Cryptogamie, Algol., 2006, 27 (2): 153-164

The use of CHAID classification trees as an effective descriptor of the distribution of *Rosenvingiella radicans* (Prasiolales, Chlorophyta) in urban environments

Juan Luis MENÉNDEZ [a], Fabio RINDI [b], José M. RICO [a] & Michael D. GUIRY [b]*

[a] *Área de Ecología, Departamento de Biología de Organismos y Sistemas, Universidad de Oviedo, E-33071, Oviedo, SPAIN*

[b] *Martin Ryan Institute, National University of Ireland, Galway, Ireland*

(Received 6 May 2005, accepted 28 November 2005)

Abstract — Terrestrial algae are a common component of urban ecosystems, but the factors that affect their distribution are poorly understood. Rosenvingiella radicans is a filamentous green alga widespread in Atlantic Europe, where it often produces green patches at the base of urban walls. The distribution of this alga has been analysed by Chi-Square Automatic Interaction Detection (CHAID) in two western European cities, Oviedo (Spain) and Galway (Ireland). The analysis considered five factors: type of habitat, substratum, orientation of the colonized surface, type of area and intervening space. The results indicated that the type of habitat was the most important factor, although intervening space and orientation of the surface were also influential factors. Overall, it is considered that these factors interacted to create local conditions of high humidity, suitable for the colonization of the alga. No major differences in distributional patterns were detected between the two cities. This was the first study in which the CHAID procedure was applied to algae and it is concluded that its use is worthy of consideration for other species and algal assemblages.

Habitat characterization / species distribution / terrestrial algae / *Rosenvingiella radicans* / CHAID trees

Résumé – Utilisation des arbres de classification CHAID comme un descripteur efficace de la distribution de *Rosenvingiella radicans* (Prasiolales, Chlorophyta) en environnement urbain. Les algues terrestres sont des composantes communes des écosystèmes urbains, mais les facteurs qui affectent leur distribution sont mal compris. *Rosenvingiella radicans* est une algue verte filamenteuse répandue en Europe atlantique, où elle forme des “ patches ” à la base des murs des villes. La distribution de cette algue a été analysée par le CHAID (*Chi-Square Automatic Interaction Detection*) dans deux villes d'Europe de l'Ouest : Oviedo (Espagne) et Galway (Irlande). L'analyse a pris en compte cinq facteurs : type d'habitat, substrat, orientation de la surface colonisée, type d'aire et d'espace intermédiaire. Les résultats montrent que le type d'habitat est le facteur le plus important, bien que l'espace intermédiaire et l'orientation de la surface soient aussi des facteurs

* Correspondence and reprints: jluism@asturnatura.com
Corresponding editors: Fabio Rindi & John Huisman

influents. En plus, il est envisageable que ces facteurs interagissent pour créer des conditions locales de forte humidité, utiles pour la colonisation de l'algue. C'est la première étude dans laquelle la procédure de la CHAID est appliquée aux algues, et il est conclu que son usage serait utile pour les autres espèces et assemblages d'algues.

Algues terrestres / arbres de la CHAID / caractérisation de l'habitat / distribution des espèces / *Rosenvingiella radicans*

INTRODUCTION

Ecological research has traditionally focused on the structure of ecosystems in natural environments. However, the massive worldwide growth in the number and size of cities that has taken place in the last century has increasingly attracted the interest of ecologists to these environments. Some of the most-developed aspects are the description of plant assemblages occurring in urban environments (Dana *et al.*, 2002) and the impact of cities in natural ecosystems (McDonnell *et al.*, 1997). Terrestrial algae are a widespread component of urban ecosystems. Species of green algae and cyanobacteria are common in urban habitats, both in temperate and tropical regions (Wee *et al.*, 1980; Lee *et al.*, 1982; Tripathi *et al.*, 1990; Ortega-Calvo *et al.*, 1991; Rifón-Lastra *et al.*, 2001; Rindi & Guiry, 2004; Uher *et al.*, 2005). The widespread availability of artificial substrata, such as cement, asphalt and concrete, in urban habitats provides a range of surfaces suitable for the colonisation of terrestrial algae. However, very few investigations of urban algae have attempted to analyse in some detail the factors affecting the distribution of these organisms. Most studies available on this subject are purely descriptive (Wee *et al.*, 1980; Ortega-Calvo *et al.*, 1991; Rindi & Guiry, 2003; Uher *et al.*, 2005) and works analysing the effect of individual factors are very rare (e.g., Rindi *et al.*, 1999).

