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Application of Geomatic Tools for the Analysis of Space Use in Iberian Lizards

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Doutor Neftalí Sillero Pablos
Professor Paulo Alexandre Justo Fernandez

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APPLICATION OF GEOMATIC TOOLS FOR THE ANALYSIS OF SPACE USE IN IBERIAN LIZARDS

Elena Argaña Pérez

Dissertação apresentada ao Instituto Politécnico de Castelo Branco para cumprimento dos requisitos necessários à obtenção do grau de Mestre em SIG – Recursos Agro-Florestais e Ambientais, realizada sob a orientação científica do Doutor Neftalí Sillero Pablos e do Professor Paulo Alexandre Justo Fernandez da Escola Superior Agrária do Instituto Politécnico de Castelo Branco

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DECLARAÇÃO

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Resumo

Existem poucos estudos na Península Ibérica no âmbito das áreas vitais e da distribuição espacial de lagartixas. Atualmente existem novos avanços tecnológicos na área da Geomática, nomeadamente recetores GPS de alta precisão e técnicas de fotogrametria terrestre. Neste trabalho irei apresentar dois casos de estudo. O primeiro foi efetuado em Moledo (Viana do Castelo, noroeste de Portugal). A área de estudo é caracterizada por quatro muros de pedra e uma pequena área de praia com rochas e vegetação. Analisei as áreas vitais e os padrões de distribuição espacial de duas espécies sintópicas (*P. bocagei* e *P. hispanica* tipo 1A). Marcámos com marcadores coloridos 76 lagartixas (57 *P. bocagei* e 19 *P. hispanica* tipo 1A) e usámos um recetor GPS (precisão de 50 cm) durante 8 dias para gravar as posições de lagartixas marcadas e não marcadas. Num Sistema de Informação Geográfica calculámos as áreas vitais de indivíduos marcados com mínimo polígono convexo 95% (MPC), e os padrões de distribuição espacial de indivíduos marcados e não marcados de *P. bocagei* e *P. hispanica* tipo 1A de acordo com o sexo e variáveis climatológicas através de estatística espacial (LISA: Associação Espacial de Indicadores Locais). Ambas as espécies apresentaram distribuição espacial segregada: cada espécie selecionou diferentes áreas, onde a *P. hispanica* tipo 1A ocupou as áreas menos favoráveis. As áreas vitais estimadas da *P. hispanica* tipo 1A foram maiores que as da *P. bocagei*. Além disto, as lagartixas maiores de *P. bocagei* tiveram áreas vitais menores e os machos da *P. bocagei* exibiram áreas vitais maiores que as fêmeas.

O segundo caso de estudo, foi efetuado no Jardim Botânico da Universidade do Porto (Porto, noroeste de Portugal). A área de estudo é caracterizada por um muro de pedra com uma altura máxima de quatro metros e mínima de dois metros e um comprimento total de 60 metros. Identifiquei as áreas vitais, a distribuição utilizada, os centros de atividade, e os padrões de distribuição espacial de uma população de *P. bocagei*. O trabalho de campo foi dividido em duas partes: captura/marcação e gravação das posições. Marcámos 39 lagartixas com marcadores coloridos (durante 6 dias de captura) e usámos o software I^3S para a identificação permanente através de fotografias do peito. No sentido de analisar a superfície vertical do muro inserido num Sistema de Informação Geográfica (SIG), corrigimos cinco fotografias do muro através de uma transformação projetiva para se obter distâncias reais entre as localizações das lagartixas. Gravámos as posições das lagartixas durante cinco meses. Calculámos as áreas vitais com mínimo polígono convexo 95% (MPC), a distribuição utilizada (95%) e os centros de atividade (50%) com um Kernel density estimator (KDE). Analisámos as posições das lagartixas com estatística espacial (LISA). A distribuição da localização da *P. bocagei* foi estendida por todo o muro de pedra. Cada sexo selecionou diferentes áreas do muro. As *P. bocagei* maiores tinham áreas vitais maiores, os machos tinham uma distribuição utilizada maior que as fêmeas, e mais centros de actividade que as fêmeas.

Palavras chave: Área vital, Análises espaciais, Kernel, MPC, SIG, GPS, Lagartixa, Podarcis

Abstract

There are few studies in the Iberian Peninsula on lizards' home ranges and spatial distribution. Nowadays there is new geomatic techniques, namely GPS of high accuracy and close-range photogrammetry techniques. I present here two study cases. The first one was conduced in Moledo (Viana do Castelo, north-west of Portugal). The study area is characterised by four stone walls, and a small beach area with rocks and vegetation. I analysed the home ranges and the spatial distribution pattern of two syntopic species (*P. bocagei* and *P. hispanica* type 1A). We marked with colour inks 76 lizards (57 *P. bocagei* and 19 *P. hispanica* type 1A) and we used a GPS (accuracy of 50 cm) to record the positions of marked and unmarked lizards during eight days. In a Geographical Information System platform we calculated the home ranges of marked individuals with minimum convex polygon 95% (MCP), and the spatial distribution patterns of marked and unmarked *P. bocagei* and *P. hispanica* type 1A according to the sex and to the climatological variables by spatial statistics (LISA: Local indicators of Spatial Association). Both species were spatially segregated: each species selected different areas, where *P. hispanica* type 1A occupied the less favourable areas. Home ranges of *P. hispanica* type 1A were bigger than those of *P. bocagei*. Also, bigger lizards of *P. bocagei* had smaller home ranges and *P. bocagei* males had bigger home ranges than females. The second study case was conduced at the Botanical Garden of the University of Porto (Porto, north-west of Portugal). The study area was characterized by a stone wall with a maximum height of four meters and a minimum of two meters and with a total length of 60 meters. I identified the home ranges, the utilization distribution, the core areas, and the spatial distribution pattern of a population of *P. bocagei*. Fieldwork was divided in two parts: capturing/marking and recording positions. We marked 39 lizards with colour inks (during 6 capturing days) and we used the software I3S for lizard permanent identification through pictures of the chest. In order to analyse the vertical surface of the wall in a Geographical Information System (GIS), we corrected five photographs from the wall by a projective transformation to obtain true distances among lizards' locations. We recorded lizards' positions during five months. We calculated lizards home ranges with minimum convex polygon 95% (MCP), the utilization distribution 95% (UD) and core areas (50%) with Kernel density estimator (KDE). We analysed the lizards' records with spatial statistics (LISA). The distribution of the *P. bocagei* location was widespread along of the stone wall. Each sex selected different areas of the wall. Bigger *P. bocagei* had bigger home ranges, males had a bigger UD than females, and males had more core areas than females.

Keywords: Home range, Spatial analysis, Kernel, MCP, GIS, GPS, Lizards, Podarcis

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List of Acronyms

ANOVA	Analysis of Variance
AT	Acoustic telemetry
DGPS	Differential GPS
ETRS89	European Terrestrial Reference System 1989
FKD	Fixed Kernel Density
GAM	Generalized Additive Models
GCP	Ground Control Point
GIS / SIG	Geographical information System / Sistema de Informação Geográfica
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
h	Smoothing factor
IGS	International GNSS Service
KDE	Kernel Density Estimator
LISA	Local Indicator of Spatial Association
MCP / MPC	Minimum Convex Polygon / Mínimo Polígono Convexo
Pit-tag	Passive integrated transponder
PT-TM	Portugal-Transverse Mercator
PTT	Platform transmitter terminal
RENEP	Rede Nacional de Estações Permanentes
RINEX	Receiver Independent Exchange
RTK	Real Time Kinematics
VHF	Very high Frequency
WGS84	World Geodetic System 1984

1 INTRODUCTION

The large majority of studies about spacial patterns and social behaviour started in 1920 with Howard's book "Territory in bird life". Other authors followed him with studies related to territoriality, home ranges, and animal behaviour, mainly for birds and mammals (Nice 1941, Calhoun and Casby 1958, Ashby 1872), while few studies were performed for other taxa as reptiles (Stamps 1977, Rose 1981). Focusing on my work research field, in the particular case of the Lacertidae family, there are also few studies related to territorial behaviour, home ranges, activity patterns and animal behaviour (Capula et al. 1993, Castilla et al. 1999, Verwaijen and Van Damme 2008). In the small-sized lizards' case, there are also some bibliographical studies of home range and behaviour (Gil et al. 1988, Foá et al.1994, Diego-Rasilla and Pérez-Mellado 2003).

To conduct a study about home range and animal behaviour is important to use tracking techniques which allow us obtaining as much information as possible with less cost in time and money. Nowadays, there are many techniques as GPS (global position system), GIS (Geographical Information System) or radio telemetry, that could be essential tools to study and understand the ecology and home range of the species. For example, Girard et al. (2002) used the GPS to investigate at which extent increasing the number of locations affects home-range size estimations, with a data collection on moose (Alces alces); Selkirk and Bishop (2002) suggested that GIS enables a deeper understanding of the parameters influencing each home range estimate; and Osterwalder et al. (2004) used techniques of radio telemetry to document the spatial ecology and social organization of Australian lizards (*Egernia major*).

My dissertation is integrated in the project HOUSE: a multidisciplinary approach to determine home ranges of Iberian lacertids, funded by FCT (Fundação para as Ciências e a Tecnologia). The aim of the project is to analyse the home range of several lacertids of the Iberian Peninsula in two situation (syntopy/non-syntopy). I am going to present in my dissertation two study cases of home ranges of Iberian lizards.

In order to clarify some important concepts related with my dissertation, I will start by introducing home range, territory, utilization distribution concepts, as well as some other topics that will form this work.

1.1 What is a home range?

Home range is the area where the individual performs their daily activities. The concept of home range has been thoroughly studied and discussed, and Burt's (1943) definition of the mammal's home range is considered nowadays the general concept: "[...] area traversed by the individual in its normal activities of food gathering, mating and carrying for young. Occasional sallies outside the area, perhaps exploratory in nature, should not be considered as in a part of the home range". After Burt (1943), many researchers tried to apply new approaches to the home range definitions. Jewell (1966) defined the home range as the area where an animal normally travels to achieve their routine activities. He claimed that the occasionally forays outside of the home range may be an important mechanism to maintain or extend the size of the home range. Jennrich and Turner (1969) defined the home range as "the area of the smallest region which accounts for 95% of an animal's utilization of its habitat". This was the most precise and probabilistic definition of home range, where the standard *p-value* (0.05) was used to define the outliers, or the localities outside of the home range. One of the easiest way to estimate the home range was to draw the smallest convex polygon which contain all of the captures points for an animal, (see details in Jennrich and Turner 1969), thereby attempting to minimize errors in the home range estimation. In the same study, Jennrich and Turner (1969) used the concept of "utilization distribution", but they did not defined it; the idea of the concept was firstly suggested by Hayne (1949) as a distribution of location points of an animal inside the home range. After that, Van Winkle (1975) described the utilization distribution as "the two-dimensional relative frequency distribution for the points of location of an animal over a period of time." In a much simpler way, Anderson (1982) described the utilization distribution as a "space use and not necessarily resource use". Years later, Worton (1989) use the concept of utilization distribution as "the distribution of an animal's position in the plane". Thus, based on these studies, the utilization distribution is all the area that the animal uses, without being limited by presence or absence of a resource, over the time. I would like to conclude with a definition by Powell (2000), where the home range is considered as a cognitive map, i.e. the area that the animal knows and keep in memory because it has some value.

1.2 Territory as a part of the home range

The territory is one particular area characterized by having exclusive resources and which should be defended. The concept of territory was studied and defined by many authors over the past century. Burt (1943) reviewed some of the definitions of territory developed until their time and considered the definition given by Noble (1939) as the best and simplest until that moment: "territory is any defended area". Years later, Kaufmann (1983), on the assumption that territoriality is one form of social dominance, defined territory as "a fixed portion of an individual's or group's range in which it has priority of access to one or more critical resources over others who have priority elsewhere or at another time. This priority of access must be achieved through social interaction". Maher and Lott (1995) reviewed the literature analysing territoriality definition. They found 48 different conceptual and operational definitions, concluding that territoriality is defined in many ways for many purposes. The criteria of "defended area" was used in the 50% of the papers and most often across vertebrates. The researchers studying mammals chose the spatial criteria, i.e. the amount of home range overlapping, more than other researchers studying other taxa. Due to my interest is focused on reptiles, I want to follow Maher and Lott (1995) considerations about the reptiles references of territoriality, given that they compiled definitions for more classes of vertebrates. They defined territoriality with two criteria, as an exclusive area that is defended and as amount of overlaps between the animals areas. Powell (2012) currently defined territory as "an area within an animal's home range to which the animal has exclusive, or perhaps priority use. Thus, a territory is a special type of home range or a particular part of home range." Burt (1943) and Powell's (2012) definition show us that we cannot confuse the territory concept with the home range one, although they may be related.

In some species, individuals defend their territories in certain parts of the species' range but not in other parts (Powell 2000). Even in territorial species, traits can be displayed only in specific periods (breading season). Also, in some species, only the individuals defend their territories against members of the same sex, meanwhile in other species, mated pairs or family groups (which sometimes contains non-family members), defend territories (Powell 2000). So far, there have been a large number of animal studies related to the territorial traits, behaviour and ecology of territoriality, namely for birds (e.g. Howard 1920, Brown 1969) and mammals (e.g. Burt 1940, Ostfeld 1990), some for reptiles (e.g. Brattstrom 1974, Stapley and Keogh 2004) fishes (e.g. Sammarco 1983), and ants (e.g. Alcock 1987, Adams 1994).

1.3 Home range estimators and their limiting factors

The definition of home range by Burt (1943) is simple and clear, but over the time, many of the researchers realized of the difficulties of how the home ranges are calculated, and when an "occasional sally" is really occasional or instead a simple part of the home range. I want to clarify that the main concept that will be used in this work is the home range.

Powell (2012) reported an example of how a female of black bear with their home range clearly defined, decided to visit other area far away from her home range (Powell et al. 1997). Powell interpreted that this area, which the female bear were visited, have been part of her home range in other years. Therefore, an animal can have more than one home range which changes over the time. In the study of the movements and home ranges of Arctic foxes (*Alopex lagopus*), Franfjord and Prestrud (1992) saw that the foxes may be familiar with a 100km^2 area, although they used regularly only a small portion where food was abundant. Therefore, these authors considered that the concept of home range did not fit correctly in their foxes' study. A home range should be thus defined only for an interval of time, e.g. a month, a season, a year, or a lifetime (Franfjord and Prestrud 1992, Fieberg and Börger 2012). As I explained before, the 100km^2 area would be a utilization distribution in the Arctic foxes case, and the small portion of area they used regularly would be the home range. If the home range is defined by time intervals, the Arctic foxes and the female bear cases would be more clear.

Several authors have reviewed methods of home range estimators (Hayne 1949, Stickel 1954, Van Winkle 1975). Laver and Kelly (2008) revised recent home range studies based on some criteria, such as the analysis of the correctness of data collection, the reporting of estimators, and the implementation of advances in estimators. The dimension of time was considered by Laver and Kelly (2008) as an improvement of the development of home range theory.

Following the assumption by Powell (2000), “a home range estimator should delimit where an animal can be found with some level of predictability”. There are two main tools to estimate the home range: Minimum complex polygon (MCP) and Kernel density estimator (KDE). Based on the work by Laver and Kelly (2008), the MCP is the most popular estimator, in spite of criticism (Van Winkle 1975, Powell 2000). The method draws the smallest possible convex polygon that covers all known or estimated locations of the animal (Hayne 1949). It is a parametric technique and assume that the data fit the distribution pattern as a circle (Hayne 1949) or an ellipse (Jennrich and Turner 1969). In the other hand, KDE is one of the recent advances in estimators and has become prevalent, but it requires several choices regarding the parameters used (Laver and Kelly 2008), as their values have a large effect on the size of the home range (Kazmaier et al. 2002). The most important and difficult aspect of using Kernels is to choose the smoothing factor (h) (Worton 1989), as depends on user's choices. If a small value of “h” is used, fine detail of data can be observed, while a large value of “h” obscures all but the most prominent features (see details in Worton 1989). The value of the smoothing factor depends on the kind of study, the animal or the scale factor. KDE is a non-parametric estimator because it is not based on the assumption that data conform a specified distributional parameters (Seaman et al. 1999).

