.29	44.58
C. vulgatum	19	21.70	43.06
S. graminea	13	14.24	42.45
P. aviculare	14	13.63	21.43
L. autumnalis	16	12.85	32.21
V. serpyllifolia	14	11.28	30.77
R. repens	11	10.50	34.38
M. matricariodes	8	9.29	7.81
M. lupulina	10	8.25	30.86
A. millefolium	9	7.47	32.03
P. vulgatum	13	6.34	17.55
S. rubra	3	4.86	0.00
G. uligomosum	4	4.25	3.13
H. piloselia	6	3.73	25.63
F. virginiana	4	3.47	37.50
R. acetosella	3	2.86	34.38
O stricta	2	0.69	12.50
V. officinalis	2	0.43	7.81

H. pilosella (/9)

	Occur	QF_1	QF_2
C. vulgatum	8	34.03	38.28
H. pilosella	9	33.68	33.68
T. officinale	8	33.68	37.89
T. repens	5	32.29	58.13
P. vulgatum	7	25.69	33.04
V. serpyllifolia	6	24.31	36.46
L. autumnalis	6	22.92	34.38
F. virginiana	3	20.83	62.50
M. lupulina	5	20.14	36.25
S. graminea	3	17.71	53.13
R. repens	3	14.24	42.71
O stricta	3	11.11	33.33
P. major	2	5.90	26.56
V. officinalis	2	2.78	12.50
A. millefolium	2	1.74	7.81
R. acetosella	1	0.69	6.25
G. uligomosum	0	0.00	0.00
M. matricariodes	0	0.00	0.00
P. aviculare	0	0.00	0.00
S. rubra	0	0.00	0.00

T. Officinale (40)

	Occur	QF_1	QF_2
T. repens	25	42.42	67.88
T. officinale	40	42.11	42.11
C. vulgatum	29	28.91	39.87
V. serpyllifolia	25	22.02	35.23
P. major	19	19.69	41.45
S. graminea	15	16.17	43.12
P. vulgatum	10	14.84	29.69
L. autumnalis	17	12.58	29.60
M. lupulina	12	12.58	41.93
O stricta	10	7.73	30.94
R. repens	10	7.73	30.94
H. pilosella	9	7.50	33.33
A. millefolium	8	6.72	33.59
F. virginiana	4	4.69	46.88
P. aviculare	7	3.75	21.43
R. acetosella	3	2.58	34.38
V. officinalis	6	1.95	13.02
M. matricariodes	2	0.39	7.81
G. uligomosum	1	0.08	3.13
S. rubra	0	0.00	0.00

V. serpyllifolia (/25)

	Occur	QF_1	QF_2
T. officinale	25	50.25	50.25
C. vulgatum	24	36.38	37.89
V. serpyllifolia	25	35.23	35.23
T. repens	13	28.50	54.81
M. lupulina	11	19.75	44.89
P. vulgatum	17	18.75	27.57
S. graminea	9	17.87	49.64
P. major	10	15.50	38.75
O stricta	9	12.25	34.03
L. autumnalis	13	11.63	22.36
H. piloselia	7	7.50	26.79
R. repens	6	7.13	29.69
F. virginiana	2	6.00	75.00
A. millefolium	4	5.50	34.38
R. acetosella	3	4.13	34.38
V. officinalis	6	3.13	13.02
G. uligomosum	1	0.13	3.13
P. aviculare	1	0.13	3.13
M. matricariodes	0	0.00	0.00
S. rubra	0	0.00	0.00

P. major (/20)

	Occur	QF_1	QF_2
T. repens	15	54.84	73.13
T. officinale	19	46.56	49.01
P. major	20	40.00	40.00
C. vulgatum	12	24.69	41.15
V. serpyllifolia	10	21.09	42.19
S. graminea	7	16.40	46.86
L. autumnalis	7	13.91	39.73
R. repens	9	13.44	29.86
P. vulgatum	8	11.72	29.30
O stricta	4	7.34	36.72
P. aviculare	5	7.19	28.75
M. lupulina	3	6.25	41.67
R. acetosella	1	4.69	93.75
A. millefolium	4	4.53	22.66
F. virginiana	3	4.38	29.17
H. piloselia	3	2.97	19.79
M. matricariodes	2	0.78	7.81
V. officinalis	3	0.78	5.21
G. uligomosum	1	0.16	3.13
S. rubra	0	0.00	0.00

Open sites (/19)

	Occur	QF_1	QF_2
T. repens	13	59.87	87.50
T. officinale	17	30.92	36.72
S. graminea	8	21.88	51.95
M. lupulina	6	16.45	52.08
P. major	8	14.64	34.77
C. vulgatum	8	13.16	31.25
V. serpyllifolia	8	13.16	31.25
A. millefolium	6	11.18	35.42
F. virginiana	2	9.21	87.50
L. autumnalis	7	8.39	22.77
O stricta	4	7.24	34.38
P. vulgatum	6	7.07	22.40
P. aviculare	3	4.44	28.13
H. piloselia	3	4.11	26.04
R. repens	2	1.48	14.06
M. matricariodes	1	0.33	6.25
V. officinalis	1	0.16	3.13
G. uligomosum	0	0.00	0.00
R. acetosella	0	0.00	0.00
S. rubra	0	0.00	0.00