Rosenvingiella radicans (Kützing) Rindi, McIvor & Guiry (Prasiolales, Chlorophyta) is a filamentous green alga widespread in urban environments in Atlantic Europe, where it often produces green patches at the bases of old walls. The taxonomic identity of *R. radicans* has been recently clarified by Rindi *et al.* (2004). This species was well known by the phycologists of the early 19th century and in the past many names have been used to designate it. Whereas in the older literature this alga was usually considered a filamentous form of *Prasiola crispa* (Lightfoot) Meneghini (Boye Petersen, 1928; Knebel, 1935), in several recent studies (Rindi *et al.* 1999; Menéndez Valderrey & Rico, 2001; Rindi & Guiry, 2003) it has been regarded as a terrestrial form of *Rosenvingiella polyrhiza* (Rosenvinge) P.C. Silva, a marine species mainly distributed in cold-temperate regions of the northern hemisphere, frequently reported from supralittoral habitats and estuaries (Burrows, 1991; Hardy & Guiry, 2003). Rindi *et al.* (2004) provided morphological and molecular evidence of the distinctness of *R. radicans* from both *P. crispa* and *R. polyrhiza* and documented the widespread distribution of *R. radicans* from supralittoral habitats to sites located hundreds of km from the sea.

Rindi *et al*. (1999) analysed the distribution of *R. radicans* (as *R. polyrhiza*) in Galway City, on the west coast of Ireland. Their observations, based on a comparison of expected and observed frequencies of occurrence of *R. polyrhiza* in relation to several factors, suggested that a number of factors affected the distribution of this alga. The results indicated that type of habitat, type of substratum, orientation of the surface, type of area and intervening space were some of the most important, probably because they all interacted to determine local conditions of higher or lower dampness and availability of nutrients that may be more or less favourable for the colonization of *R. radicans*. The aim of the present study is to examine the relative importance of each environmental factor on the distribution of *R. radicans* and compare the distribution of this alga in Oviedo (northern Spain) and Galway (western Ireland), using a method entirely new to phycological research. Classification and decision trees are a simple and visually effective method for analysis of complex ecological data; they can be used for interactive exploration and for description and prediction of ecological patterns and processes (Kass, 1980; Biggs *et al.*, 1991; De'Ath *et al.*, 2000). Classification based on the Chi-Square Automatic Interaction Detection (CHAID) procedure is largely used in social and medical sciences (Elphinstone, 1986; Chung *et al.*, 2004; Welte *et al.*, 2004; Tan *et al.*, 2005) and, although less frequently employed, has also proven useful in biological studies (Schroder *et al.*, 1992; Wolter & Menzel, 2005). We present here the results of an investigation in which CHAID algorithms are used as a simple and effective visual method to examine the habitat requirements of *R. radicans*.

MATERIALS AND METHODS

Study sites

The distribution of *R. radicans* was studied in the cities of Oviedo and Galway. Oviedo, in north-western Spain, is located at an altitude of 200 m and about 20 km from the coast. Its older parts, in which the collections were made, follow a medieval plan, with narrow streets and some public squares in the centre, around which residential and commercial zones, with wider streets, occur. The substratum of the bases of walls is mainly limestone in the city centre, and asphalt and cement in the peripheral areas. Galway City is situated in the inner part of Galway Bay, on the western shore of Ireland; for details about the characteristics of the urban area of Galway, see Rindi *et al.* (1999).

Sampling

In January 2001 and December 2002, surveys were carried out to examine the distribution of *Rosenvingiella radicans* respectively in the central parts of Oviedo and Galway City. A careful visual search for green patches referable to *R. radicans* was made and a map of the distribution of the alga was prepared for both cities. Identifications were confirmed by microscopic examination of samples collected at each site in which green patches were noted (obtained by scraping a surface of 1 cm^2).