As we see, there are some limiting factors that affect the estimation of the home ranges. Most studies of home range were done with birds and mammals, probably because of the popularity of these taxa for ecological study, the long tradition of these studies in the literature, the relative ease of detection of the species, and available technology (Laver and Kelly 2008). For our purposes, the study of two species of small lizards from a spatial point of view, there is not so much literature and many of the assumptions that have been made so far may not be applied in specific cases.

1.4 Data collection techniques for home range studies

Some questions come to my mind when I think about data collections for the study of home range of a species. How do we collected the positions and information relatives to an animal? Which techniques can we use?

First I would like to define the position concept. The position is the location of an object on the surface of the Earth, expressed through a geographic coordinate system, cartographic projections, a grid or through distances and azimuths to a point with known coordinates (Gaspar 2004). Thus, it is necessary to collect the positions of the animals to study their home ranges and to record information about what the individual do from a spatial point of view.

Radio-tracking is a geomatic technique that collect positions of an animal through the radio signals. There are three types of radio-tracking: very high frequency (VHF) radio tracking, satellite tracking, and GPS tracking. VHF tracking is the standard technique in use since 1963, with the work developed by Cochran and Lord Jr (1963). VHF radio-tracking is by far the most useful and versatile type of radio tracking, as it is relatively low cost (cheaper than GPS and Satellite tracking), with a reasonable accuracy (more than Satellite tracking but less than GPS tracking) and depending on the size of the transmitters and the battery, could have a long life (during years). One of the main disadvantages is that it is labour-intensive (Mech 2002), but it allows investigators to gather a variety of information (Mech 1983). A conventional VHF radio-tracking systems consist on transmitting and receiving systems. Basic transmitting systems include a transmitter, power supply, transmitting and receivers antennas and a receiver. A radio frequency signal (from 27 Mhz to 401 Mhz) is sent by a transmitter attached to the animal; the receiver is able to detect this signal and to store it (Mech 2002). Satellite tracking requires a much higher initial cost and is much less accurate and has a shorter live than VHF system (Mech 2002). It is also very good for monitoring long-range movements, as it requires no personnel in the field. Satellite telemetry utilizes a platform transmitter terminal (PTT) attached to an animal, and the PTT sends an ultra high frequency (401.650 MHz) signal to satellites. The satellites calculate the animal's location based on the Doppler effect and relay this information to receiving/interpreting sites on the ground (Mech 2002). GPS tracking requires a high initial cost and at present it is relatively short-lived and only applicable to mammals with big size, or to birds on which solar cells can be used (Mech 2002). However, for very small animals (e.g. lizards) there is not available device for GPS tracking. GPS tracking is highly accurate and does not require frequent field visits. It uses a GPS receiver in an animal collar to calculate and record the animal's location, time, and date at programmed intervals (Mech 2002).

Nowadays there are many studies using telemetry methods, as automated acoustic telemetry (AT) for fishes (Humston et al. 2005), radio-telemetry with a collar transmitters for small mammals (Ribble et al. 2002), differential GPS telemetry collars for moose (Girard et al. 2002), or the first study in which radio telemetry has been used with a flying insect in the field (attachment transmitters to a beetle's pronotum) (Hedin and Ranius 2002).

There are some studies with radio telemetry in herpetology, mainly for amphibian (Rowley and Alford 2007), snakes (Brito 2003), and lizards (Osterwalder et al. 2004). Nevertheless, only some of these works were done for small animals. One of the important thing about this research field is to choose the appropriate technique. To study the home range and behaviour of a small lizards (e.g. three g of weight), telemetry techniques are not the best because of the very high cost and the high labour-intensive.

The study of the home ranges in small animals, namely small-sized lizards, have been limited to manual labour, such as the technique of the experimental plot. The plot consists in a regular grid of ground marks (e.g. painted symbols on stones), frequently with a separation of 1 m. Individuals are captured with a noose. After making them, they are released and recaptured within the study area. The ground marks allow geo-referencing the individuals by manual measurements of the distance between the animal positions and the nearest ground marks. This is very useful to estimate the home range of lizards (Gil et al. 1988, Marco and Pérez-Mellado 1999, Diego-Rasilla and Pérez-Mellado 2003), but these techniques are time-consuming in fieldwork. After presenting some of the techniques used nowadays to study home range and animals behaviour, we realized that in our work it was not possible to use any of this techniques. The satellite tracking and the GPS tracking were discarded because of the big size of the devices (i.e. the transmitters to attach into the animals) and their high cost. The lizards which we work are small for this kind of transmitters. However, the VHF tracking is a cheaper technique, and there are small size transmitters (e.g. 0,19 gr) to used for our species. The disadvantages of this technique is the time-consuming labour (Mech 2002), as it would take more time than with the handheld GPS to record data, and with a lower accuracy (handheld GPS has better accuracy than VHF tracking). Automatically VHF tracking provides only the presence or absence of the lizards (Kenward 2001). Thereby, we decided to used a handheld GPS with a high accuracy (around 50cm). We needed a GPS receiver without high errors in the positioning process, as it must not exceed the distance that an animal moves between two consecutive positions. To my knowledge, so far none studies were performed with a handheld GPS receiver. Therefore, this is the first study using a handheld GPS receiver, with the propose of utilize this device to record many lizards' positions as quickly as possible with the least possible effort and submetric accuracy.

1.5 Global Positioning System

Following the line of reasoning of the previous section, I will introduce briefly some concepts relative to the GPS. The NAVSTAR GPS (NAVigation System with Time And Ranging Global Positioning System) is a satellite-based radio navigation and time information to suitably equipped users. GPS has been under development in the U.S.A. since 1973 as military system. It is available for civil users since 1995 with the configuration of a system of 24 satellites placed in orbits of about 20.200 km altitude above the Earth's surface. At least, four satellites are simultaneously visible above the horizon, anywhere on Earth, 24 hours a day. GPS is primarily a navigator system which fundamental principle is based on the measurement of pseudoranges between the user and four satellites. It is designed to provide a real-time navigation, and also to support geodetic positioning with high accuracy (Seeber 2003) (depending of the GPS receiver). How the GPS receiver position is calculated? Satellites transmit the signals, which travel until the GPS receiver antenna, the GPS receiver detects the signals transmitted and converts it into useful measurements (observables) initially, the three-dimensional coordinates of the receiver's antenna can be calculated from three observed distances (the distance from the GPS to each satellite) by the trilateration technique, based on the measurement of time that the satellite signal takes to reach the GPS receiver. Additionally to this, GPS satellites send the information about their location (ephemeris data) through the navigation message. This ephemeris data are predicted from previous GPS observations at ground control stations, but they are subject to errors due the fact of the difference between the real position and the predicted model (El-

Rabbany, 2002). Because some GPS applications require more precise ephemeris data than the broadcast ephemeris, several institutions including the International GNSS Service (IGS) provide to the users a number of different products with the precise ephemeris. We can download this products freely from the IGS website (http://igscb.jpl.nasa.gov/components/prods.html) (some software do it automatically). The GPS position calculations is based on the known ephemeris of the satellites and the intersection of the spherical shell. As the receiver clock is not synchronized with the satellite clock, a fourth distance measurement is necessary in order to solve the clock synchronization error (Torge 2001). GPS signals must provide a means for determining positions in real-time (Seeber 2003).There are many different GPS receivers in the market, with different sizes, shapes and technical characteristics which differ according to the purpose of the work or study to accomplish.

1.6 Spatial analysis

Geographical Information System (GIS) have been used for some studies related to home ranges and spatial distributions, and it has been successfully applied in wildlife analysis, as GIS enable firm understandings of animals movement, habits and distributions (Stone et al. 1997, Selkirk and Bishop 2002). GIS allows working with the spatial points patterns of animals according with certain parameters, such as substrate temperature, ambient temperature or humidity, which are important to understand their behaviour. Interest in spatial patterns and processes by ecologist is not new (Watt 1947, Skellam 1951). Many statistical methods have been developed for the analysis of spatial point data (e.g. Nearest-neighbor analysis: examines the distances between an event and its nearest neighbour). Spatial statistics is useful to evaluate the spatial association of one variable on a set of positions, that is, to understand how the animals are positioned in certain places, clustered or not, at certain times, therefore, we can interpret the behaviour of animals in their home range. Point processes and point patterns are different concepts (Perry et al. 2006): a pattern is the realization of a process, where each point (referred as an event) is defined by some set of coordinates. With this information we can analyse if there are clusters or not, significant patterns between of the events, and others questions to understand the animals behaviour.

1.7 Sympatry and Syntopy

In one of the study case which I am going to present in this dissertation, we have worked with two species (*P. bocagei* and *P. hispanica* type 1A) which coexist in the same localities, that is, both species used the same area to perform their normal daily activities. The terms describing this geographical relationship between these species are defined as follows. The concept of sympatry refers to two or more related species sharing the same geographic distribution, regardless of whether or not they occupy the same micro-habitat. Thereby, syntopy concept refers to two or more related species which occupy the same micro-habitat. These species occur together in the same locality, are observed in close proximity, and might possibly interbreed (Rivas 1964). The idea of studying the home range of these two species is to analyse their relationship, if there is competition for the space that they share and how is their interspecific relation.

1.8 The interspecific competition for sympatric and syntopic species

The interspecific competition is a form of competition in which individuals of different species compete, caused by limiting resources including food, water or space. The interspecific competition could be an important factor limiting the population size of many species. When two species share the same geographical area, the competition between both species will be driven to the exclusion of one of this species (McGinley and Caley 2008a). The general idea focusing in home range studies is to study the relationship among the species and how they share the space and specifically the home ranges. Are the home ranges of sympatric species affected due the interspecific competition? There are some studies about home ranges of simpatric species. In the specific case of two simpatric species of bats, the home ranges of *Pipistrellus pipistrellus* were three times larger than of *P. pygmaeus*, although the *P. pygmaeus* colony was approximately 2.5 times larger than the *P. pipistrellus* colony (Nicholls and Racey 2006). Thus, in this particular case, the species with smaller colony size had bigger home ranges, which was not expected, assuming that the competition between species with a big size colonies exerted more competition for the space than small size colonies. However, it has been demonstrated for carnivore species that home range size does not necessarily increase with group size (Macdonald 1983). Focusing on syntopic species' home range, as our study species are located in a sympatric area (Kaliontzopoulou et al. 2012), and in this specific case (see in section bellow, Study area (1º study case)), they are strictly syntopic (Kaliontzopoulou et al. 2011). I want to rephrase the previous question, are the home ranges of syntopic species affected by the interspecific competition? Ribble and Stanley (1998) studied the home range of two species of syntopic mice (*Peromyscus boylii and P. truei*). Home ranges of both species were smaller at higher conspecific density, but they showed in other studies of that genus that there were an inverse relationship between population density and home range. Thereby, home range size of the species could be modified in a syntopic situation. It is expected some competition between syntopic species, as well that one species will be numerically more abundant than the other, and the exclusion caused by the space and resources competition. Also the size of the individuals of the species is a variable to consider: if individuals of a species are larger than other species, therefore it has more opportunities to compete for resources such as food and space, choosing the best areas. The possibility to breed with females (in species where hybridization occurs) of other species could induce that the males of the more competitive species have access to more females than the other species. This will probably affect the population structure of the less competitive species. These are many hypotheses related to this topic, because there is a lack of knowledge in this research field, as well as non information about reptiles or even about the home range of syntopic lizards it is readily available. In the specific case of the lizards, the competition for better areas such as basking areas could affect the activities of the individuals of the weak species. Lizards are active within a limited range of body temperature (Cowles and Bogert 1944), which could affect to the behaviours as mating and feeding. Similarly, the dominant lizard species could keep with the better refuges which will hinder the antipredatory behaviours of the less competitive species. Knowing the home range of the syntopic species and their spatial distribution could corroborate many of these assumptions. There are not studies related to the home ranges, where *P. bocagei* and *P. hispanica* type 1A were in syntopy. To our knowledge, nobody did a study of the home range with two or more *Podarcis* species in sympatric areas.

1.9 Studies of a long time periods

Home range studies need a long period of research to analyse correctly animals' spatial distribution. The duration of each study also depends on what species and features we want to study. One of the question that the research tried to answer with this long time studies is how home range change along time, thus, it is possible to relate the home ranges changes with the activity of the animals or the seasons. Home range size, overlaps among home ranges and core areas, distribution size and their changes a long the time, were other important topics to study. As an example of long time studies I am going to describe some studies which answered these important questions. In the section of this introduction “home range estimators and their limiting factors” we reported a study case of two years where a total of 15 foxes were radio-collared (Franfjord and Prestrud 1992). One of the results of this study showed that the largest ranges were 10-100 times greater than previously reported for Arctic foxes. To study these Arctic foxes, which travel miles a day and whose activities changes with the different seasons (mating and breeding), would not be enough to monitor their movements only during a few months for home ranges and spatial distribution studies. The home range of this Arctic foxes changed along the time, and it was in this study that Franfjord and Prestrud (1992) suggested that the home ranges should be defined by time intervals (e.g. month or season). Other example of a long time home range research was a black bear monitoring study, where Robert A. Powell and their research team have been studying the behaviour and movement of a female of black bear during multiple years (Powell et al. 1997, Powell 2012). After years of study, this female left their current home range and travelled in direct line to other area far away. Powell supposed that this female were visiting another home ranger area that have been part of her home range in previous years. By monitoring the black bear for many years, it was possible to observe this case of black bear's home range. Powells (2012) suggested that an animal can be familiar with an area not use regularly, as an old home range.

Focusing on reptiles, Knapp and Owens (2005) studied the home range of 18 (10 males, 8 females) Bahamian Andros iguanas (*Cyclura cychlura cychlura*) with telemetry methods during five months (divided into breeding season and non-breading season). Their data suggested that males expanded their home ranges during the breeding season and also that core areas did not overlap in the non-breeding season. The duration of this study was shorter than the studies described above for the mammals, but was enough time to analyse the overlaps and changes of the home ranges of the iguanas. Thus, the time needed for a study depends on the goals of the study and the species. Some studies need more than a long time period of animals tracking to study the home ranges changes, a previous studies of the behaviour of the animals could be necessary to divide the season or the different periods to study the evolution of the home ranges changes. In the previous study, Knapp and Owens (2005) observed during a study of three years the courtship and the ovoposition dates of the iguanas, thereby they divided the home ranges by breeding and non-breading season. This is an important factor to be in mind when we want to study the home ranges of the species a long of the time, thus, it is possible to divide the study period in different group as did Knapp and Owens (2005).

1.10 The case of lizards on the Iberian Peninsula

The Iberian Peninsula is situated in the south-western part of Europe. It is surrounded on the South and East by the Mediterranean sea, and on the North and West by the Atlantic Ocean. The Iberian Peninsula is separated in the North-East from central Europe by the Pyrenees mountain range and from Africa by the Strait of Gibraltar in the South. The Pyrenees acts as a geographical barrier separating it from the rest of Europe (in Sillero et al. 2009). This particular situation and the two major climatic areas (Atlantic regions and Mediterranean regions) made of the Iberian peninsula a refuge for biodiversity. Focusing on Reptiles, there are 57 species (including Balearic Islands), 27 belonging to the Lacertidae family (Carretero et al. 2011). There are several studies concerning the abundance and micro-habitat of lizards (Martín and Salvador 1997, Díaz et al. 2005), activity patterns (Martín-Vallejo et al. 1995, Aragón et al. 2001, Carrascal and Díaz 1989), as well as lizards physiology (Martín and López 1995, López and Martín 2011). Focusing in the home range research field, Gil et al. (1988) studied the use of space in a population of Iberian Wall Lizards (*Podarcis hispanica hispanica*) from the Sierra de Francia (Salamanca), where it was found a strong variation in home range size between individuals, even among individuals of the same sex. Males had bigger home ranges than females. A high degree of overlapping among females was found, more than among males. Females overlapped more with males than males with females. In the Columbretes islands (Castellón), Swallow and Castilla (1996) studied the *Podarcis hispanica atrata* home range. They compared their results with the result found by Gil et al. (1988) for *P. h. hispanica*: the home range area of *P.h. atrata* males and females were slightly larger than *P. h. hispanica*. Marco and Pérez-Mellado (1999) studied a *Lacerta schreiberi* population from the Sierra de Bejar (Salamanca). Mating success of males were positively correlated with the size (snout-vent length), but was not correlated with the home range size. Diego-Rasilla and Pérez-Mellado (2003) studied the home range and the habitat selection of *P. hispanica* in the Sistema Central Mountains (Salamanca). Home range areas among seasons were significantly different, but not among sex or age classes. The thermal properties of micro-habitat used by lizards did not differ between seasons but varied with respect the time of the day. Studying the relationships between home range size, quality of home range, and degree of aggressiveness as well as their effect on survivorship in juvenile male lizards (*Psamodromus algirus*), in a forest near Navacerrada (Madrid), Civantos (2000) observed that the more aggressive individuals had a larger home ranges than the less aggressive ones. Furthermore, the survivors' home ranges were larger and with more complex cover of vegetation than those of non-survivors. In juveniles of this species, the home range size and the animal size were not significant correlated.

