Urban Forestry & Urban Greening 20 (2016) 218–226

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

journal homepage: www.elsevier.com/locate/ufug

# A sampling methodology to facilitate biodiversity assessment in public green spaces

Paulo Farinha-Marques[a,b,*], Cláudia Fernandes[a,b], A. Rita Gaio[c], Joaquim Pinto Da Costa[c], Filipa Guilherme[b]

[a] Department of Geosciences, Environment and Spatial Planning, Faculty of Sciences, University of Porto, Rua do Campo Alegre 687, 4169-007 Porto, Portugal
[b] Research Centre in Biodiversity and Genetic Resources, Campus Agrário de Vairão, Rua Padre Armando Quintas, 4485-661 Vairão, Portugal
[c] Mathematics Centre of the University of Porto, Faculty of Sciences, Rua do Campo Alegre 687, 4169-007 Porto, Portugal

ARTICLE INFO

*Article history:*
Received 5 January 2016
Received in revised form 15 July 2016
Accepted 20 September 2016
Available online 21 September 2016

*Keywords:*
Finite mixture models
Multivariate analysis
Public green spaces
Urban biodiversity

ABSTRACT

The growing concern with biodiversity loss has raised the attention on the importance of cities as habitats for a unique assemblage of plants and animals, particularly its public green spaces. Public green spaces, namely parks, gardens and green squares, are often too numerous to allow a detailed study of all of them. Due to their high heterogeneity, a random selection or a stratification based on few features would have consequences on the statistical validity of subsequent biodiversity analysis. Therefore, we aim to present a sampling methodology for public urban green spaces for the selection of a representative group that reflects the diversity of the original population. First, the stratification is based on a selection of variables considered relevant for biodiversity research and easy to evaluate, specifically total area, vegetation cover, impermeable area, water, age, dominant function and space character. Then, a clustering method, through finite mixture modelling, is applied to generate groups of similar green spaces. The application of the proposed sampling methodology was tested in Porto, Portugal. It aims to facilitate site selection for urban biodiversity surveys, in order to improve the accuracy and reliability of biodiversity analysis in public green spaces.



## 1. Introduction

The growth and sprawl of urban centres are causing severe impacts on overall biodiversity (Djoghlaf et al., 2010); simultaneously, these processes also create opportunities for species adaptable to urban habitats and allow new biological patterns (Savard et al., 2000). Although urban biodiversity survival depends on the existence of a variety of spaces (Gilbert, 1991), green spaces are the ones that provide the most favourable conditions to support a greater number of species.

Regarding the occurrence of biodiversity, urban parks and gardens have gradually started to raise the scientists' attention and interest (Thompson, 2002; Bryant, 2006); as man-made habitats, they can be of great significance in any city, particularly when natural green spaces are not so close or accessible.

Public green spaces are particularly significant in the urban context, as they combine a variety of situations concerning spatial design, vegetation cover, soil permeability to water, human use and management, and the ability to support plant and animal species within the urban environment (Gilbert and Anderson, 1998; Redford and Richter, 1999; Cornelis and Hermy, 2004; Hunter and Hunter, 2008; Kong et al., 2010).

Quantitative fieldwork on biodiversity assessment is costly, intensive and demands great technical expertise (Farinha-Marques et al., 2011). The complexity related to urban flora and fauna assessment has consequences in terms of site selection and sampling options. Flora and fauna surveys are often carried out in randomly selected sites, especially if they focus on green space typologies with similar morphological, structural and functional characteristics (Muratet et al., 2008). Common strategies for the stratification of urban green spaces often include the "urban-to-rural gradient" approach (generally based on distance to city centre; e.g Angold et al., 2006), a division according to park area (e.g. Garden et al., 2010) or a broad categorization according to surrounding land use

* Corresponding author at: Department of Geosciences, Environment and Spatial Planning, Faculty of Sciences, University of Porto, Rua do Campo Alegre 687, 4169-007 Porto, Portugal.
*E-mail addresses:* pfmarque@fc.up.pt (P. Farinha-Marques), cofernandes@fc.up.pt (C. Fernandes), argaio@fc.up.pt (A.R. Gaio), jpcosta@fc.up.pt (J.P.D. Costa), filipa.guilherme@fc.up.pt (F. Guilherme).