For each site at which the alga occurred, a number of environmental factors were noted; for each, several different categories were defined. These were: type of habitat (wall, post, ground, ground next to wall (GNW: ground at a distance of no more than 2 m from a wall), open corner, closed corner, cavity, protrusion), substratum (cement, brick, limestone, recent paint, old paint, wood, asphalt, barren ground), orientation of the colonized surface (north, 337º to 22.5º; south, 157.6º to 202.5º; east, 67.6º to 112.5º; west, 247.6º to 292.5º; north-east, 22.6º to 67.5º; north-west, 292.6º to 337.5º; south-east, 112.6º to 157.5º; south-west, 202.6º to 247.5º; when the alga occurred on open ground, orientation was defined as the orientation of the nearest wall), type of area (residential, historical, commercial or mixed), intervening space (narrow streets, < 8.15 m wide; medium sized streets, 8.14 to 14.6 m; broad streets, > 14.6 m). On the basis of these data, a set of observed frequencies for each category of each factor was prepared for the occurrence of *R. radicans*.

Distribution frequencies expected in the case of a completely random distribution of the alga were obtained by randomly selecting a number of points on a grid placed on the maps of the two cities. The sites corresponding to these points were visually examined, and their characteristics in relation to the environmental factors listed above were noted, noting also the presence or absence of the alga. In most cases, no presence of green patches was noted in these points. Presence or absence (*yes* / *no*) of *R. radicans* in the sites sampled was treated as dependent variable; the sites in which the alga was present were attributed to the category *yes* of the dependent variable. Three trees were created, the first including city (Oviedo and Galway) as an environmental factor in order to study possible differences between the two cities, and the other two to study the distribution in each city independently.

Statistical analysis

The null hypothesis that the factors considered had no significant effect on the distribution of *R. radicans* (i.e., *R. radicans* was randomly distributed) was tested by comparing the distribution data of *R. radicans* with a distribution expected on the basis of the frequencies obtained from the random points, using the CHAID and CHAID exhaustive algorithms (Biggs *et al.*, 1991; Kass, 1980). CHAID algorithms, a stepwise method, evaluated the relationships between each environmental factor and the dependent variable, fusing together homogeneous categories and maintaining unchanged the heterogeneous ones. An important characteristic of this procedure is that the results of the algorithm can be represented on a tree-graphic way, where the root node is composed by all the patches sampled. The steps of the CHAID exhaustive algorithm used here can be resumed as:

1. For each predictor X, select the pair of categories whose critical level respect the dependent variable Y, presence, is the lowest. The method used to calculate this critical level was the χ^2 test (Sokal & Rohlf, 2001).
2. This pair is fused together in a compound category.
3. A new critical level is calculated using the new of categories.
4. Repeat steps 1, 2 and 3 until only two categories remain. Then, look for the group of categories that had shown the lowest critical level.
5. Calculate a new critical level using the Bonferroni correction for the X and Y categories.

6. Select the predictor variable whose corrected critical level is the lowest. This level is compared with a pre-established α_{split} level.
   a. If the α_{split} is greater than the corrected critical level, split the node according with the group of categories of X.
   b. If α_{split} is equal or lower than the corrected critical level, this is a terminal node.
7. Continue developing the tree until one stop rule is reached. These stop rules were the development of only 7 levels and less than five cases on each parental or filial node.

Trees were validated to determine their size and to establish how good their structure was to make predictions on the distribution of the alga; due to the different number of data between cities, two different ways of cross-validation were used (Breiman *et al.*, 1984): in the case of the general and the Oviedo trees, the population was divided in two samples: a training subset with 65% of the data and a checking subset; a tree was built with the first, and it was used to check the other one; if both models were coincident, it was concluded that the tree was useful for making predictions. In the case of Galway, a V-fold cross validation was used: data were divided into 6 random subsets; trees were generated with 5 of the subsets and were used to test the other sample. Precision of trees was calculated as the risk of bad classification. In order to interpret the tree there are some parameters to consider for each terminal node: node (n), number of patches of the node; number of patches with *Rosenvingiella* on the node (presence *yes*); gain (%), percent of patches colonised of the node; index (%), the main parameter, percent of patches colonised of the node respect the total patches colonised on the root node.

The statistical software used was ANSWERTREE (SPSS Inc., Chicago, USA).

RESULTS

A total of 1039 sites were examined in both cities, Oviedo and Galway, and 336 of them showed the presence of *R. radicans*. The tree in Fig. 1 shows that the main factor affecting its distribution was the kind of habitat; this tree shows the more frequent presence of *Rosenvingiella* on walls (129 patches), especially those oriented North and North-West; when they are facing North-East, East and South, narrow streets are the most colonised. Posts, cavities and closed corners are the other habitats more often colonized, while the few patches found in ground were, like the previous, more often colonised in northern orientations. This is the general pattern observed in Oviedo and Galway. No differences between cities have been observed. Table 1 shows the importance of the five more important nodes according to the index.