As we saw previously, there have been some studies related to the home ranges and animals behaviour of lizards in the Iberian Peninsula, but not all the species have been studied at the home range level .Focusing on the genus *Podarcis,* due the two study species of my work belong to this genus, I did not found many information relative to the home range and spatial behaviour of these lizards. Nowadays, we know about *P. hispanica* that males have bigger home range than females, also that females overlaps their home ranges more with females than with males and home ranges of *P. hispanica* are different by seasons (referenced above). In the case of *Podarcis bocagei*, the other species of interest of this work, I have not been found any articles about home ranges or spatial behaviour. In fact there are not studies of the home ranges of the *P. hispanica* type 1A (see section "Study species and distribution"), or even studies about the home ranges in sympatric areas of *P. bocagei* and *P. hispanicas* type 1A. Curiously, no studies were found with GIS techniques, radio-telemetry or GPS for small and medium size lizards in the Iberian Peninsula, all studies related about home ranges of small lizards were done with the experimental plot methodology.

1.11 Study aims

The aim of the present study is to analyse the home range and the spatial distribution patterns of two species of Iberian lizards. I am going to present two study cases, the first one is a case of two Iberian lizards (*Podarcis bocagei* and *P. hispanica* type 1A) in a syntopy situation, which was conduced in the north-west of Portugal in a small village called Moledo (Viana do Castelo) (see study area section 3.1.1). The second study case was performed with a population of *Podarcis bocagei*, which was conduced in the city of Porto, located in the north-west of Portugal, inside the Botanical Garden of the University of Porto (see study area section 3.2.1). Each study case was done with a different technique to collect data, taking into account a spatial approach. I am going to use different tools to analyse data collected in a spatial point of view.

Specifically, my study aims are:

1) **Spatial distribution**: Always from a local point of view, I attempt to see if there are significant patterns between the species, sex and age for both study cases. To achieve this goal, for the study case of the syntopic species, I have used several variables such as climacteric parameters which were recorded in the field.
2) **Home range size**: To establish the size of the home ranges of males and females of both species in their specific study cases. For the study case of the Botanical Garden, I will also set up the size of the home ranges and the utilization distribution of adults and subadults for each sex.
3) **Overlaps**: To determine overlaps among lizards' home ranges by species and sex. In the study case of the Botanical Garden I will determine overlaps of the home ranges by sex, and the core areas' overlaps by sex and age.

2 STUDY SPECIES AND DISTRIBUTION

Our study species are *Podarcis bocagei* (Seoane, 1984), with the common name of Bocage's wall lizard, and *Podarcis hispanica* (Steindachner, 1870) type 1A (*sensu* Harris and Sá-Sousa 2002), with the common name of Iberian wall lizard. Both species are sister taxa, as they are members of the *P. hispanica* species complex (Pinho et al. 2006, Kaliontzopoulou et al. 2011).

P. bocagei is a small-sized lizard, but bigger than others *Podarcis* lizards as *P. hispanica**. It is a relatively robust lizard without depressed body and with a high skull, in which the orbits protrude slightly above the pileus (much less than in *P. hispanica* type 1A). Adult males have green backs and flanks brown, meanwhile adult females and immatures have back and flanks brown. The ventral coloration is mainly yellow (Galán 2009) (Fig. 1). *P. bocagei* is especially a ground-dweller, but also inhabits stones wall constructed by the human (Kaliontzopoulou et al. 2010).

Fig. 1: Photograph of 2 individuals *Podarcis bocagei*, Male in the left and female in the right.

P. bocagei is endemic to the Iberian Peninsula, restricted to the north-west (Galán 2009). In Spain, it is distributed in almost all Galicia, north-west of Zamora, some areas of west, centre and north of Leon and some points in the west, centre and south of Asturias. In Portugal, it occurs in the north of the Douro River, occupying much of Minho and Douro Litoral, as well as some mountain areas (Marão, Alvão and Montesinho) of Tras-os-Montes. The oriental limit of *P. bocagei* is located in the north of Palencia, and the southern limit in the north-west of Zamora. In Portugal reaches further south, to the town of Espinho, on the left bank of the mouth of the Douro River. Island populations have been reported off the coast of Lugo, A Coruña, and Pontevedra (Galan 2009) (Fig. 2).

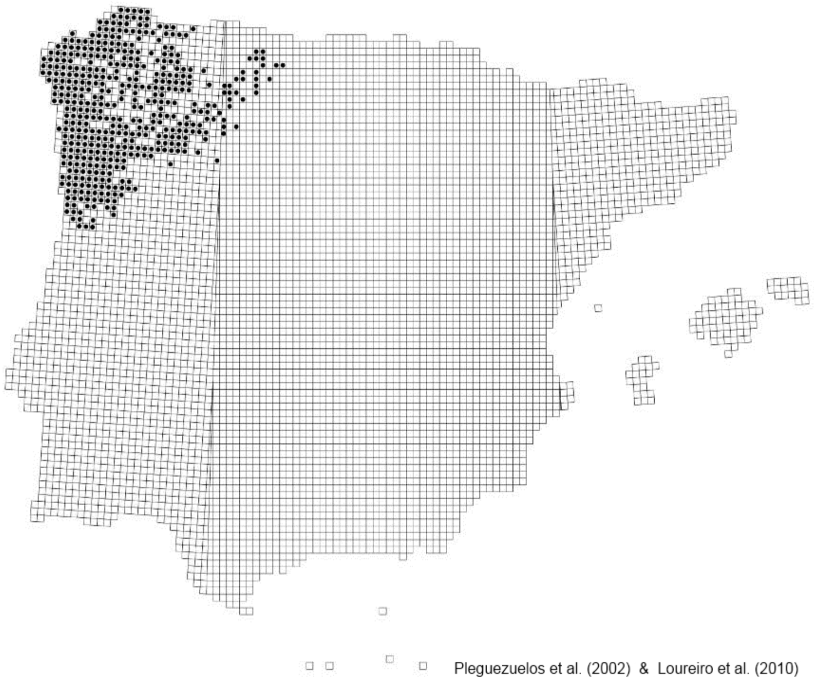

Fig. 2: Distribution map of *P. Bocagei*.

*Podarcis hispanica** is a polymorphic species found in south-western France, Iberian Peninsula (except in the northernmost border area) and north-western Africa (Sá-Sousa et al. 2002). Currently, it includes 16 different lineages (Kaliontzopoulou et al. 2011). *P. hispanica* type 1A is still not described formally as a correct species. However, the form *P. hispanica* type 1 (including the lineages 1A and 1B) was described morphologically by Sá-Sousa (2000). It is a small-sized lizard, with the head and body very depressed. The coloration is mainly dark, reticulated, with marbled and/or striped dorsal patterns, and whitish or pearly belly. This form was distributed in Galicia and northern and central Portugal (Sá-Sousa 2000).

P. hispanica type 1A (Fig. 3) is especially saxicolous, being more restricted to big rock outcrops, and normally climbing perpendicular surfaces (Sá-Sousa et al. 2002).

Fig. 3: Photograph of 2 individuals *Podarcis hispanica* type 1A. Male in the left and female in the right.

The distribution of both study species is showed in Fig. 4 (see details in Kaliontzopoulou et al. 2011).

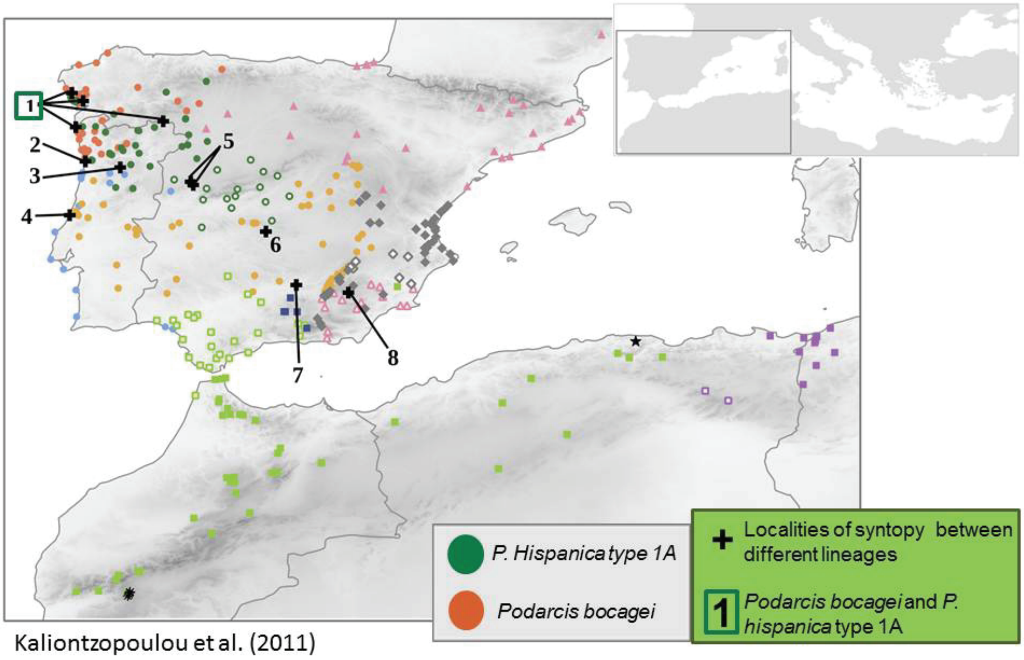

Fig. 4: Geographical distributions of the 16 mtDNA lineages of the *Podarcis hispanica* species complex. Black crosses indicate localities of syntopy between different lineages, specifically between *Podarcis bocagei* and *P. hispanica* type 1A (1); *P. bocagei* and *Podarcis carbonelli* (2); *P. carbonelli* and *P. hispanica* type 1A (3); *P. carbonelli* and *P. hispanica* type 2 (4); *P. carbonelli* and *P. hispanica* type 1B (5); *Podarcis vaucheri* southern Spain and *P. vaucheri* southern-central Spain (6); and *P. hispanica* s.s. and *P. hispanica* Galera type (7).

3 MATERIALS AND METHODS

3.1 FIRST STUDY CASE: SYNTOPIC SPECIES

3.1.1 Study area

The study was conduced in the north-west of Portugal in a small village called Moledo (Viana do Castelo). The study area is situated closed to an urban area (41° 50' 19.8168" N, 8° 52' 24.2472" W), and it is limited by buildings, stone walls, and small fields of traditional agriculture. Specifically, it is characterized by four stone walls and a small beach area with rocks and vegetation. The total length of the stone walls was about 350 meters, with a maximum height of 2 meters and a minimum of 20 cm. The beach area had approximately 0.5 ha. (Fig. 5)

Fig. 5: Location of Moledo beach, at the north-western of Portugal. Left image shows in detail the 4 stone walls and the beach area (yellow line).

3.1.2 Study species

The study species are *Podarcis bocagei* and *P. hispanica* type 1A. Both species live in sympatry in this study area (Kaliontzopoulou et al. 2011) (see Fig. 3 in section "study species and distribution").

To appoint into the following text the species P. hispanica type 1A, I am going to simplify calling it *P. hispanica*, but always I will want to refer to *P. hispanica* type 1A.

3.1.3 Field Work

3.1.3.1 Capturing and marking

The fieldwork was performed during the months of April and May of 2011. Lizards were captured in the 28th of April and the fieldwork were in the first twelve days of May, excluding four days because of the bad weather. We captured 76 lizards by noose (García-Muñoz and Sillero 2010): 57 of these were *P. bocagei* (20 females and 37 males) and the other 19 were *P. hispanica* (11 females and 8 males). We marked temporally in the moment of the capture with a unique number on the belly. The number belong to a number series, unique for each person. The place of capture was identified with the number of the lizard in a plastic tape. Each lizard's capture position was georeferenced with a professional Trimble GPS receiver (GeoExplorer XT) with a horizontal error around 50 cm. Several morphological measurements were recorded with a 0.01 mm precision digital calliper: snout-vent length (SVL); trunk length (TRL); head length (HL); pileus length (PL); head width (HW); head height (HH); mouth opening (MO); front foot length (FFL); hind foot length (HFL) (Fig. 6).

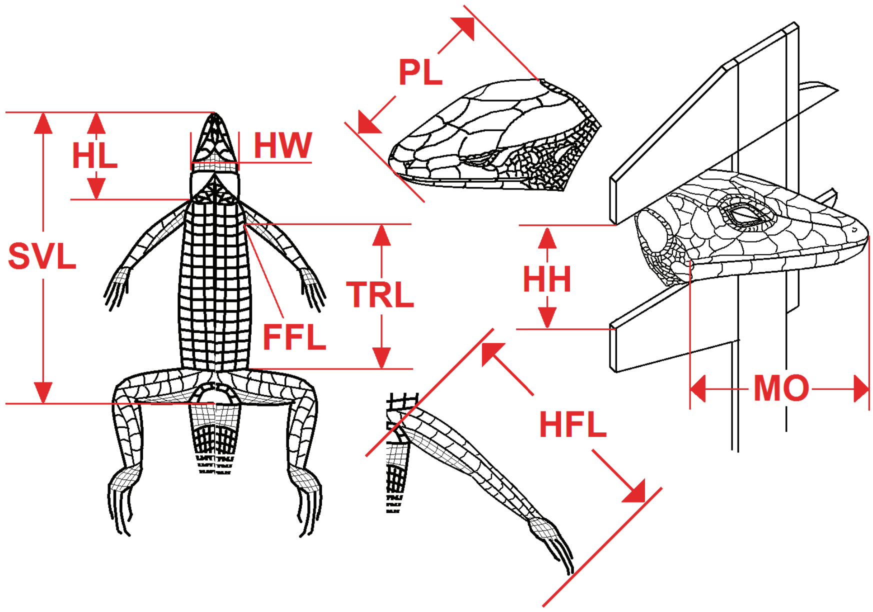

Fig. 6: Diagram of the lizards measurements.

Additionally, we took lizards photographs, tissue (tail) and blood samples, as well as excrements. We marked the lizards with coloured inks for visual identification during recording position fieldwork (54 lizards were marked with a code by three dots of colours in their back, and 22 lizards were marked with two colours in their legs with different combinations) (Fig. 7). Each lizard had a unique code of colours. Finally, we release them in the same place of capture. Except SVL measures that will be used in this work to represent total body size, all the measures and samples were used for other study (Project PTDC/BIA-BEC/102179/200 “On the road to speciation: an integrated analysis of the evolution of reproductive isolation in a cryptic species complex").

Fig. 7: Photographs of lizards marked with the two coded types.

3.1.3.2 Lizards tracking

We waited few days before going to the field, in order to be sure that the lizards returned to their normal life activities after being captured. The fieldwork lasted eight days (the time of durability of animals' inks). In the field, we walked randomly around the study area looking for lizards on the walls, stones and ground. We conducted this activity during daylight hours (with favourable climatic conditions). We recorded the position of each lizards with the Trimble GPS receiver during 40 seconds, as well as information related to the lizards and their activities (see below). We recorded for each lizard both the ambient temperature and humidity with a hygro-thermometer (Fluke®-971 hygrothermometer to the nearest 0.1ºC and 0.1%, respectively), and substrate temperature with a infraredthermometer (Fluke® 68, precision 0.1ºC, accuracy according to the manufacturer ±1%) directing the laser pointer to the centre of the lizard's locality at a distance of approximately 20 cm. (to measurement the temperature of the local where we saw the lizards).

