INTER AND INTRA-PATCH LANDSCAPE CONNECTIVITY: A COMPARATIVE MEASUREMENT FOR ITALY AND THE UK

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Abstract

Landscape fragmentation (LF) is a process widely caused by road infrastructure and urbanised areas. LF consists in dividing a natural environment in different fragments separated from each other and in reducing the original land surface. The most obvious effects are: the isolation of animal and plant species, the reduction of biodiversity, and loss of connectivity between natural areas. In the literature, there are several indicators available for quantifying LF. A relevant way to evaluate fragmentation is the measurement of its reciprocal variable, i.e. landscape connectivity, which describes the ability of species to move through the landscape. Intuitively, connectivity decreases when fragmentation increases. In this work, we assess connectivity in four landscape units, two located in Sardinia (Italy), and two in Wales (the UK). We apply the connectivity index (*CIx*), which provides us with information on the connectivity of wilderness areas in cities. It is a component of the City Biodiversity Index (CBI) -also known as Singapore Index- which is a combination of 23 indicators. This index can provide answers on the degree of connectivity of a habitat, considering intra and inter patch movement. We consider as target species the hedgehog, which is widespread mainly in urban and suburban contexts and suffers from the negative effects of LF. We will assume five possible connection scenarios between isolated patches through the application of various buffers between 50 and 2,000 m.

Key words: Landscape fragmentation, connectivity index, comparative approach

Introduction

Landscape fragmentation (LF) is a relevant process, where large habitat areas -called patches- become smaller and more isolated than in the original condition (EEA, 2011, JAEGER, 2000). It may be caused by natural and anthropogenic factors (BATTISTI, ROMANO, 2007). This process can be caused by linear and mobility infrastructures (TMI), such as railways and roads and by urbanised surfaces, which can reduce the movement of animal species and landscape connectivity (BISSONETTE, ADAIR, 2008). LF is measurable through several indices. In this work, we assess the reciprocal phenomenon, i.e. landscape connectivity, by developing on the connectivity index (*CIx*). This index provides us with information on the connectivity of wilderness areas in cities and is a component of the City Biodiversity Index (CBI) -also known as Singapore Index- which is a combination of 23 indicators (DESLAURIERS et al, 2017). Connectivity is defined as "the degree to which the landscape facilitates or prevents movement between patches" and can be "measured by the probability of movement between all points or areas of intervention of a landscape" (TAYLOR et al, 1993). Connectivity has two main meanings. Structural connectivity refers to the spatial organization of the elements that make up the landscape and the relationship that they present. Functional connectivity describes how far landscape structure influences the dispersion capacity of individuals, i.e. the ability of animals to move through the landscape. Functional connectivity is sometimes referred to as horizontal connectivity. The main elements that enable functional connectivity are corridors, which are connecting structures that facilitate movement between different patches (BATTISTI, ROMANO, 2007).

In this work, we assess *CIx* in four landscape units, two located in Sardinia (Italy), and two in Wales (the UK). We consider as target species the hedgehog, which is widespread mainly in urban and suburban contexts and suffers from the negative effects of LF.

This paper unfolds as follows. In the next section, we will present the method adopted to measure LF. In section three, we will apply the method to the comparison of two countries, i.e. Italy and the UK. In the fourth section, the results are presented and discussed, while in section six the conclusion of this paper will be presented.

Material and Methods

The scientific literature is rich in indices capable of measuring the LF. In this work, we adopt the *CIx*, which has been revised in 2012 so that it describes -beyond the usual inter-patch connectivity- also the intra-patch connectivity (CHAN et al, 2014). This is relevant, as the survival of many species depends on their ability to move between and within habitat areas (LA POINT et al, 2015; RUDD et al, 2002). *CIx* obeys to the following formula (Equation 1):

$CIx = \frac{1}{A_{tot}}(A_{G1}^2 + A_{G2}^2 + \cdots + A_{Gn}^2)$ $CIx = \frac{\sum_i A_{Gi}^2}{A_{tot}}$

where

A_{Gi} indicates the size of group *i* of connected patches, and

A_{tot} is the total extent of natural areas.