Oviedo

In January 2001, 887 sites were examined, and 284 patches of *R. radicans* were found. In contrast, the alga was found in only 18 of the 622 sites randomly selected. The main factor affecting the distribution of *R. radicans* in Oviedo was the type of habitat. The classification tree (Fig. 2) shows a more frequent presence of the alga on walls, GNW, and closed corners (169 patches, 59.5% of colonised

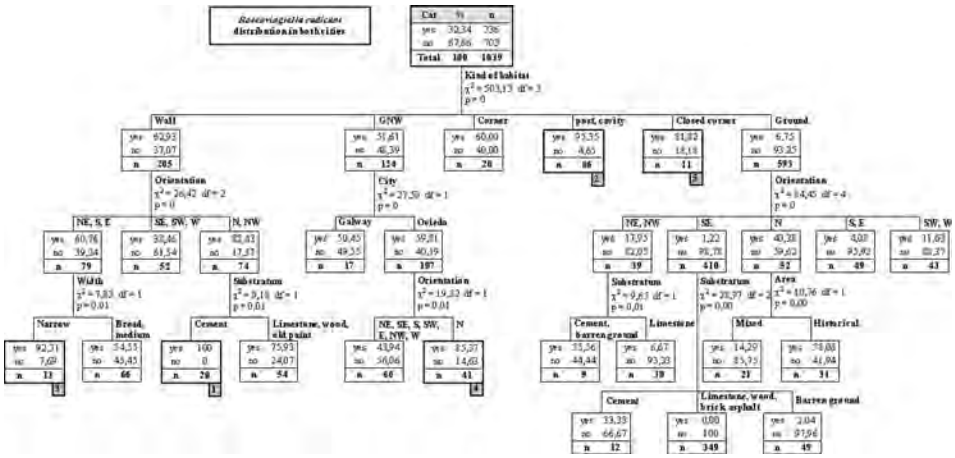

Fig. 1. General decision tree for *Rosenvingiella radicans* for both cities. Risk estimation: 0.097 ± 0.01; tree precision 85.86%. Data on nodes are the percent of patches for the categories of the dependent variable, and the total number of patches found. The nodes were assigned in order of importance (number enclosed in shadow squares) attending to the index factor.

Table 1. Gain resume for the both cities tree nodes to the category *yes* on the dependent variable.

Node squared as	*Node number*	*Node (n)*	*Gain (%)*	*Index (%)*
1	19	20	6	309,2
2	4	86	24,4	294,8
3	17	13	3,6	285,4
4	22	41	10,4	264,0
5	5	11	2,7	253,0

patches) and posts and cavities (70 patches) than expected. Intervening space and orientation were also important factors; the node squared as 1 (the one with the highest index; Table 2), was composed of patches present on posts and cavities in broad and narrow streets. Intervening space also influenced the distribution of the alga when growing on walls: walls colonised in narrow streets composed node 2, and had a high percentage of colonisation (with 87.5% probability of finding a patch of *R. radicans* in this environment). On walls in broad and medium-sized streets, orientation was the next most important factor affecting the distribution, and north-facing colonised walls had also a good index (node 4). The same was found for GNW and closed corners: these habitats were more frequently colonized when facing North (node 3). Ground was the habitat least frequently colonized: only 1.49 % of the patches were found in this habitat. The classification tree did not indicate a major role of substratum and kind of area. On walls, *R. radicans* occurred most frequently at the base (10 cm above the ground) and higher patches only occurred beside broken rainpipes.