3.1.4 Office work

3.1.4.1 GPS Dictionary

We created a GPS data dictionary with the Trimble GPS Pathfinder office software v 5.0, transferring it posteriorly to the Trimble GPS receiver. We created three different features (Body Marked, Leg Marked and Unmarked) for each type of lizards' colour marks (plus those without marks). For all the observed lizards, we recorded the activity (active, basking, mate, mate guarding, fight, feed, refuge, sleeping, inactive, and not observed); position (sun or shadow); height on the wall (top, middle, or down); interaction (Male PB, Male PH, Female PB, Female PH, Juvenile PB or Juvenile PH); sky (no clouds, partly clouds, or cloudy); wind (no wind, wind, or strong wind); substrate temperature, ambient temperature; and ambient humidity.

For the marked lizards' sightings (Body Marked and Leg Marked), we recorded in addition the identification number (automatically created by the GPS receiver) and colours code. For the unmarked lizards' sightings, we recorded also the species, sex, and age.

Not all data collected in the field were used for the accomplishment of my dissertation, however they will be used in future studies.

3.1.4.2 Differential correction of the GPS data

After recording the positions of lizards with the GPS receiver, it was necessary to make a differential correction of the data to improve the accuracy of the locations. The differential GPS (DGPS) is used to improve the position of a roving station by applying corrections provided by a GPS monitoring station (reference station).There is a network of permanent GPS / GNSS stations distributed throughout Portugal, of continuous observation, which broadcast the observations into the Reference System ETRS89 for positioning in real-time using the technique RTK (Real Time Kinematics), or for post-processing with RINEX (Receiver Independent Exchange) files. In this work, the roving station is our GPS receiver. The ordinary DGPS procedure makes corrections in the measurement domain. It is a flexible correction and works well within a radius of several hundred kilometres about the reference station. Because the decorrelation of the biases with distance (orbit, ionospheric and tropospheric delay), the accuracy decreases roughly by about 1 m per 100 km (Seeber 2003).

The post-processing was done with the Trimble GPS Pathfinder office software v 5.0. We used the data from a reference station in RINEX format which can be obtained from the official site of the Instituto Geográfico Português, on the Rede Nacional de Estações Permanentes (RENEP: http://www.igeo.pt/produtos/geodesia/vg/renep/renep.asp#). The reference station was in Paredes de Coura (PCOURA) (41° 54' 43.73609" N, 8° 33' 36.20408" W), because it is the closest site of our study area. Each RINEX file contains the observation data for the period of 1 hour with an interval of 5 seconds. For our work, we used the RINEX files to correct the GPS data recorded, namely a RINEX file per hour, during the nine days of fieldwork.

After performing the differential correction, the data were exported to the shapefile format, with the WGS84 reference system. The Trimble GPS Pathfinder office software v 5.0. allowed us adding other information to the data recorded, namely the date and time of the recorded locations. With the ArcGIS 9.3 software (ESRI) we did the coordinate transformation of WGS84 reference system to the ETRS89 reference system with the PT-TM06.projection. In the same software we added the X and Y coordinates to the data information.

3.1.5 Spatial analysis

3.1.5.1 Home range analysis

We estimated home range areas with the Minimum Complex Polygon (MCP), which is the smallest convex polygon possible that covers all known locations for the animal (Hayne 1949). It is nowadays the most popular home range estimator (Laver and Kelly 2008), based on the 95% of the lizards locations (Jennrich and Turner 1969). We used R software, namely the package AdehabitatHR, which is a collection of tools for the estimation of animals home range (Calenge 2011). Home ranges were determined for 35 marked individuals, 28 *P. bocagei* (12 females and 16 males) and 7 *P. hispanica* (4 females and 3 males), with five or more sightings, in order to be able to exclude 5% of the locations as occasional sallies. The result of this process is a shapefile type polygon with a code of the animal and the area. To create a MCP we needed at least three locations. In this study case, we did not recorded more than 12 locations per individual, therefore for each individual we just excluded one location.

3.1.5.2 Home range overlapping analysis

In order to determine the overlaps among lizards' home ranges, either by species and by sex, we computed a geometric intersection of the home ranges by the R software (see home ranges analysis). To calculate the overlaps among the home ranges we used the ArcGis 9.3 (ESRI), namely the Union tool (ArcToolbox).

3.1.5.3 Spatial statistic Analysis

To identify significant spatial clusters of similar values for marked and unmarked lizard locations, we measured the autocorrelation of substrate temperature, ambient temperature, humidity, species and sex using the spatial statistic tool LISA (Local Indicator of Spatial Association) (Anselin 1995). The LISA statistic is an indicator of local hot spots, similar to G_i and G_i^* statistic (Getis and Ord 1992). It is used to asses the influence of individual locations on the magnitude of the global statistic and to identify “outliers”, as in Moran scatterplot (Anselin 1993). Thus, LISA provides the cluster map and the Moran scatter plot for each analysis. We used the free software Geoda (https://geodacenter.asu.edu/), which includes functionality ranging from simple mapping to the visualization of global and local spatial autocorrelation and it works directly with shapefile (see details in Anselin et al. 2006). Firstly, we created spatial weights (based on Euclidean distance), which is a spatial relationships among area, distance, length, or proximity, for example. In our case, it is done for the data set (each shapefile).

For the autocorrelation among the climatological parameters and the species, we used the shapefile with all lizards records (1098 sightings for marked and unmarked lizards). As LISA is designed for continuous variables, we classified the species locations as 1 and 0 for *P. bocagei* and *P. hispanica*, respectively. To identify spatial patterns between the sex we used the shapefile with the 1025 recorded lizards with known sex, we did the analysis for each species (we split the shapefile in separated species), and we classified the sex of female and male as 1 and 0, respectively.

3.1.5.4 Non spatial analysis

I analysed the relationship between home range size and lizards' species and sex with ANOVA for parametric data and with Kruskal wallis test for non parametric data, and the relationship between home range size and lizards' SVL with a linear regression. The relationship among the number of overlaps by species and sex were analysed with two-way ANOVA, and the analysis of the relation between the species and sex overlaps were done with Chi^2 test. Normality of data were checked with Saphiro test. Homocedasticity of variance were tested with Bartlett test. Not normal data were transformed to logarithms. I applied the Tukey test as ANOVA post-hoc analysis. GAM test (Generalized Additive Models with integrated smoothness estimation), with a Gaussian family, were applied as non-parametric alternative to linear regression. The linear regression were done with the 33 of the 35 lizards that we used for the MCP, because two of this 35 lizards did not have morphometrical measurements. All analysis were performed with R software (http://www.r-project.org/).

3.2 SECOND STUDY CASE: BOTANICAL GARDEN

3.2.1 Study area

The study was conduced in the city of Porto, located in the Northwest of Portugal, inside the Botanical Garden of the University of Porto (41° 9' 10.962" N, 8° 38' 34.2708" W) (Fig. 8). Specifically, the study area is characterized by a stone wall with a maximum height of four meters and a minimum of two meters and with a total length of 60 meters.

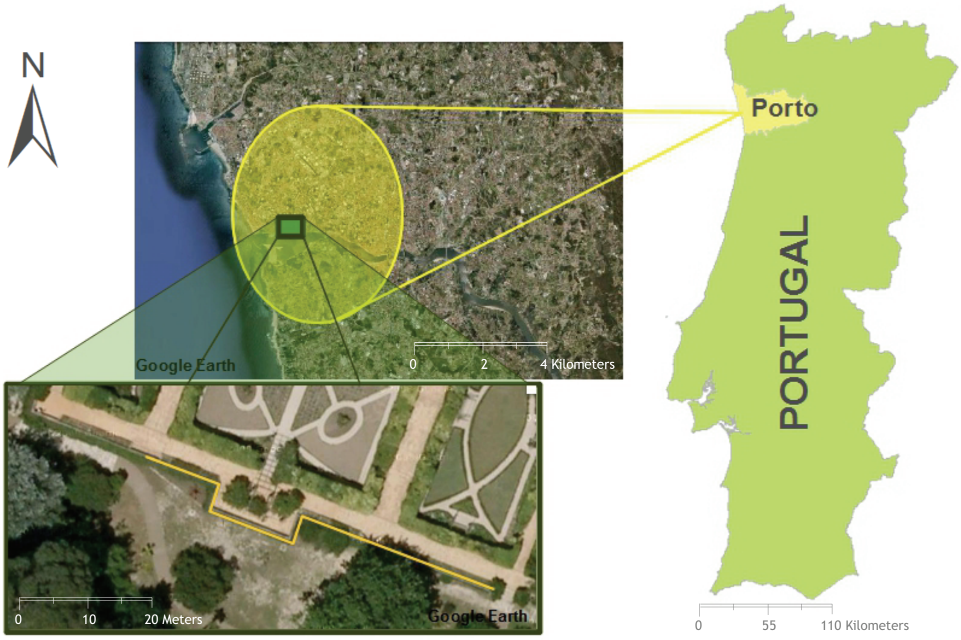

Fig. 8: Location of the Botanical Garden, at the north-western of Portugal. Bottom image shows in detail the situation of the stone wall (yellow line).

3.2.2 Study species

Our study species in this study case is *Podarcis bocagei*, which mostly perform their daily activities in the stone wall of the Botanical Garden.

3.2.3 Wall image generation

Lizards' positions were recorded using a referenced mosaicked image of the Botanical Garden wall. This image was the result of mosaicking several independent images of the wall. For this part of the work, we had the collaboration of Professor José Alberto Gonçalves and Engineer Nelson Pires, Geomatic Researchers from the Faculty of Sciences of the University of Porto. Firstly, we took 11 photographies with a compact digital camera (Canon PowerShot A495), covering the five different flat surfaces of the wall. We used a projective transformation to rectify each image from radial distortions, namely: Perspective, Scale, Rotation and Translation (Wong 2007). The result is a new rectified image which turns possible to obtain direct true measures of the reality. This transformation mathematically modulates an image of flat (or almost flat) objects with a high accuracy, with the prerequisite that at least four Ground Control Points (GCP's) are provided to each image (Gonçalves and Piqueiro 2004). The GCP's were established by measuring horizontal and vertical distances between two ropes with a laser distance sensor (Stanley Tru Laser TLM130i to the nearest 2 mm). Therefore, two ropes were placed vertically (one red and one blue) from the top of the wall to the bottom, as showed in Fig. 9. The horizontal distance between the ropes provided the length between two GCP's, and the vertical distance, the height between two GCP's (Fig. 10). In this way, we obtained the four GCP's necessary to correct each image.

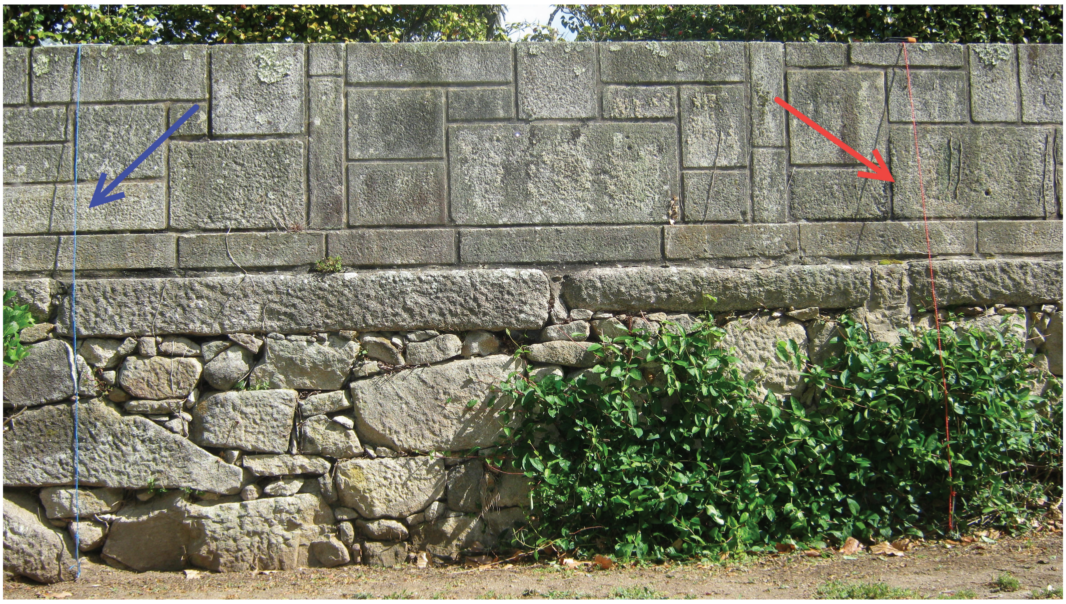

Fig. 9: A photograph of the stone wall. The blue arrow indicates the blue rope and the red arrow, the red rope.

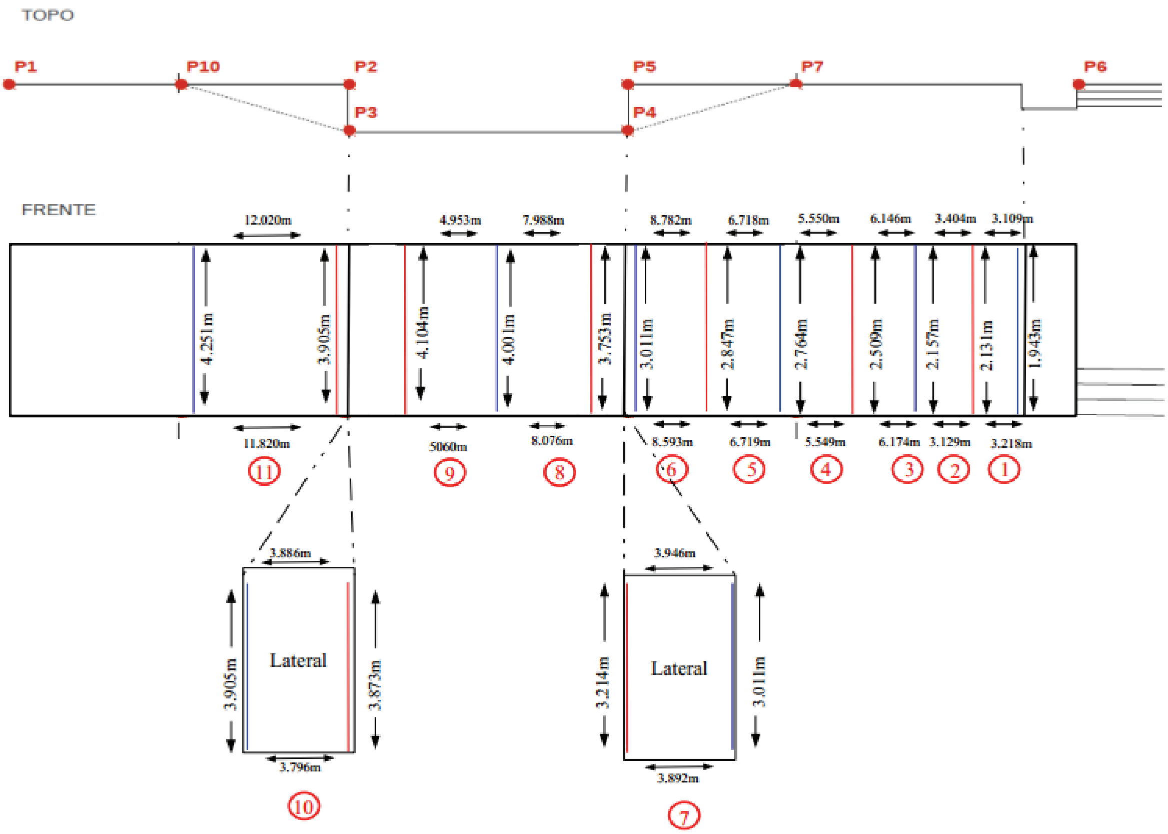

Fig. 10: Diagram of stone wall with the position the ropes (red and blue) for each photograph and the measurements (vertical and horizontal).

After this step, we defined five origins references in the top right of each face of the wall (Fig. 11) to facilitate the correction of the images. Then, 11 photographs were geometrically corrected by a Projective Transformation applying a program written in C language by Professor José Alberto Gonçalves.