http://dx.doi.org/10.1016/j.ufug.2016.09.004
1618-8667/

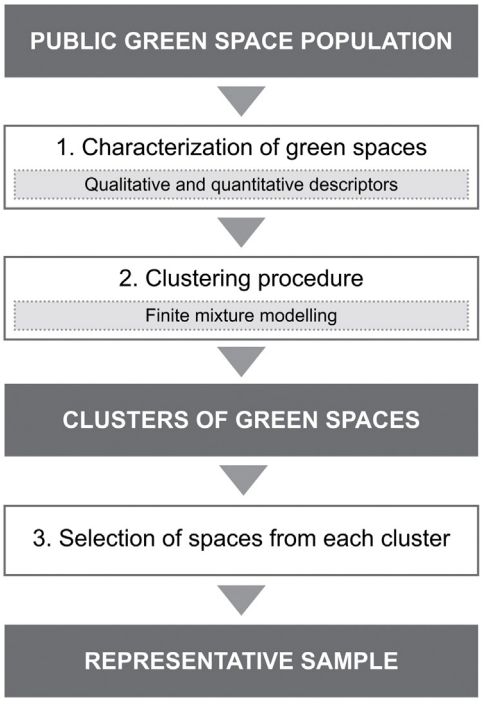


**Fig. 1.** Conceptual diagram of the adopted methodology.

or land cover (e.g Imai and Nakashizuka, 2010; Lizée et al., 2011). However, these procedures are not optimal when the population reveals high heterogeneity regarding several intrinsic features, as usually occurs with designed green spaces.

While studying the set of public parks, gardens and green squares of the city of Porto, Portugal, over the course of a research project concerning urban biodiversity, we came across an extraordinary diversity of key features displayed by these sites. Facing the impossibility to analyse all these green spaces, due to time and logistic restraints, the need for an adequate sampling strategy became obvious, as typical sampling strategies could generate a sample that might not be representative of the whole population of public parks, gardens and green squares.

In order to guarantee the representativeness of the sample, the stratification of the population must take into account several features of the green spaces, in order to capture as much of the diversity of the original population as possible. Green spaces should thus be characterized by relevant variables for the occurrence of biodiversity and, for efficiency purposes, the characterization should be fast and include only variables that are easy to assess; all of the characterization can be executed before any previous knowledge on the biodiversity levels from each space.

The main purpose of this paper is to present a sampling strategy for green space selection, in the context of biodiversity assessment, as follows: 1) to characterize public green spaces according to relevant variables for biodiversity; and 2) to test the application of a clustering method (finite mixture models) for the selection of a representative group of these spaces, for later detailed survey of flora and fauna. The application of the methodology was tested for the selection of a sample of public parks, gardens and green squares in Porto and its results are here presented.

## 2. Methodology description

The adopted methodological design is outlined in Fig. 1 displaying a three step procedure. In short, after the inventory of all public green spaces, the first step consists of the characterization of the green spaces, regarding the selected variables; the second step involves the statistical procedures leading to the identification of clusters of green spaces; and finally the third step corresponds to the selection of representative elements from each cluster.

### 2.1. Characterization of public parks, gardens and green squares

Public green spaces, namely parks, gardens and green squares, are highly relevant in an urban context: i) as designed spaces, they are highly diversified in terms of their spatial characteristics; ii) due to the intensive presence and pressure of the human users. All these aspects make public green spaces highly heterogeneous and difficult to assess as a whole. This research issue was addressed with an innovative and efficient strategy, after a careful reflection on the relevant variables for biodiversity and their evaluation.

The variables used in the analysis are: 1) total area; 2) vegetation cover; 3) impermeable area; 4) water; 5) age; 6) dominant function; 7) space character. This set of variables was determined by their ecological, social and spatial importance for the occurrence of biodiversity, supported by relevant literature and experts' opinion, and subject to statistical limitations. Moreover, priority was given to those variables that, in addition to their recognized influence on urban biodiversity, could best characterize public urban green spaces with easily accessible data and without prior knowledge of the existing biodiversity.

#### 2.1.1. Total area

The size of the green space (area) is an important factor as larger areas tend to include more habitat types and thus more species than smaller ones (Franken and Hik, 2004; Angold et al., 2006; Fink et al., 2009). Moreover, other size related issues could also be mentioned like the edge effect (Laurance et al., 2007; Hostetler and Knowles, 2009) and the fact that many species are rare (or absent) in small habitats and more abundant within extensive areas (DeLong and Brittingham, 2009).

#### 2.1.2. Vegetation cover

The presence of vegetation improves the potential of an urban space to accommodate a higher diversity of species. Naeem et al. (1994) proved the importance of vegetation by revealing that systems with the greatest percentage of different vegetation layers show the highest diversity. Other studies refer the relation between structural complexity and productivity, litter accumulation and soil structure, creating a resource rich habitat that enhances biodiversity (Gandolfi et al., 2007).

#### 2.1.3. Impermeable area

One of the most common guidelines for the promotion of biodiversity in urban green spaces relates to the ratio permeable area/impermeable area. Several studies highlight the advantages of permeable surfaces as they allow water infiltration, contributing not only for the storm water management but also to water storage, and thus, ensuring conditions for the establishment and survival of living beings (Ignatieva et al., 2008; Shaffer et al., 2009; Müller, 2010).

#### 2.1.4. Water

Water elements are recognized wildlife magnets, particularly vital for some species groups, such as amphibians, and play an important role in the design of public green spaces (Hermy and Cornelis, 2000; Gaston et al., 2005; DeLong and Brittingham, 2009). This is even more relevant in the urban context where, commonly, smaller watercourses are highly modified and restrained, and access to water by animal species is almost limited to the existing water elements in gardens and parks, with the obvious