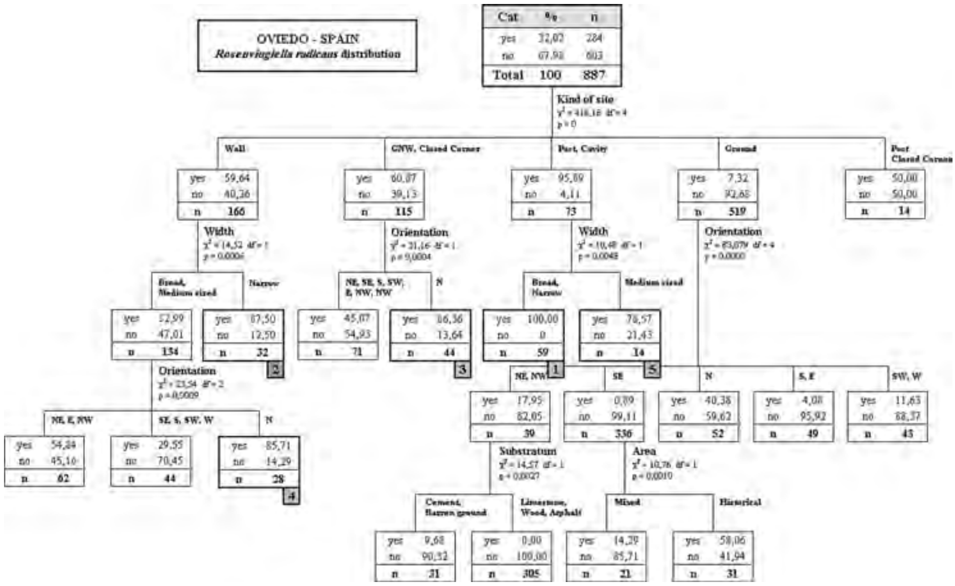

Fig. 2. Decision tree for *Rosenvingiella radicans* for Oviedo. Risk estimation: 0.147 ± 0.012; tree precision 85.34%. Data on nodes are the percent of patches for the categories of the dependent variable, and the total number of patches found. The nodes were assigned in order of importance (number enclosed in shadow squares) attending to the index factor.

Table 2. Gain resume for the Oviedo tree nodes to the category *yes* on the dependent variable.

Node squared as	*Node number*	*Node (n)*	*Gain (%)*	*Index (%)*
1	10	1	9	312.3
2	7	6.7	20.8	273.3
3	9	3.6	9.9	269.7
4	19	5	13.4	267.7
5	11	3.2	8.5	245.4

Galway

In December 2002, 52 patches of *R. radicans* were found in the city centre of Galway. No *R. radicans* was found at any of the 100 random points selected for Galway. As in Oviedo, the type of habitat was the main factor influencing the distribution of the alga in Galway (Fig. 3), and most patches were found on walls. In relation to orientation, walls facing north-west and west were the most colonised, being the node 1, the one with the highest index (Table 3). Walls facing south were the least colonized; north-east and north were intermediate. The node 2, with the second highest index, was the one formed by patches on posts and closed corners. Patches on corners formed the next main node. GNW and ground were colonised rarely by *R. radicans*.

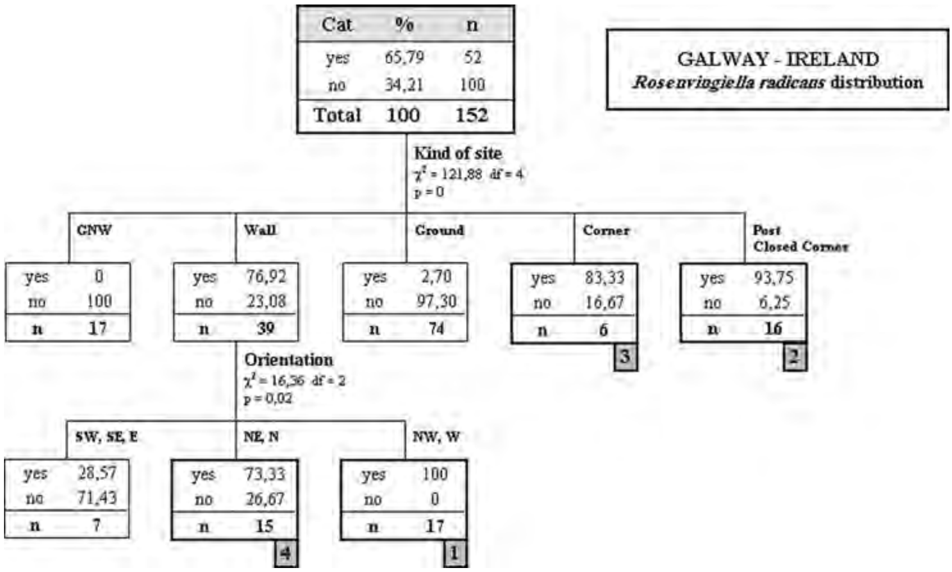

Fig. 3. Decision tree for *Rosenvingiella radicans* for Galway. Risk estimation: 0.066 ± 0.02; tree precision 93.42%. Data on nodes are the percent of patches for the categories of the dependent variable, and the total number of patches found. The nodes were assigned in order of importance (number enclosed in shadow squares) attending to the index factor.