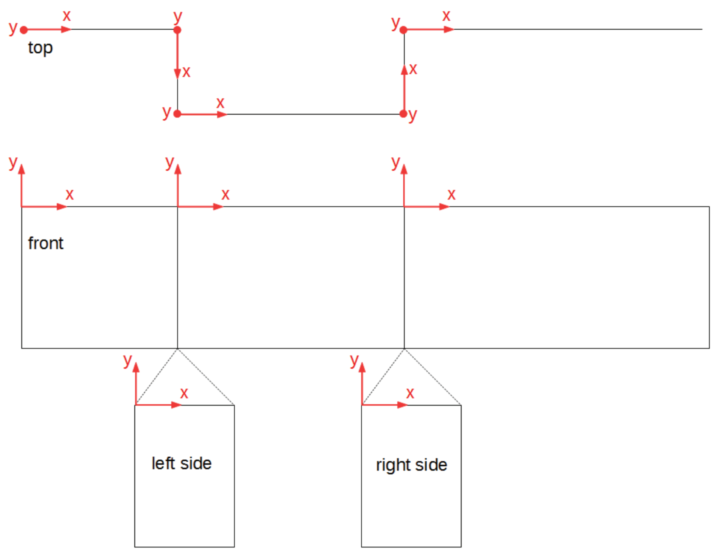

Fig. 11: Diagram of the five origins references of the wall.

Eleven new images were created, without radial camera distortions. We used these images to measure the true distances of the lizards positions in the wall. With all the images corrected and rectified, we created a mosaic joining all the images in the same planar reference frame using the PCI Geomatica software (Fig. 12).

Fig. 12: Mosaic of the stone wall already corrected.

3.2.4 Fieldwork

3.2.4.1 Capturing, Marking and Recapturing

We performed six captures campaign during the months of May, June, July, August and September of 2012 (Table 1).

Table 1: Summary of captures. Date: days of captures, captures: number of lizards captured for each day, recaptures: number of recaptured lizards. Number of female and male lizards (adults and subadults).

Date	Captures	Recaptures	Female		Male	
			Adult	Subadult	Adult	Subadult
10/05/12	25	0	9	6	6	4
24/05/12	7	4	3	0	4	0
19/06/12	28	20	9	2	10	7
11/07/12	17	15	6	3	6	2
09/08/12	8	7	4	1	2	1
04/09/12	7	7	2	0	5	0

We captured the lizards by noose (García-Muñoz and Sillero, 2010), and marked them temporally in the moment of the capture with a unique number on the belly. The number belonged to a number series, unique for each person. The place of capture was identified with the number of the lizard in a plastic tape. The exact coordinates of each lizard's capture position were recorded in a shapefile by digitizing a point on the mosaicked wall image using a Netbook with Quantum GIS 1.7 software. Several morphological measurements were recorded with a 0.01 mm precision digital calliper: snout-vent length (SVL); trunk length (TRL); head length (HL); head width (HW); head height (HH); front foot length (FFL); hind foot length (HFL) (Fig. 13). Except SVL measures that will be used in this work to represent total body size, the rest of the measures were not used. We collected six pictures of each lizard for permanent individual identification (see below): overview picture of the back and the belly, femoral pores; chest; dorsal and back view of the head. The following data were recorded per individual: temporal number, colour code (assigned to mark), sex, size class (adult or subadult), presence of external parasites, tail condition, photography numbers, and weight.

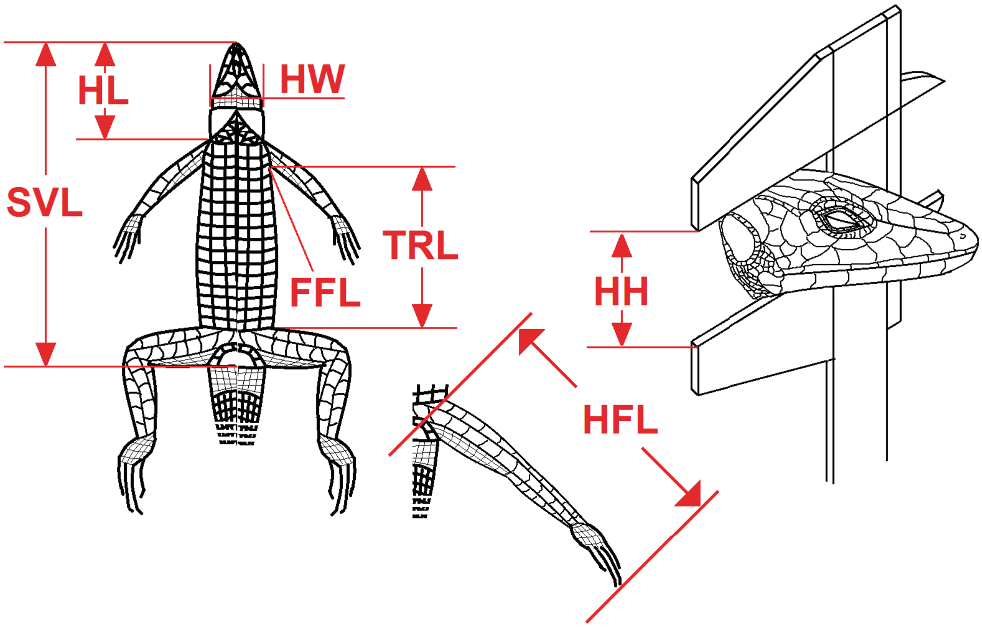

Fig. 13: Diagram of the lizards measurements.

We sexed lizards based on lizards' morphology (Galán 2009), such as shape and coloration, but also we relied on the external morphology of the femoral pores once it is considered a good character for sexing of individuals (Arnold and Ovenden 2002)

We marked the lizards with coloured inks, for visual identification during recording position fieldwork, with a code by three dots of colours in their back; each lizard had a unique code of colours. Finally, we released them in the same place of capture. The captures were planned when the animals' inks were erased. These processes were repeated during the six captures done in this work. Each capture process was conduced in a single day.

3.2.4.2 Lizards tracking

After each captures, we waited two or three days before going to the field, in order to be sure that the lizards returned to their normal life activities. We performed 31 days of tracking lizards during the five months (Table 2). We walked around the stone wall looking for lizards. We conducted this activity during daylight hours (with favourable climatic conditions). We recorded the position of each lizards in the same way as the lizards' places of capture (see above).

Table 2: Tracking lizards calendar: dates we performed the lizards tracking, number of sighted lizards per day, and the time tracking we spend in the work for each day

Month	Day	Sighting Lizards	Time Tracking
Maio	15	14	09:30-15:00
	16	24	12:00-19:30
	17	18	15:30-19:00
	23	23	10:00-19:00
	30	17	10:00-17:00
	31	6	10:30-13:00
Junho	4	18	10:00-18:30
	11	3	10:30-11:30
	21	46	10:30-14:15
	22	83	10:30-19:20
	23	43	09:30-18:00
	24	12	10:30-12:30
	25	28	9:30-13:00/17:30-19:30
	27	30	10:30-13:30/16:00
July	9	1	10h- 11:15
	16	29	10:00-13:00/17:00- 19:30
	17	1	10:30-11:30
	18	20	10:30-19:00
	19	9	16:30-19:00
	21	10	13:30-18:00
	26	8	15:30-18:00
	27	1	15:00-16:00
August	2	0	10:00-12:45
	13	29	10:00-18:00
	16	30	10:00-18:00
	22	16	11:00-18:00
September	6	12	10:00-13:00/17:30-19:00
	7	15	10:00-13:30/16:00-18:00
	10	28	10:00-13:00/14:30-17:00
	11	4	16:00-18:00

For each sighted lizard, we recorded the colour code, the activity (basking, refuge, running, mate, mate guarding, fighting, feeding, active and not observed); position (sun, shadow and mixed); interactions with unmarked lizards (female adult, male adult, subadult and others); micro-habitat (rock in a big fissure or rock in a small fissure, above vegetation and bellow vegetation), commentaries, hour and date. Environmental temperature, humidity and wind velocity were also registered each hour during the tracking time with a portable meteorological station (Skymate portable meteorological station). Not all data collected in the field were used for the accomplishment of my dissertation, however they will be used in future studies.

3.2.4.3 Photographic identification of lizards

Many types of ecological studies require a unique identification of individuals. Until the last decade, the most common way of permanently identification was by marking with different techniques like tattoo for mammals (Cheeseman and Harris 1982), Pit-tag (Passive integrated transponder) for fishes (Castro-Santos 1996), and also toe-clipping for amphibians and reptiles (Funk et al. 2005, Olsson and Shine 1995). Some of these techniques (e.g. toe-clipping) have caused controversy (McCarthy and Parris 2004). Nowadays there is others techniques less invasive for the animals, such as the technique that we chose for this work, the photographic identification. This is a relatively new technique that already was been used to identify animals. For instance, Sacchi et al. (2007) created a classification code with the different features of the *Podarcis muralis*. Pierce (2007) used a free software package (I^3S) for the identification of Whale sharks. Focussing on lizards, Perera and Pérez-Mellado (2004) suggested the photographic identification technique as a non-invasive marking for lacertid lizards, and Sacchi et al. (2010) studied the same software than Pierce (2007) for lizard identification. For our work, we chose the Interactive Individual Identification System (I^3S Classic version 2.0) software (http://www.reijns.com/i3s/download/I3S_download.html), in order to identify the lizards of the Botanical garden.

We took photographies from the chest of the lizard with a Camera canon PowerShot A495 (ISO: auto, AWD: auto, Focus: punctual and Quality: 10M). Pictures should be taken correctly for posterior identification: thus, the body of the lizard should be stretched (we needed to see the collar of the lizard in the pictures), and shoulder scales should be well focused, in order to see the picture with enough detail. Also, front legs should not overlap with the body. We created xy coordinates on the picture. The order of clicking was very important, always the same: top (control 1); pectoral (control 2) and bottom (control 3). The spots of Control 1 and 3 were (counting from outside to inside of the lizard) located in the intersection between the first line of scales of the chest, the second line of abdominal scales (scales large and rectangular), and the scales of the collar (point is marked on the inside part). For the Control 2, the spot were located in the upper point of the union between scales three and four of the first line of ventral scales (ventral line contains 6 scales). After defining the control spots, we marked all intersections between the scales of the area defined by control points (at least 12 control spots; Fig. 14).

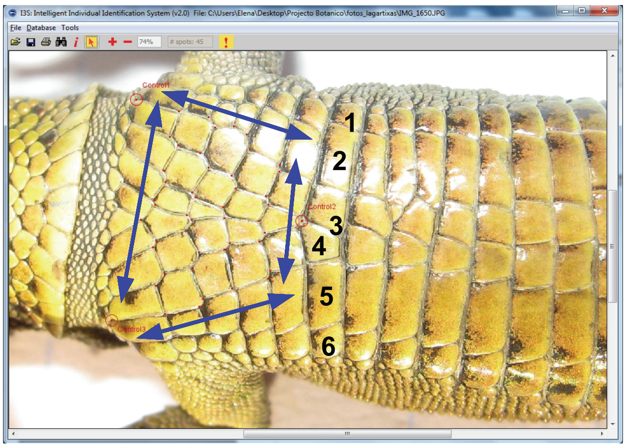

Fig. 14: Caption of the I^3S software. Diagram of the three control points and the located spots (red spots). Blue narrow delimiting the scales intersections area where the red spots must be located.

Following this process, we created a unique fingerprint for each lizard of the first capture, which was added to a database. After the first capture, we created a unique fingerprint for the following captures, but they were not added to the database. First, we compared each fingerprint with the database information: if we find a match, the image is identified and renamed, and if there was not a match, the fingerprint is added to the databased (see recaptures individuals identified with the I^3S software in Table 1).

3.2.5 Spatial analysis

3.2.5.1 Home range Analysis

I estimated the home range with the Minimum Complex Polygon (MCP) using the methodology described in the previous section (1st study case). Home ranges were determined with the MCP for 21 *P. bocagei* (9 females, 6 adult and 3 subadults; and 12 males, 8 adult males and 4 subadults) with five or more sightings, in order to be able to exclude 5% of the locations as an occasional sallies. The result of this process is a shapefile type polygon with a code of the animal and the area. In this study case, I recorded until 85 locations per individual; therefore, for each individual I excluded a maximum of five locations and a minimum of one location, in order to calculate the home range based on the 95% of lizards locations. I used the Fixed Kernel Density Estimator (FKD) (Worton 1989) to estimate the 95% of utilization distribution as in the MCP method. This estimation density method works evaluating each point in their distribution, based on the point that surround it. Thus, it gives a density value according to the number of points that surround the point that have been evaluated. Then, it creates a raster where a grid is overlapped to each point, assigning a pixel density to each point based on their proximity to an evaluation point. In the end of the process, a surface (raster) is created which contains pixel values of kernel density estimate of the distribution. The h (smoothing factor) is used to described the search radius about the evaluation point (Laver 2005). I have chosen this method instead of adaptative kernel estimator because it is the most accurate estimator with the smallest variance (Powell 2000). Kernel estimator ignores time sequence information, assuming that all locations data points are independent. It estimates the probability that an animal will be in any part of its home range; and it does not estimate the importance (according to the use of the animal) of each part of the home range area (see details in Powell 2000). The fixed kernel estimator is implemented in Hawth's Analysis Tools. In this study case, I have performed the Kernel estimator because I have more sightings per lizards than in the 1st study case. I combined the MCP and the Kernel methods for the home range analysis as suggested by Row and Blouin-Demers (2006). Thereby, it allows using the Kernel home ranges in habitat selection studies of herpetofauna. I adjusted the smoothing value h until the area of the 95% kernel equals visually the area of the MCP. I used the areas corresponding to the kernel line of 50% (Anderson 1982) to identify the main activity areas or core areas. I performed the Kernel for the individuals with more recorded positions to adjust the Kernel and the MCP and to determine the value of h, the scale factor and the cell size. Following the descriptions of the Hawth's tools available online (http://www.spatialecology.com/htools/kde.php), I used 100 values as a scaling factor, because

Kernel density estimates often produce very small numbers (e.g. 0,000000146); thus, the scaling factor simply multiplies these small values by a constant (e.g. 100), because grids only allow the storage of single precision floating point numbers. Then, the h value was 65 as a result of the adjustment to the MCP. I chose 10 pixel as the size cell to have more detail depending on the study area. The output of this process is a raster created with the extent of point data and the smoothing factor, which is a floating point grid. As well, we obtain shapefiles with the percent (50% and 95%) volume contours, which represent the boundary of the area that contains x% of the volume of a probability density distribution.

3.2.5.2 Home range overlapping analysis

To calculate the overlaps among the lizards' home ranges and among the core areas by sex and age I used the same method as in the previous chapter, Union tool, implemented ArcGis 9.3 (ESRI).

3.2.5.3 Spatial statistic Analysis

To calculate the spatial distribution patterns of *P. bocagei,* I used the LISA analysis with the same methodology as in the 1st study case. Lizards' sex and age were the parameters used for these analysis. For the analysis related to the sex and age, I performed the univariate LISA, using a shapefile with 584 observed lizards' records in the wall surface and calculating a spatial weights (based on Euclidean distance) for the data set. I classified individuals' sex (female and male) and age (adult and subadult) as 1 and 0, respectively, as I explained in the previous section. These two new fields were the variables used for the LISA, to analyse the distribution pattern between sex and age. To see the differences in the distribution pattern of the individuals along time, I used a LISA on sex values, splitting the individuals' sightings per month (for May until September).

3.2.5.4 Non spatial analysis

The relationship between home range (MCP) size and lizards' sex and age was analysed with two-way ANOVA. To see if lizards' size is related to home range sizes, I used linear regression. The relationship among the utilization distribution size and the core area size with the lizards' sex and age were analysed with two-way ANOVA. To see if lizards' size is related to the utilization distribution sizes and if lizards' size is related to the number of core areas per lizard, I used linear regression. The relationship among the number of overlaps by sex and age were analysed with two-way ANOVA, and the analysis of the relation between the sex and age overlaps were done with Chi^2 test. For the ANOVA analysis, data were checked for assumptions of normality and homogeneity of variance with the test of Bartlett for parametric samples. I applied the Tukey test as post-hoc analysis of the significant differences identified by the ANOVA. For the regression linear analysis, data were checked for the normality assumption with the test of

Shapiro. When these conditions were met, linear regressions were applied. The statistics procedures were done with 21 lizards used for the MCP, and with ten lizards used for the Kernel.