As we posit in advance, connectivity of each individual group of patches includes intra- and inter-patch connectivity, as shown below (Equation 2):

$$CIx = CI_{Intra} + CI_{Inter}$$

where

CI_{Intra} stands for intra-patch connectivity and

CI_{Inter} for inter-patch connectivity.

They are obtained according to the following expressions

$$CI_{Intra} = \frac{\left(\sum_i A_{GiPi}{}^2\right)}{A_{tot}}$$
$$CI_{Inter} = \frac{\sum_{i,j}(2 \times A_{GiPi} \times A_{GjPj})}{A_{tot}}$$

where

A_{GiPi} and A_{GjPj} represent the area of any single patch in each group A_{Gi}.

The CBI Manual (CHAN et al, 2010) recommends a 100 meters threshold distance for designation of related patches. However, this distance may be changed to meet specific research requirements, for example, for species specific studies, where dispersion distances are known (DESLAURIERS et al, 2017). In this study, we choose the hedgehog (*Erinaceus europaeus italicus*) as target species. We compare two countries, by applying *CIx* to four Landscape Units (LUs) of approximately the same extent (about 1,000 km^2), in Sardinia (Italy) and Wales (the UK) (Figure 1).

We use the GIS to perform our study, because it has been proved useful in spatial analysis and in measuring landscape (habitat) fragmentation (DE MONTIS et al, 2018; DE MONTIS et al, 2017). We use data freely available online (RAS, 2008; WALES, 2017). *CIx* was obtained by implementing GIS analyses and using data in shapefile format. Tunnels and bridges were excluded from infrastructure traits. According to the road type, we have applied a buffer with various widths (Table 1).

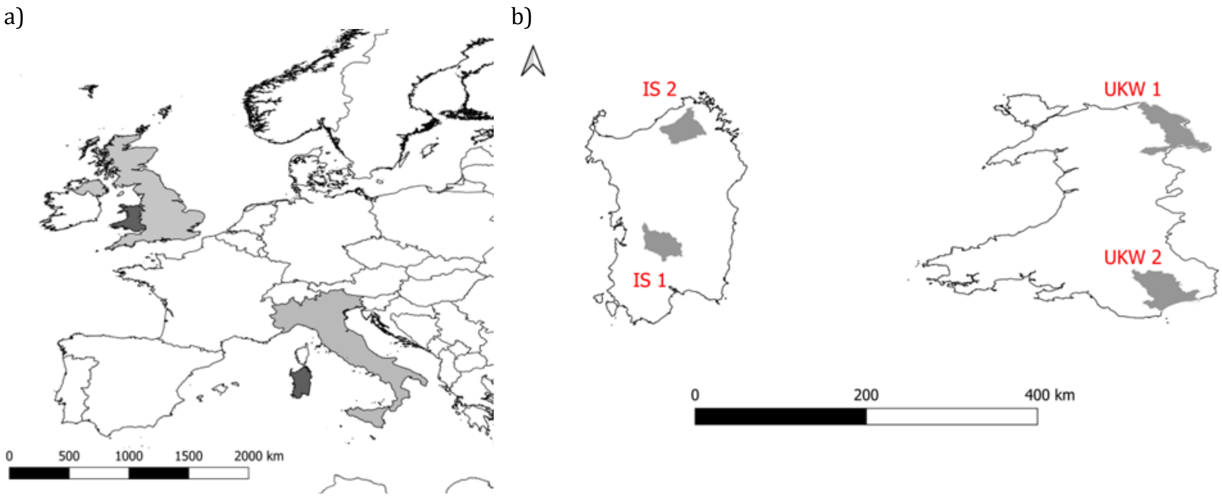

Fig.1. a): Sardinia and Wales (in dark gray);
b) Regione delle Giare basaltiche (IS1), Limbara (IS2), North-East (UKW1), and South-East (UKW2) (in gray).
Source: Own elaboration of data provided by Global Administrative Areas and Regions Sardinia and Wales.

Table 1 Buffer application to the different types of linear infrastructures.