Table 3. Gain resume for the Galway tree nodes to the category *yes* on the dependent variable.

Node squared as	*Node number*	*Node (n)*	*Gain (%)*	*Index (%)*
1	8	17	32.7	292.3
2	5	16	28.8	274
3	4	6	9.6	243.6
4	7	15	21.2	214.4

DISCUSSION

The results presented here indicate that CHAID classification trees may be helpful in demonstrating which combinations of factors produce suitable conditions for the growth of *Rosenvingiella radicans*. For this type of environment, the information that this method may provide is particularly valuable; due to the high number of factors that must be considered and the generally irregular distribution of the alga, it is very difficult to use balanced sampling methods designed to test effects and interactions of individual factors by univariate analyses (such as, for example, ANOVAs). The results suggest that the type of habitat is the most important factor affecting the distribution of *R. radicans* in both cities, and that width of the intervening space and orientation of the surface play also an important role. In Oviedo, *R. radicans* grows more frequently than expected on walls and GNW, especially facing N, NW and W; most of the walls colonized occur in narrow streets. In Galway, the alga is more common on walls, corners and closed corners than in other types of habitats, and walls facing NW and W are the favoured habitat. Substratum and type of area seem to have a comparatively secondary importance.

The general picture offered by these results indicates that moisture retention is fundamental for patch-development in *R. radicans*, which is in general agreement with the indications of previous studies (Rindi *et al.*, 2004; Rindi *et al.*, 1999). Cities, consisting mainly of artificial surfaces, represent a type of environment with harsh conditions for the colonisation of organisms (Rebele, 1994). Several species of cyanobacteria, due to their high capacity to withstand severe irradiance, heat and desiccation stress, can colonize a large range of artificial surfaces (Lüttge, 1997). Most eukaryotic algae, however, do not have such a wide tolerance. Although several terrestrial green algae have developed physiological adaptations conferring resistance to long dry periods, in urban areas their distribution is restricted to the limited habitats in which the environmental conditions are favourable for their colonization and growth. For such organisms, cities are effectively fragmented ecosystems in which they can colonise only the limited patches offering suitable conditions (Trepl, 1995). Filamentous green algae, particularly species of *Rosenvingiella* and *Klebsormidium*, are the most common organisms occurring at the bases of urban walls (Ortega-Calvo *et al.*, 1991; Rindi & Guiry, 2004). However, they can produce well-developed populations only when a certain level of dampness and shelter from extreme temperatures and light irradiances occur. Type of habitat, orientation of the surface colonized, substratum and width of intervening space jointly determine the retention of moisture in a certain site, and can therefore influence the distribution of these algae. Conditions of higher humidity generally occur at the base rather than on upper parts of walls, and the fact that patches of *R. radicans* were only rarely found higher than 10 cm from the ground is thus not unexpected. Walls situated in narrow streets (which have a short intervening space) are more sheltered from direct sunlight and wind, and will therefore have conditions of higher humidity than walls with medium-sized and broad intervening space; this is in agreement with the higher occurrence of *R. radicans* on walls with a short intervening space in Oviedo. The more frequent occurrence of the alga on walls facing North-West and West in Galway and North in Oviedo may be due to climatic features of the regions in which the two cities are located. In western Ireland, North-West and West are the directions of the prevailing wind. As heavy rain is frequently associated with strong wind, walls facing these directions will receive a generally higher amount of rainfall than walls facing other directions; the rainfall will accumulate at the base of these walls, producing conditions of high dampness. Closed corners and cavities are also a type of habitat providing local conditions of high moisture, and indeed *R. radicans* occurs in these habitats with a higher frequency than expected. It is noteworthy that the tree based on the data for both cities shows the position of the city in a small secondary node, suggesting a limited importance of this factor. This is not an unexpected conclusion, since Oviedo and Galway are located in regions with similar climatic regimes. The North Atlantic Drift of the Gulf Stream strongly affects both north-western Spain and western Ireland, and produces a temperate climate characterized by limited seasonal variation and relatively mild winter conditions. Levels of atmospheric humidity and rainfall are persistently high in both regions.