4 RESULTS

4.1 FIRST STUDY CASE: SYNTOPIC SPECIES

4.1.1 Descriptive Data

A total of 1098 lizards (marked and unmarked) were sighted during the study: 828 were *P. bocagei* (338 females, 444 males and 46 unknown sex) and 270 were *P. hispanica* (126 females 117 males and 27 unknown sex) (Fig. 15). Of these recorded lizards, 1025 (marked and unmarked) were recorded with known sex, 782 were *P. bocagei* and 243 were *P. hispanica*. 706 unmarked lizards were recorded, 536 *P. bocagei* (240 females and 296 males) and 170 *P. hispanica* (76 females and 94 males)(Fig. 16). Of the 76 marked lizards 88.16% (67 lizards) were sighted at least one time. We recorded 319 sightings for marked lizards, 247 were *P. bocagei* (99 females and 148 males) and 72 were *P. hispanica* (49 females and 23 males).

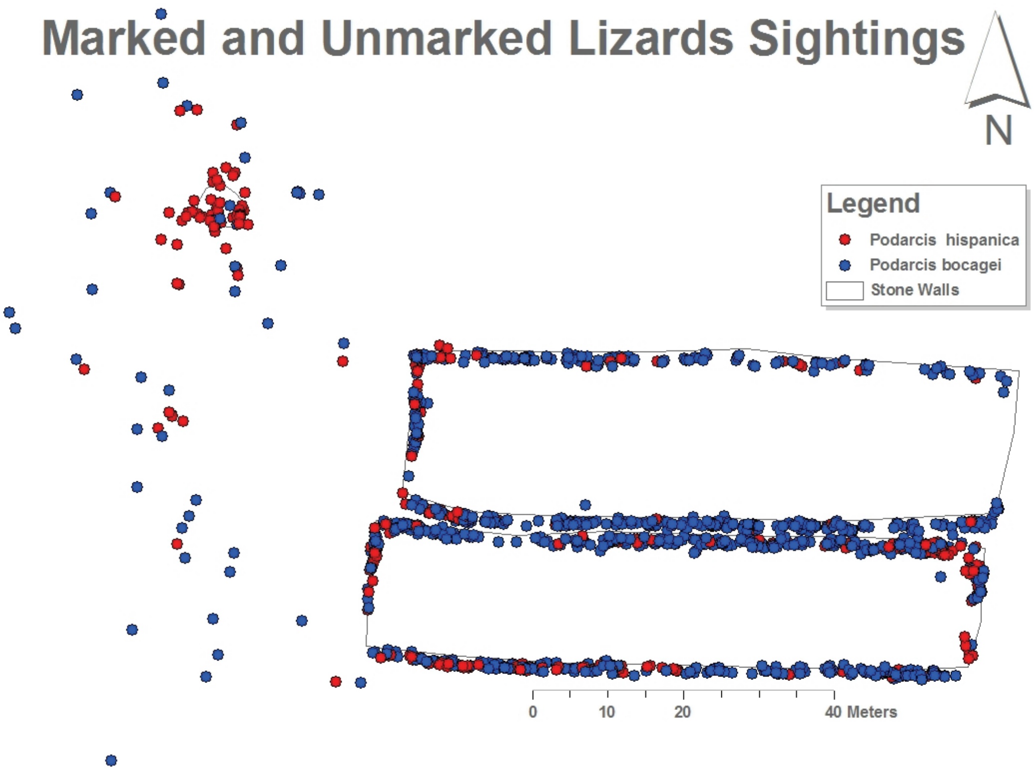

Fig. 15: Map of the 1098 lizards' positions recorded. The grey colour define the four stone walls and a big rock in the middle of the beach.

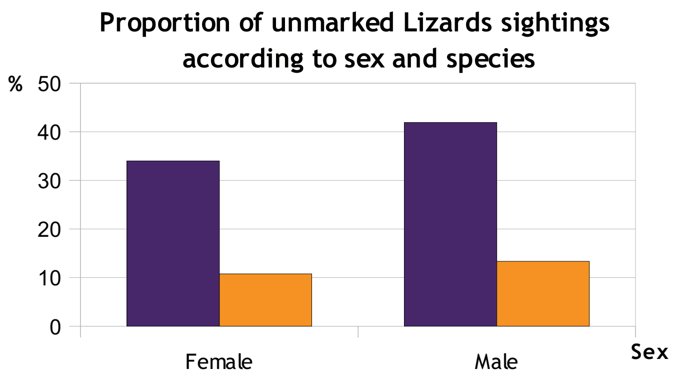

Fig. 16: Proportion of unmarked lizards sightings. 75.92% *P. bocagei* (purple columns) (35.99% females and 41.93% males) and 24.08% *P. hispanica* (orange columns) (10.76% females and 13.31% males).

The mean of sighted marked lizards with more than 5 sightings (n=35) was 7.34± 0.35 (mean ± SE) and ranged from 5 to 12 sightings per lizard. The average of the SVL measures (as body size) for the marked lizards (n=33) for *P. bocagei* females (n=12) was 54.36 mm ± 1.73 mm (range= 48.92-60.34 mm) and for males (n=15) 51.23 mm ± 1.82 mm (range=40.77-59.77 mm); for *P. hispanica* females (n=4) was 45.42mm ± 3.65 mm (range=38.28-54.15mm) and for males (n=2) 46.27mm ± 2.19 mm (range= 44.08-48.46mm) (see in Table 3).

Table 3 (1): *P. bocagei* (PB) and *P. hispanica* (PH) summary of the physical traits. number of sightings per lizard and home range areas. CODE: identity code, M: male, F: female, SVL: snout-vent length; MCP: minimum complex polygon.

Sightings	CODE	SP	SEX	SVL (mm)	MPC area (m^2)
12	RBB	PB	M	56,2	6,972649
12	MCH	PB	M	NA	11,90886
11	VBV	PH	F	40,65	29,706407
10	BBP	PH	M	48,46	8,014233
10	RYY	PB	M	61,3	5,091004
10	VYV	PB	F	52,39	0,967922
10	YYV	PB	F	56,17	3,201123
9	BYY	PH	F	54,15	18,557073
9	YRR	PB	M	57,74	8,517053
8	BBB	PB	F	57,68	6,309776
8	BBR	PB	M	59,77	2,704841
8	BYR	PB	M	47,88	19,453661
8	VYY	PB	F	52,58	5,768549
7	BBV	PB	F	52,95	2,695205
7	RRR	PB	M	48,52	20,03437

Table 3 (2): *P. bocagei* (PB) and *P. hispanica* (PH) summary of the physical traits. number of sightings per lizard and home range areas. CODE: identity code, M: male, F: female, SVL: snout-vent length; MCP: minimum complex polygon.

Sightings	CODE	SP	SEX	SVL (mm)	MPC area (m^2)
7	VBY	PH	F	48,6	19,058011
7	VVY	PH	F	38,29	3,159468
7	YVYV	PB	F	38,65	6,070767
7	YYB	PB	F	60,34	0,312222
7	YYVV	PB	M	45,15	109,960051
7	HD	PH	M	NA	9,542617
6	BBY	PB	F	59,64	0,482139
6	BRB	PB	M	55,36	1,336159
6	RBY	PB	M	49,04	2,177873
6	VVYY	PB	M	44,12	10,840766
6	YVV	PB	F	57,12	2,811081
6	YYY	PB	F	58,58	0,75314
5	BBYY	PB	M	46,16	0,382132
5	BYP	PH	M	44,08	14,058357
5	BYV	PB	F	57,31	0,362247
5	RRYY	PB	F	48,92	0,147838
5	YBR	PB	M	57,07	0,573479
5	YBYB	PB	M	40,77	2,651969
5	YRY	PB	M	58,35	0,501274
5	YYBB	PB	M	41,01	37,579561

4.1.1.1 Spatial distribution pattern

For the LISA autocorrelation analysis of the species we obtained the map bellow (Fig.17). It is showed that both species were spatially segregated. There were found isolated *P. hispanica* in areas where the *P. bocagei* was with a cluster pattern and vice versa, but the Isolated *P. bocagei* were found also around the cluster *P. hispanica* in the beach area. And we observed that *P. bocagei* was clustered in the stone wall but not in the beach area, in contrast to *P. hispanica* which were found cluster in the stone wall and in the beach. The map also showed that the *P. bocagei* were found cluster inside the areas where the *P. hispanica* were cluster. We obtained a Moran's I = 0.1327, which confirmed the local autocorrelation of LISA analysis.

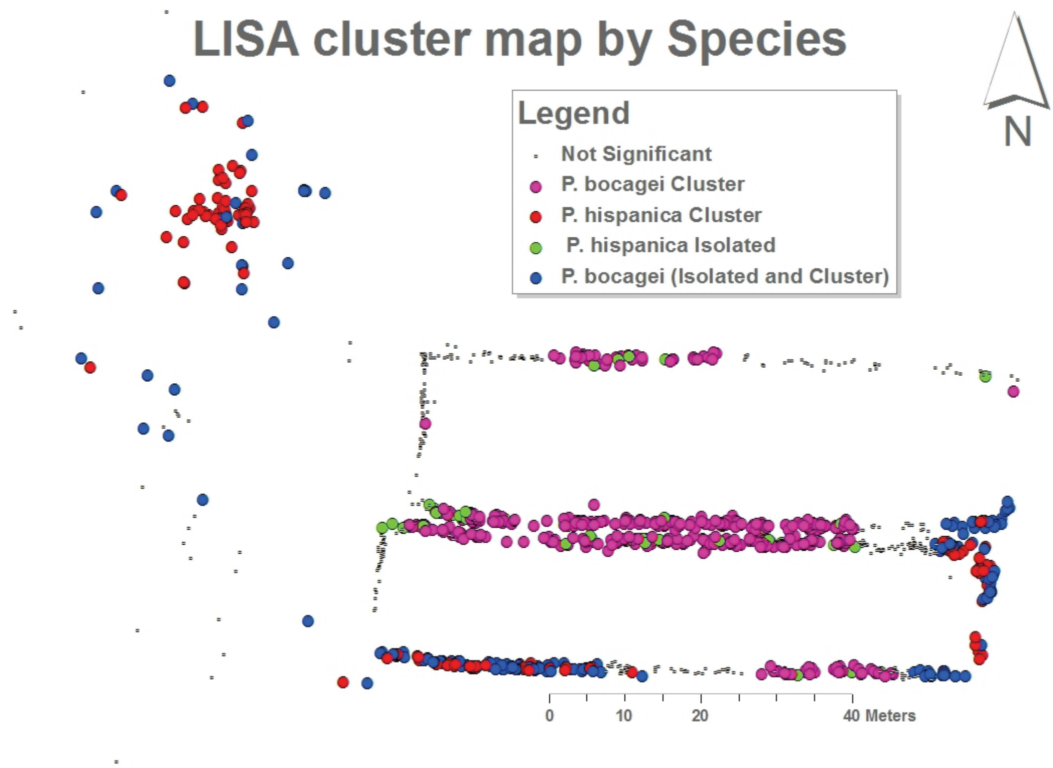

Fig. 17: LISA cluster map by species. Clusters of *P. bocagei* or *P. hispanica*: significant groups of neighbouring individuals of each species; Isolated *P. bocagei* were surrendered by *P. hispanica* and isolated *P. hispanica* were surrendered by *P. bocagei*.

For the LISA analysis by species and sex we obtain the maps bellow (Fig. 18 and 19). In which maps we could see that the majority of the recorded data of both species, for this study, did not had a significant pattern, 87.59% of P. *bocagei* records and for *P. hispanica* 72.42% of the recorded lizards were with a regular pattern. LISA found isolated males inside females clusters and vice versa for *P. hispanica*, comparing with the distribution of *P. bocagei*, the LISA showed that the *P. hispanica* lizards had a cluster pattern in the area of the big rock of the beach, where the *P. bocagei* only showed an outlier distribution in that area. *P. bocagei* was widespread in all the study area. We obtained a Moran's I = -0.0072, for the *P. bocagei* LISA analysis by sex, which confirmed the negative autocorrelation of LISA analysis (outlier), and for the *P. hispanica* LISA analysis by sex we obtained a Moran's I = 0.1059, which confirmed a local autocorrelation of LISA analysis (clusters and outliers).

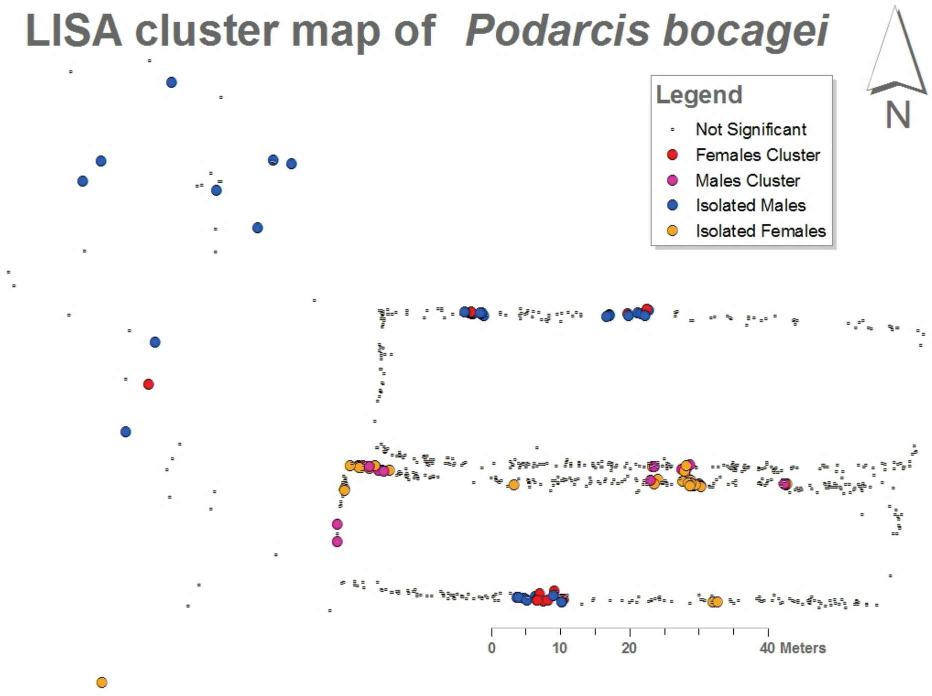

Fig. 18: LISA cluster map of *P. bocagei* by sex. Females or males clusters: significant groups of neighbouring females or males; Isolated females: Females surrounded by males and isolated males were surrounded by females.

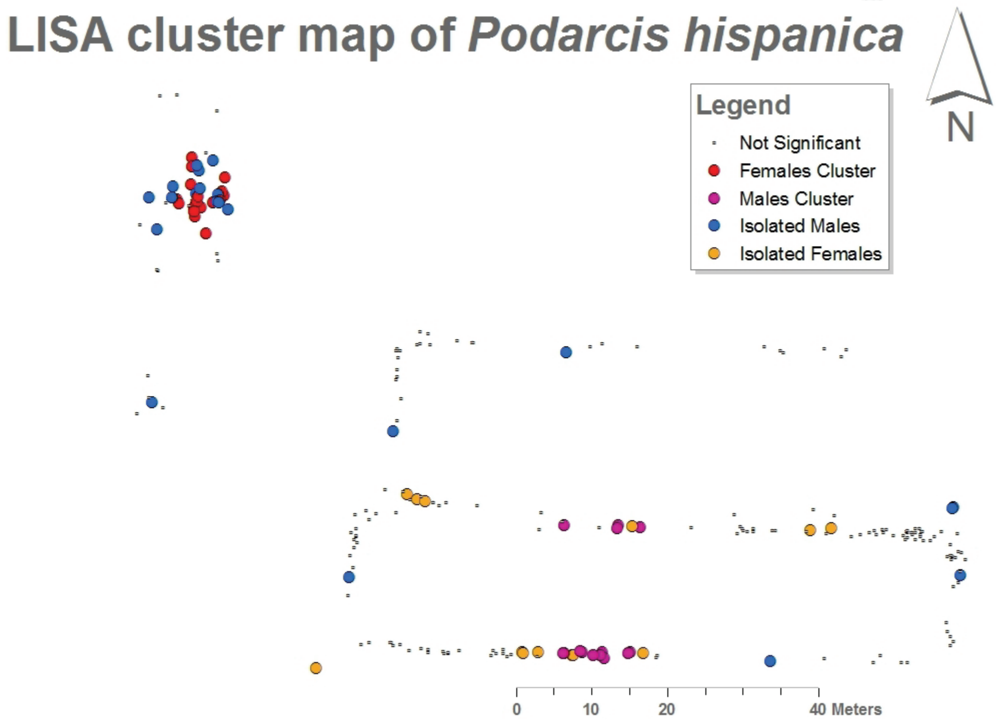

Fig. 19: LISA cluster map of *P. hispanica* by sex. Females or males clusters: significant groups of neighbouring females or males; Isolated females: Females surrounded by males and isolated males were surrounded by females.