Treed sites (/12)

	Occur	QF_1	QF_2
T. officinale	12	33.59	33.59
C. vulgatum	11	23.70	25.85
P. major	6	22.66	45.31
V. serpyllifolia	9	22.35	29.81
T. repens	6	21.09	42.19
L. autumnalis	5	17.19	41.25
R. repens	5	14.06	33.75
P. vulgatum	8	10.94	16.41
H. piloselia	2	7.81	46.88
R. acetosella	1	7.81	93.75
S. graminea	4	4.94	14.81
P. aviculare	2	4.17	25.00
V. officinalis	3	3.65	14.58
O stricta	6	0.78	4.69
A. millefolium	1	0.78	9.38
M. matricariodes	1	0.78	9.38
G. uligomosum	1	0.26	3.13
M. lupulina	1	0.26	3.13
F. virginiana	0	0.00	0.00
S. rubra	0	0.00	0.00

DAL sites (/14)

	Occur	QF_1	QF_2
T. repens	11	64.73	82.39
T. officinale	14	40.85	40.85
L. autumnalis	12	32.81	38.28
C. vulgatum	10	28.57	40.00
V. serpyllifolia	8	21.39	37.44
M. lupulina	5	20.98	58.75
A. millefolium	6	14.06	32.81
H. piloselia	4	13.84	48.44
P. major	6	11.38	26.56
P. vulgatum	8	10.27	17.97
R. repens	2	7.81	54.69
R. acetosella	2	7.14	50.00
S. graminea	2	4.69	32.81
F. virginiana	2	2.68	18.75
P. aviculare	1	2.23	31.25
O stricta	1	0.22	3.13
G. uligomosum	0	0.00	0.00
M. matricariodes	0	0.00	0.00
S. rubra	0	0.00	0.00
V. officinalis	0	0.00	0.00

SMU sites (/14)

	Occur	QF_1	QF_2
T. repens	11	54.91	69.89
P. major	10	37.28	52.19
S. graminea	7	27.45	54.89
T. officinale	11	23.88	30.40
C. vulgatum	8	22.10	38.67
R. repens	8	21.21	37.11
V. serpyllifolia	6	10.04	23.44
P. vulgatum	7	9.60	19.20
P. aviculare	4	8.04	28.13
M. lupulina	1	2.01	28.13
L. autumnalis	2	1.12	7.81
M. matricariodes	2	1.12	7.81
H. piloselia	1	0.67	9.38
O stricta	1	0.45	6.25
G. uligomosum	1	0.22	3.13
A. millefolium	0	0.00	0.00
F. virginiana	0	0.00	0.00
R. acetosella	0	0.00	0.00
S. rubra	0	0.00	0.00
V. officinalis	0	0.00	0.00

MSVU sites (/16)

	Occur	QF_1	QF_2
T. officinale	16	48.63	51.88
C. vulgatum	13	31.64	38.94
V. serpyllifolia	11	27.54	40.06
S. graminea	9	23.05	40.97
P. vulgatum	7	21.29	48.66
T. repens	7	20.90	47.77
O stricta	8	18.75	37.50
F. virginiana	3	14.06	75.00
M. lupulina	7	11.91	27.23
P. major	4	7.42	29.69
H. piloselia	5	6.84	21.88
A. millefolium	3	5.08	27.08
V. officinalis	6	4.88	13.02
L. autumnalis	4	3.32	13.28
R. repens	2	1.37	10.94
P. aviculare	2	0.39	3.13
R. acetosella	1	0.20	3.13
G. uligomosum	0	0.00	0.00
M. matricariodes	0	0.00	0.00
S. rubra	0	0.00	0.00

Edge sites (/7)

	Occur	QF_1	QF_2
P. major	7	70.54	70.54
P. aviculare	7	48.66	48.66
M. matricariodes	6	45.54	53.13
T. repens	7	41.96	41.96
S. rubra	3	25.00	58.33
G. uligomosum	3	21.43	50.00
T. officinale	6	16.96	19.79
M. lupulina	2	7.14	25.00
L. autumnalis	3	6.25	14.58
A. millefolium	1	1.79	12.50
F. virginiana	1	1.79	12.50
C. vulgatum	1	0.89	6.25
H. piloselia	1	0.89	6.25
V. serpyllifolia	1	0.89	6.25
S. graminea	1	0.45	3.13
O stricta	0	0.00	0.00
P. vulgatum	0	0.00	0.00
R. repens	0	0.00	0.00
R. acetosella	0	0.00	0.00
V. officinalis	0	0.00	0.00

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