Prasiolalean algae are well known as very nitrophilous organisms (Lewin, 1955; Schofield & Ahmadjian, 1972; Wootton, 1991; Kovacik & Batista Pereira, 2001) and inputs of nutrients can be important to determine a high local abundance of *R. radicans*. Observations by Rindi *et al.* (1999) suggested that this may be the case for Galway, where canine (and, in some instances, human) urine is an important source of nitrogenous compounds. In the present study, this may be one of the reasons of the high frequency of *R. radicans* on corners in Galway. Furthermore, in Oviedo narrow streets can be expected to have a generally higher amount of nutrients than large squares or wide streets, due to the rain from the roofs that brings to the ground the residuals dropped by the large populations of pigeons, sparrows and other birds. However, specific experimental studies are necessary to quantify the effect of this factor. It should also be noted that our results indicate a limited importance of the type of area, which for Galway is directly related to the number of dogs roaming (higher in residential areas than in commercial areas).

Further studies, extended to other localities and replicated in time, will be necessary to assess in more detail the processes determining the distribution of *R. radicans*. This investigation was based on a single sampling for both Oviedo and Galway, which was carried out at different times and not repeated. North-western Spain and western Ireland are among the regions of Europe with highest rainfall and it is reasonable to suppose that the abundance of this species can vary in time in relation to more or less rainy periods. Despite these limitations, the present study indicates CHAID trees can be of great assistance in interpretatng the factors affecting the distribution of terrestrial algae; their use is well worth exploring in greater detail and extending to other species and algal assemblages.

Acknowledgements. Brezo Martínez is gratefully acknowledged for comments and suggestions that helped to improve a previous draft of the manuscript.

REFERENCES

BIGGS D., VILLE B. D. & SUEN E., 1991 — A method of choosing multiway partitions for classification and decision trees. *Journal of applied statistics* 18: 49-62.

BOYE PETERSEN J.B., 1928 — The aërial algae of Iceland. *In:* Rosenvinge L.K. & Warming E. (Eds), *The Botany of Iceland*. Vol. II. Part II. Copenhagen and London, J. Frimodt and Wheldon and Wesley, pp. 325-447.

BREIMAN L., FRIEDMAN J., OLSHEN R. & STONE C., 1984 — *Classification and regression trees*. Dordrecht, Kluwer Academic Publishers, 368 p.

BURROWS, E.M., 1991 — *Seaweeds of the British Isles. Volume 2. Chlorophyta*. London, Natural History Museum, 238 p.

CHUNG K.Y., OH S.Y., KIM S.S. & HAN S.Y., 2004 — Three representative market segmentation methodologies for hotel guest room customers. *Tourism management* 25: 429-441.

DANA E.D., VIVAS S. & MOTA J.F., 2002 — Urban vegetation of Almeria City - a contribution to urban ecology in Spain. *Landscape and urban planning* 59: 203-216.

DE'ATH G. & FABRICIUS K. E., 2000 — Classification and regression trees: a powerful yet simple technique for ecological data analysis. *Ecology* 81: 3178-3192.

ELPHINSTONE, C.D. 1986 — Classification procedures based on a CHAID analysis. *South African statistical journal* 20: 182-183.

HARDY F.G. & GUIRY M.D., 2003 — A *check-list and Atlas of the seaweeds of Britain and Ireland*. London, British Phycological Society, 435 p.