For the LISA autocorrelation analysis with climatological parameter for *P. hispanica* and *P. bocagei* we obtained the maps bellow (Fig. 20 and 21). We used the complete dataset (1098 recorded data) for this analysis (see Descriptive data above). The high-high and low-low values showed that there were a positive local spatial autocorrelation or cluster, and the high-low and low-high values showed that there were a negative local spatial autocorrelation or spatial outlier. As it is showed in the maps, and making a comparison, both species had different spatial patterns (clusters and outliers) according to the humidity and ambient temperature, as well a very similar spatial patterns (clusters and outliers values) according with the substrate temperature. In the case of *P. hispanica* the maps showed that the distribution of the lizards according to the values of the Substrate temperature and the humidity, had similar pattern. Nevertheless, there was an opposite pattern for the distribution of the lizards according with the values of the ambient temperature. In the case of *P. bocagei* these difference were not so obvious, the distribution patterns according with the values of the substrate temperature and the humidity were similar but only in the areas of the stone wall, thereby, in the beach areas and in the big rock of the beach the spatial distribution of the lizards were different. For the humidity parameters the low values were distributed in the stone wall and in the beach, but for the substrate temperature parameter the low values were distributed mainly in the stone wall.

Table 4: Moran's I values as a result of the LISA analysis by climatological variables.

	Moran's I	
variables	*P. bocagei*	*P. hispanica*
Substrate temperature	0.0534	0.0248
Ambient temperature	0.0221	0.0267
humidity	0.0297	0.0270

The Moran's I values for the *P. bocagei* and *P. hispanica* LISA analysis by the climatological variables were similar, which confirmed a local autocorrelation of LISA analysis (clusters and outliers) for the spatial distribution of both species (Table 4).

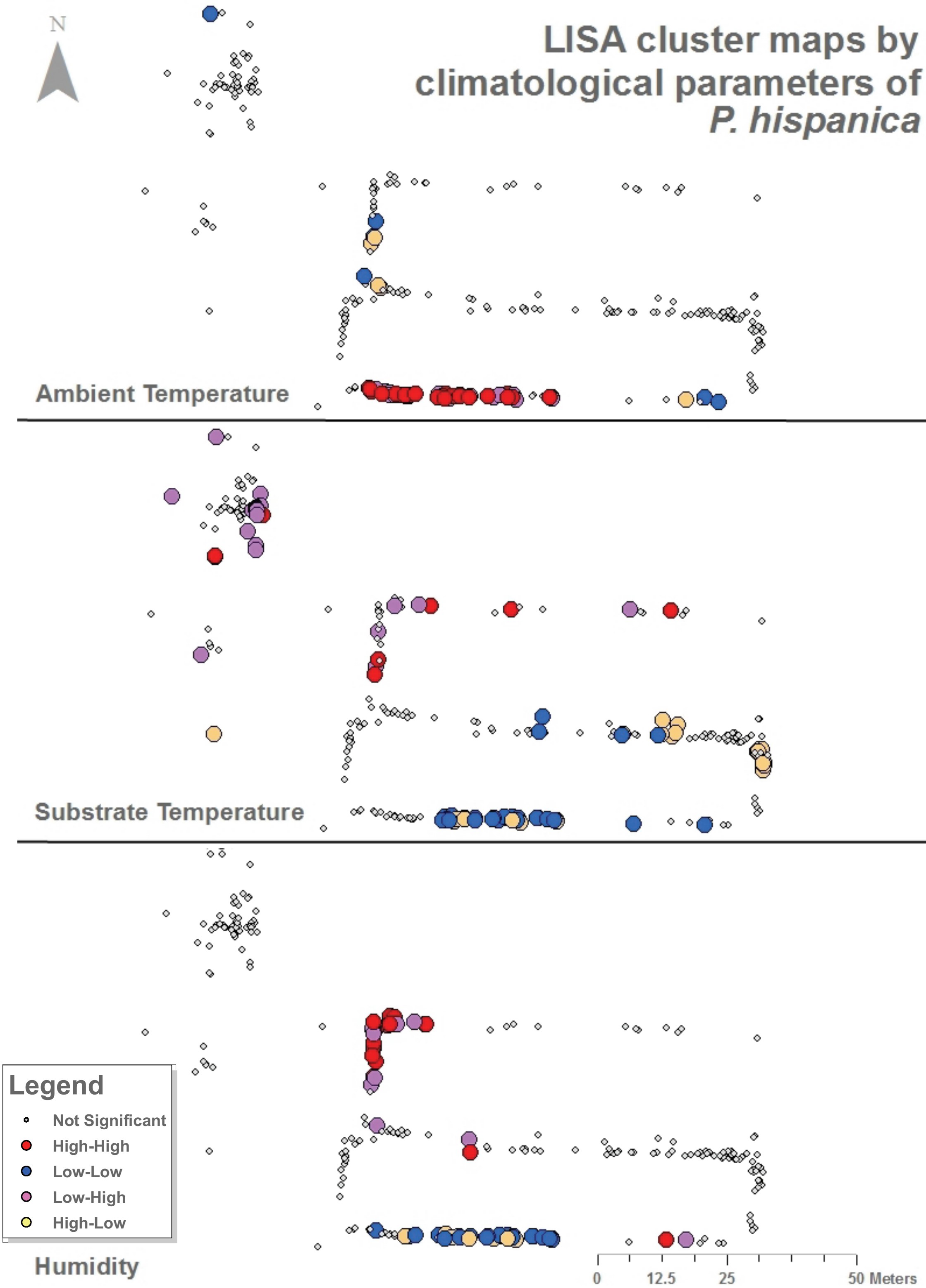

Fig. 20: LISA cluster map of *P. hispanica* by climatological parameters. High-High: High variable values surrounded by high variable values; Low-Low: Low variable values surrounded by Low variable values; Low-High and High-Low: Low variable values surrounded by high variable values and vice versa.

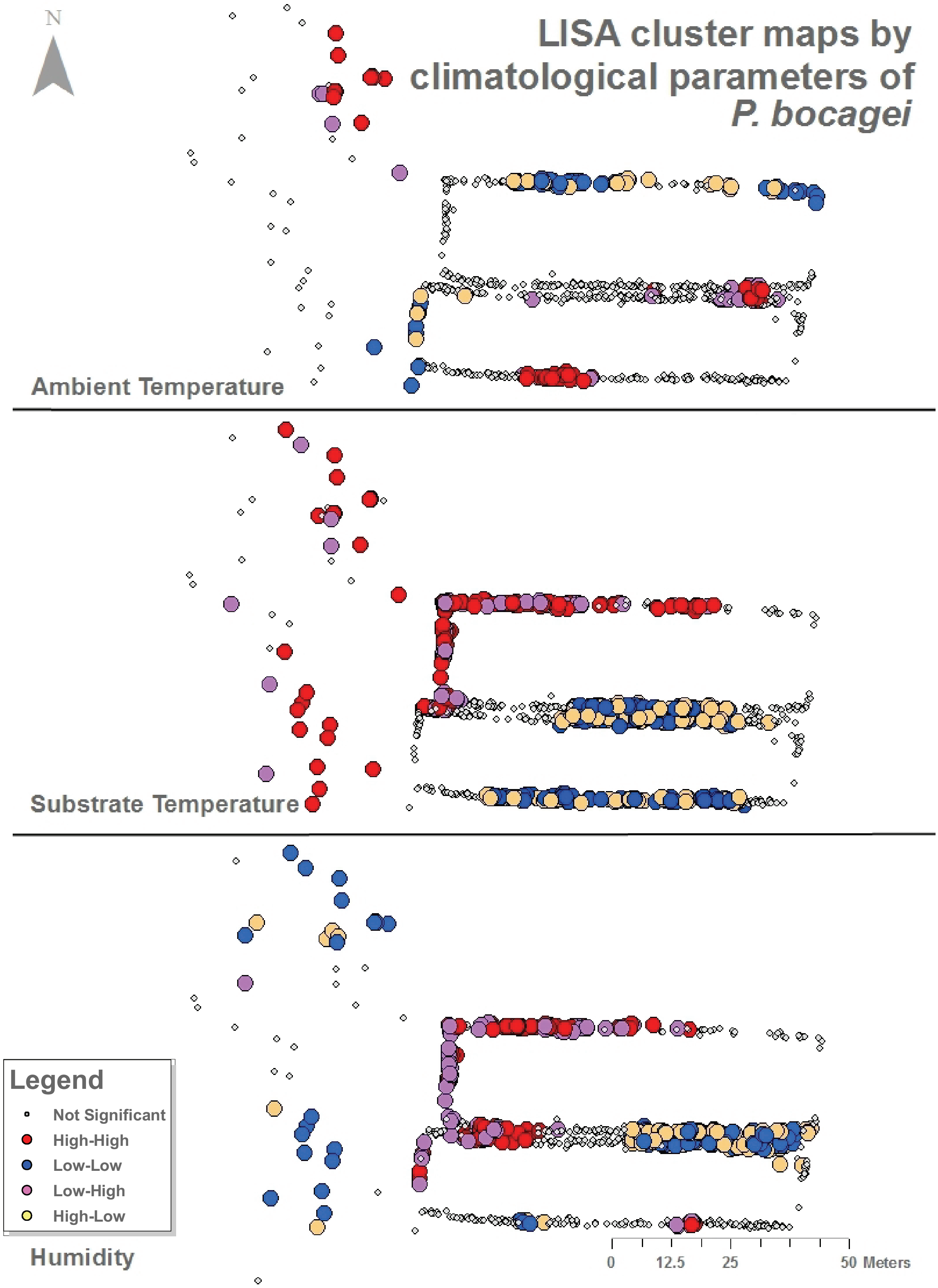

Fig. 21: LISA cluster map of *P. bocagei*. by climatological parameters. High-High: High variable values surrounded by high variable values; Low-Low: Low variable values surrounded by Low variable values; Low-High and High-Low: Low variable values surrounded by high variable values and vice versa.

4.1.2 Home range

4.1.2.1 Minimum convex polygon

It was calculated the home range (MCP) for those lizards (n=35) with 5 or more sightings (see Table 3 and Fig. 22). Home range size and shape varied among the lizards (see in Appendix A).

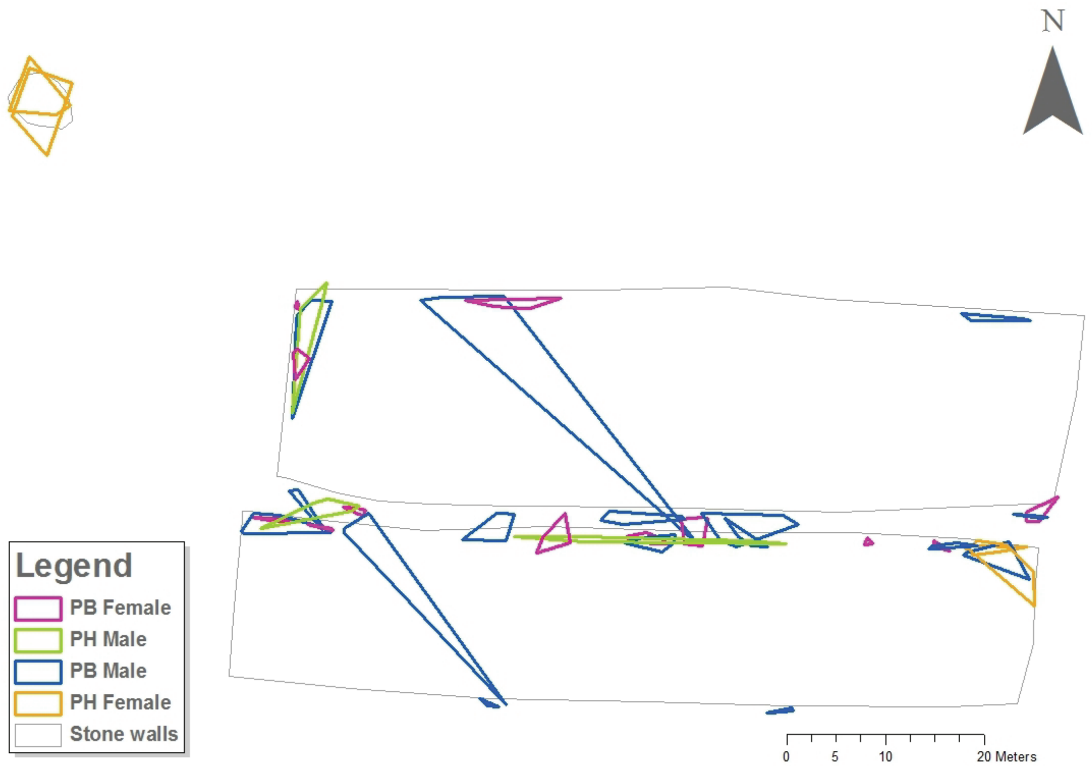

Fig. 22: Map of the home range (MCP) of *P. bocagei* and *P. hispanica*. The grey colour define the four stone walls and a big rock in the middle of the beach.

P. bocagei's home ranges (n=28, mean= 9.66 m^2 ± 4.02 m^2; range= 0.14-109.96 m^2) were significantly smaller than *P. hispanica*'s home ranges (n=7, mean= 14.58 m^2 ± 3.52 m^2; range= 3.15-29.7 $m^{2;}$; Kruskal test: *Chi*^{2}= 5.7211, *n*=35, *p-value*= 0.0167). *P. bocagei* males' home ranges (mean= 15.04 m^2 ± SE 6.79 m^2; n= 16, range= 0.38-109.96 m2) were bigger than females (mean= 2.49 m^2 ± SE 0.69 m^2; n=12, range= 0.14-6.3 m^2), with significant differences (ANOVA test: *F*= 5.368, *n*= 28, *df*= 1, *p-value*= 0.0286). For *P. hispanica,* there were not significant differences between home range size and sex (ANOVA test: *F*= 1.138, *n*= 7, *df*= 1, *p-value*= 0.335).

The linear regression analysis among *P. hispanica* 's home range size and SVL measures showed that there were not a significant association (Linear Model test: *F*=0.07759, *n*= 6, *df*= 1 and 4, *p-value*= 0.7944) (see Fig.23). However, the same analysis for *P. bocagei* 's home range size and SVL measures showed a negative slightly significant difference, where larger lizards had the smallest home ranges and vice versa, (GAM test: *n*= 27, *df*= 2, *p-value*= 0.0484) (see Fig.24).

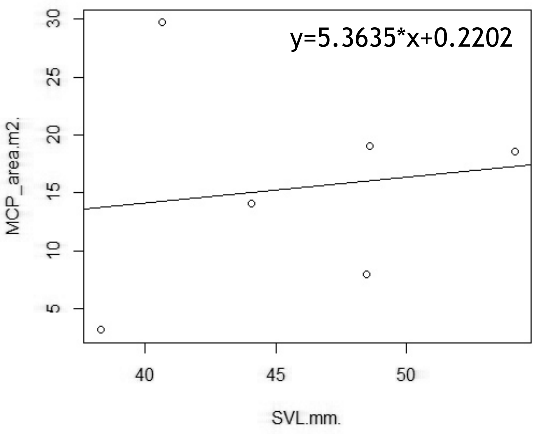

Fig. 23: *P. hispanica* linear regression.

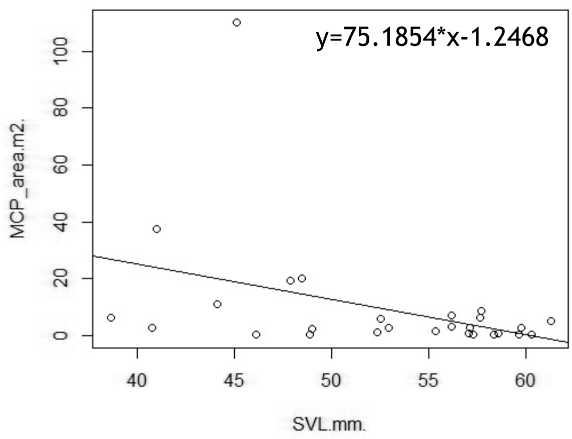

Fig. 24: *P. bocagei* linear regression.