TMIs	Buffer
'Motorways'	2 × 15 m
'Major roads'	2 × 10 m
'Secondary roads'	2 × 5 m
'Local connecting roads'	2 × 2.5 m
'Railroads'	2 × 2 m

Source: Own elaboration.

Resulting polygons were merged with the polygons of urbanized areas, in order to obtain the final geometry of fragmentation (EEA, 2011, JAEGER, 2000). As for Sardinia, natural areas, that often host hedgehogs, are: agroforestry areas, mixed forests of conifers and broad-leaved trees, coniferous woods, broadleaf forests, shrubs and shrubs, orchards and minor fruits, Mediterranean scrub, simple arable crops and horticultural crops in the open field, cork oaks. The Welsh Land Use Map is not based on the Corine Land Cover classification. For Wales, we consider the following areas: arable and horticultural crops, deciduous forests, coniferous forests, improved grasslands, and suburban zones. For more details about the calculation of *CIx*, see DESLAURIERS et al. (2017). As the dispersal distance for the hedgehog is equal to 2,000 m, we considered five possible connectivity scenarios buffers at different distances (50, 500, 1000, 1500, and 2000 m).

Results and discussion

In Table 2, we report on the values of *CIx*.

According to the results, the most fragmented (i.e. the least connected) habitats are located in the Welsh LUs. The highest values of total connectivity were detected in Limbara (more than 46,000 ha) for buffers equal to 1,000, 1,500, and 2,000 m. The lowest value has been obtained in SE Wales for a buffer equal to 50 m. The highest Intra-Patch connectivity is calculated for Limbara (8,330.72 ha) and the lowest one in Limbara (50.06 ha). The Inter-Patch connectivity has the highest value in Limbara (37,874.85 ha) and the lowest value in NE Wales (17.66 ha). The Welsh LUs are the most fragmented LUs, due to high urban pressure and high road density. Limbara appears as the least fragmented LU. In particular, the Welsh coastal areas appear as the most fragmented. The highest values of *CIx* suggest a more favorable habitat for the hedgehog in the Sardinian case studies.

Conclusions

In this paper, we have assessed landscape fragmentation by studying the reciprocal phenomenon of landscape connectivity. We have considered the *CIx* as relevant measure of connectivity and applied a comparison between Italy and the UK. Our interest focused on the effects on the hedgehog, a species very widespread in the two countries. Results demonstrate how *CIx* is able to measure inter- and intra-patch connectivity in a very interesting way. The least *CIx* values reported in Sardinia are a signature of a more favourable habitat for the hedgehog in the Mediterranean island than in the Welsh landscape units. In future studies we plan to confront this assessment with the measurement obtained through other indicators of landscape fragmentation/connectivity.

Table 2. The assessment of LF according to the CIx (figures expressed in hectars).

		LU			
Buffer width		Massiccio del Limbara	Regione delle Giare basaltiche	NE Wales	SE Wales
50 m	CI_{Intra}	50.06	2,227.71	273.20	256.19
	CI_{Inter}	18,858.15	476,52	17,66	274,34
	CIx	18,908.21	2,704.23	290.87	530.58
500 m	CI_{Intra}	8,330.72	2,227.71	273.20	255.99
	CI_{Inter}	36,920.20	2,375.43	17.66	213.35
	CIx	45,250.90	4,603.13	290.87	469.34
1000 m	CI_{Intra}	8,330.72	2,227.71	273.22	256.01
	CI_{Inter}	37,874.85	2,486.95	19.99	213.35
	CIx	46,205.57	4,714.65	293.21	469.34
1500 m	CI_{Intra}	8,330.72	2,227.71	273.22	256.01
	CI_{Inter}	37,874.85	5,142.36	19.99	213.25
	CIx	46,205.57	7,370.06	293.21	472.41
2000 m	CI_{Intra}	8,330.72	2,227.71	273.22	256.01
	CI_{Inter}	37,874.85	5,146.22	22.82	216.427
	CIx	46,205.57	7,373.93	296.04	472.44

Source: Own elaboration.

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