KASS G. V., 1980 — An exploratory technique for investigating large quantities of categorical data. *Applied statistics* 29: 119-127.
KNEBEL G., 1935 — Monographie der Algenreihe der Prasiolales, insbesondere von *Prasiola crispa*. *Hedwigia* 75: 1-120.
KOVACIK L. & BATISTA PEREIRA A., 2001 — Green alga *Prasiola crispa* and its lichenized form *Mastodia tesselata* in Antarctic environment: general aspects. *Nova hedvigia, Beiheft* 123: 465-478.
LEE K. B. & WEE Y. C., 1982 — Algae growing on walls around Singapore. *Malaysian Naturalists' journal* 35: 125-132.
LEWIN R.A., 1955 — Culture of *Prasiola stipitata* Suhr. *Canadian journal of botany* 33: 5-10.
LÜTTGE U., 1997 — Cyanobacterial Tintenstrich communities and their ecology. *Naturwissenschaften* 84: 526-534.
MCDONNELL M. J., PICKETT S.T.A., GROFFMAN P., BOHLEN P., POUYAT R.V., ZIPPERER W.C., PARMELLE R.W., CARREIRO M.M. & MEDLEY K., 1997 — Ecosystem processes along an urban-to-rural gradient. *Urban ecosystems* 1: 21-36.
ORTEGA-CALVO J. J., HERNÁNDEZ-MARINÉ M. & SÁIZ-JIMÉNEZ C., 1991 — Biodeterioration of building material by cyanobacteria and algae. *International biodeterioration and biodegradation* 28: 165-185.
MENÉNDEZ VALDERREY J.L. & RICO J.M., 2001 — *Rosenvingiella polyrhiza* (Rosenv.) P.C. Silva y *Prasiola calophylla* (Carmich. ex Grev.) Kützing (Prasiolaceae), dos nuevas Prasiolales del NW peninsular. *Anales del jardín botánico de Madrid* 58: 352-354.
REBELE F., 1994 — Urban ecology and special features of urban ecosystems. *Global ecology and biogeography letters* 4: 173-187.
RIFÓN-LASTRA.A. & NOGUEROL-SEOANE A., 2001 — Green algae associated with the granite walls of monuments in Galicia (NW Spain). *Cryptogamie, Algologie* 22: 305-326.
RINDI F., GUIRY M.D., BARBIERO R.P. & CINELLI F. 1999 — The marine and terrestrial Prasiolales (Chlorophyta) of Galway City, Ireland. A morphological and ecological study. *Journal of phycology* 35: 469-482.
RINDI F. & GUIRY M.D., 2003 — Composition and distribution of subaerial algal assemblages in Galway City, western Ireland. *Cryptogamie, Algologie* 24: 245-267.
RINDI F. & GUIRY M.D., 2004 — Composition and spatial variability of terrestrial algal assemblages occurring at the bases of urban walls in Europe. *Phycologia* 43: 225-235.
RINDI F., MCIVOR L. & GUIRY M.D., 2004 — The Prasiolales (Chlorophyta) of Atlantic Europe: an assessment based on morphological, molecular, and ecological data, including the characterization of *Rosenvingiella radicans* (Rosenvinge) comb. nov. *Journal of phycology* 40: 977-997.
SCHOFIELD E. & AHMADJIAN V., 1972 — Field observations and laboratory studies of some Antarctic cold desert cryptogams. *Antarctic research series* 20: 97-142.
SCHRODER W., FRANZLE O., VETTER L. & SAAGER W., 1992 — CHAID analysis of the terrestrial forest damage inventory of Schleswig-Holstein 1988. *Allgemeine Forst und Jagdzeitung* 163: 93-98.
SOKAL R.R. & ROHLF F.J., 2001 — *Biometry: the principles and practice of statistics in biological research*. New York, W. H. Freeman and Company, 850 p.
TAN H., LIN S.J., LAMBERT B.L. & SCLOVE S.L., 2005 — Comparing exhaustive CHAID classification tree and forward stepwise logistic regression (LR) in explaining the prescribing of antidepressants. *Value in health* 8: 396-396.
TREPL L., 1995 — Towards a theory of urban biocoenoses. *In*: Sukopp H., Mumata M. & Huber A. (Eds), *Towards a theory of urban biocoenoses*. Amsterdam, SPB Academic Publishing, pp. 3-21.
TRIPATHI S.N., TIWARI B.S. & TALPASAYI, E.R.S., 1990 — Growth of cyanobacteria (blue-green algae) on urban buildings. *Energy and buildings* 15: 499-505.

UHER B., ABOAL M. & KOVACIK L., 2005 — Epilithic and chasmoendolithic phycoflora of monuments and buildings in South-Eastern Spain. *Cryptogamie, Algologie* 26: 275-308.
WEE Y.C. & LEE K.B., 1980 — Proliferation of algae on surfaces of buildings in Singapore. *International biodeterioration bulletin* 16: 113-117.
WELTE J.W., BARNES G.M., WIECZOREK W.F. & TIDWELL M.C., 2004 — Gambling participation and pathology in the United States - a sociodemographic analysis using classification trees. *Addictive behaviours* 29: 983-989.
WOLTER C. & MENZEL R., 2005 — Using commercial catch statistics to detect habitat bottlenecks in large lowland rivers. *River research and applications* 21: 245-255.
WOOTTON J.T., 1991 - Direct and indirect effects of nutrients on intertidal community structure: variable consequences of seabird guano. *Journal of experimental marine biology and ecology* 151: 139-153.