4.1.3 Home range overlaps

There were a significant difference among home range's overlaps of both species (see the Table in Appendix B), where *P. bocagei* overlaps less times (n=28, mean= 1.67 ±SE 0.24, range= 0-4 overlaps) than *P. hispanica* (n= 7, mean= 3 ±SE 0.78, range= 1-7 overlaps, ANOVA test: *F*= 5.4202, *n*= 35, *df*= 1, *p-value*= 0.026). There were not significant differences between the sex (ANOVA test: *p-value*= 0.336) and between species and sex (ANOVA test: *p-value*= 0.0839). The Tukey test corroborated the significant differences among species (Tukey HSD test: *p-value*= 0.0275)(see Table 5).The *P. hispanica* males overlapped more their home ranges (n=3, mean= 4.3 ± 1.45 overlaps, range=2-7overlaps) than *P. bocagei* males and females (n=16, mean= 1.75 ± 0.35 overlaps, range=0-4 overlaps, n=12, mean= 1.58 ± 0.33 overlaps, range= 0-4 overlaps, respectively) (see Table 5).

Table 5:Result of the Tukey test. M: male, F: female, B: *P. bocagei* and H: *P. hispanica*.

Groups	p-value
M:B-F:B	0.9897447
F:H-F:B	0.9565885
M:H-F:B	0.0258925
F:H-M:B	0.9889872
M:H-M:B	0.0334497
M:H-F:H	0.1599801

The Chi2 analysis showed a high significant difference of the home range overlaps by species and sex (Chi2 test: *X-squared*= 29.77,*n*= 35, *df*= NA, *p-value*= 0.0009).Females of *P. bocagei* did not overlapped with *P. hispanica* females and the males of *P. hispanica* did not overlapped with other *P. hispanica* lizards and *P. hispanica* females did not overlapped with *P. hispanica* males (Table 6).

Table 6: Home range overlaps among *P. bocagei* and *P. hispanica*.BF: *P. bocagei* Female, BM: *P. bocagei* Male, HF: *P. hispanica* Female and HM: *P. hispanica* Male.

	BF	BM	HF	HM
BF	2	11	0	6
BM	11	6	5	6
HF	0	5	4	0
HM	6	6	0	0

4.2 SECOND STUDY CASE: BOTANICAL GARDEN

4.2.1 Descriptive Data

39 different lizards, 19 females (13 adults and 6 subadults) and 13 males (11 adults and 9 subadults), were captured in the five months of fieldwork. With the I^3S software we have identified 100% of the captured lizards (see appendix C for details about the captured individuals, the identification codes, the sighting per individuals during all fieldwork, the sex and age). 71,79% (28 lizards) was the proportion of the lizards sighted at least one time. It was sighting 584 lizards (Fig. 25) in the wall surface: 223 females (165 adult and 58 subadults) and 361 males (301 adult and 60 subadult). However, we have sighted 648 lizards in the total: 9,87% of sightings (n=64) were observed outside of the study area, i.e. behind of the wall, in the ground, or outside of the limits of the wall stone. We did not used these lizards for the analysis because we had not their exactly position in the wall (planar surface).

Fig. 25: Lizards' sighting distribution map.

The mean of sighted lizards with more than 5 sightings (n=21) was 26,90± 5.11 (mean ± SE) and ranged from 5 to 85 sightings per lizard. The average of the SVL measures (as body size) for adult females (n=6) was 54.43 mm±1.63 (range= 49.45-61.75 mm); for subadult females (n=3), the mean was 37.70 mm±1.19 (range= 35.76-39.89 mm); for adult males (n=8), 56.91 mm± 1.67 (range= 50.21-61.9 mm); and for subadult males (n=4), 42.92 mm± 1.88 (range= 40.22-48.46 mm; see Table 7).

Table 7: *Podarcis bocagei* summary of the physical traits, number of sightings per lizard in the wall surface and home range MCP areas. CODE: identity code, M: male, F: female, A: adult, SA: subadult; SVL: snout-vent length; MCP: minimum complex polygon.

Sighting	CODE	SEX	AGE	SVL(mm)	MCP area (m2)
85	5A	M	A	61,9	67,399467
75	1A	M	A	61,81	56,616927
60	6A	M	A	55,44	63,67484
47	7A	F	A	53,8	23,875928
41	2B	F	A	53,59	18,175259
38	3A	F	A	49,45	20,319366
29	7B	F	SA	39,89	19,455629
29	9C	M	A	59,14	44,221057
28	2A	M	A	61,22	71,955547
25	7D	M	SA	48,46	18,457484
21	7C	F	SA	37,46	46,555267
17	4A	F	A	61,75	16,237022
12	8D	M	SA	42,1	7,994246
10	5B	F	A	53,37	12,120175
9	9B	M	SA	40,9	6,123484
9	5D	M	A	51,51	1,113336
8	1D	M	A	54,07	25,518557
6	4B	M	A	50,21	5,183527
6	5C	F	SA	35,76	1,577494
5	8A	F	A	54,67	2,670116

4.2.2 Spatial distribution patterns

LISA found isolated males inside females clusters and vice versa (Fig. 26). The short part of the wall (in the figure is the right part of the wall) was the area with less lizards with a defined pattern as cluster or outlier. We obtained a Moran's I = 0.2009, which confirmed the local autocorrelation of LISA analysis (Clusters and Outliers).

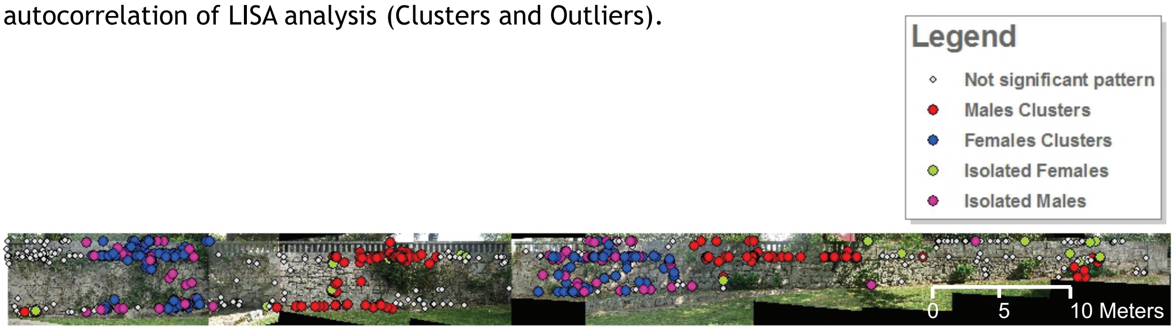

Fig. 26: Lizards' map spatial distribution patterns by sex.

LISA showed that in the areas where adult lizards were clustered the subadult lizards were isolated, and in the areas where the subadults lizards were with a cluster pattern the adult lizards were isolated (Fig. 27). As in the LISA analysis by sex, in this case there are many locations along the stone wall with a non significant pattern. The spatial distribution of the adult lizards clustered were related to the high areas of the stone wall, with more vegetation or refuges. The subadult lizards clustered were related to the low areas of the stone wall or to the place with more human disturbance, such as the oriel of the wall. The Moran's I = 0.0954 confirmed the local autocorrelation of LISA analysis (Clusters and Outliers).

Fig.27: Lizards' map spatial distribution patterns by age.

The spatial distribution pattern changed along the time (Fig. 28) The LISA found Isolated males in the areas where the females were clustered and vice versa, as in the previously analysis by sex. This pattern was usually maintained during the five month of the study, although for the month of July and September there was predominantly a non significant pattern. May and June were the months with more records lizards locations with 17.46% and 45.03% respectively (Table 8).

Table 8: Lizards positions records. M: adult males, F: adult females, Msa: subadult males and Fsa: subadult females.

	Sighting		
Month	**Males**	**Females**	**Total**
May	71	31	120
June	160	103	263
July	52	27	79
August	28	47	75
September	50	15	65

Table 9: Moran's I values as a result of the LISA analysis by sex and per month.

Month	**Moran's I**
May	0.0695
June	0.1964
July	0.0882
August	0.8910
September	0.5652

The Moran's I values for the *P. bocagei* LISA analysis by sex and per month (Table 9) showed that August and September presented a high autocorrelation for the local LISA analysis, with clearly defined the cluster patterns. While, May, June and July confirmed a local autocorrelation of LISA analysis (clusters and outliers).

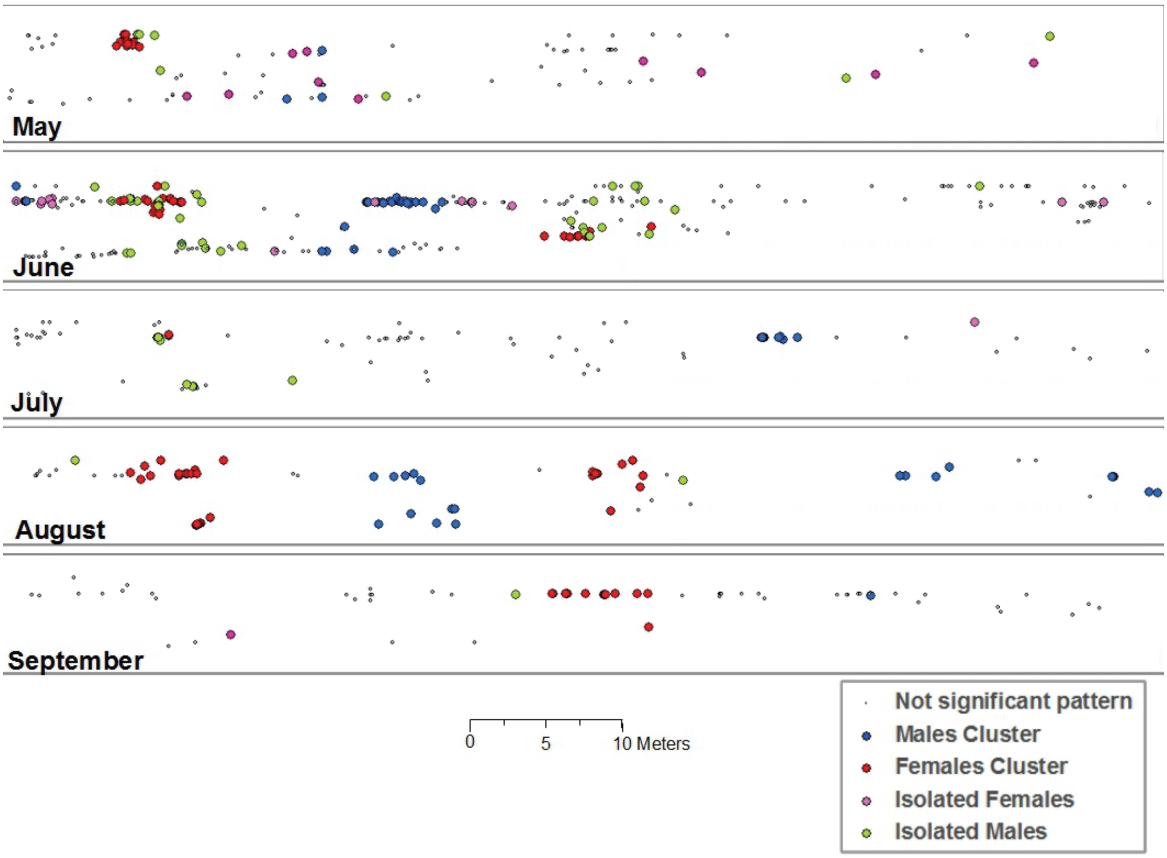

Fig. 28: Lizards' map spatial distribution patterns by age and per month.

4.2.3 Home range

As a result of the home range analysis (Fig.29) the map bellow showed, as an example, the home range (MCP) of the 95% of sightings recorded of a lizard (1A) adult male. The activity centre or core area and the utilization distribution (UD) are represented by the percent volume contour 50% and 95%, respectively, in the image. In appendix D it is shown the other maps with the same information related to the others nine lizards. The UD and the core areas were out of the boundaries of the MCP (see data information in Table 5 and 7).

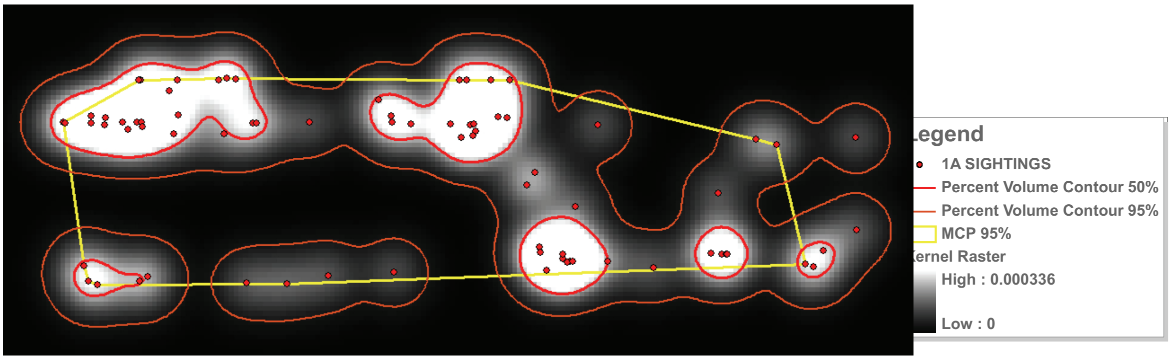

Fig. 29: Map of the home range, utilization distribution and activity centre of the lizard 1A.

4.2.3.1 Minimum convex polygon

The home ranges were calculated (MCP) for those lizards (n=21) with 5 or more sightings (Table 5). Home range size and shape varied among lizards during this study (see Appendix C). After the ANOVA analysis, it was only found a significant difference among the home range size by sex and age (ANOVA test: *F*= 6.008, *n*= 21, *df*= 1, *p-value*= 0.02535), there were not found significant differences among sex (ANOVA test: *p-value*= 0.394) or among age (ANOVA test: *p-value*= 0.227). After applied the Tukey test , we saw that the differences among the home range size by sex and age were not significant, (Tukey HSD test: P> 0.05 in all cases, see in Table 10).

Table 10:Result of the Tukey test. M: male, F: female, SA: subadult and A: adult.

Groups	P-value
SA:F-A:F	0.7324955
A:M-A:F	0.1841397
SA:M-A:F	0.9177647
A:M-SA:F	0.9250151
SA:M-SA:F	0.4604581
SA:M-A:M	0.0872909

The linear regressions analysis among home range and SVL measures showed that there were a positive association among the lizard size and the home range (MCP) area (Linear Model test: F= 7.415, n= 21, df= 19, p-value= 0.0135) (Fig. 30).

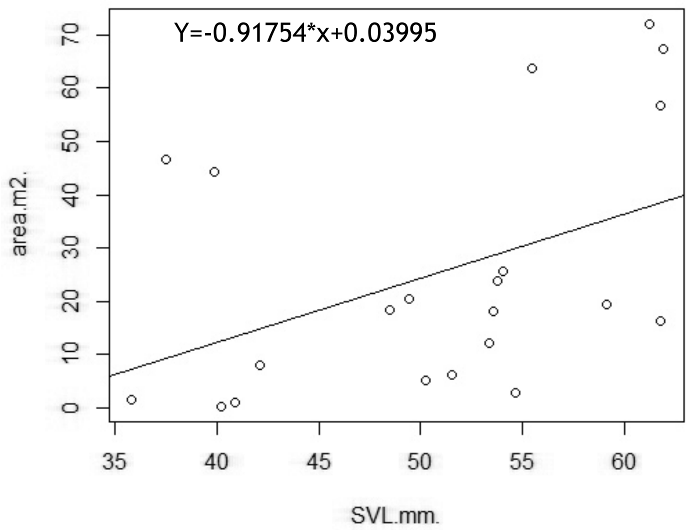

Fig. 30: Linear regression.

4.2.3.2 Utilization Distribution

Fixed kernel density (FKD) method estimated 95% of the MCP as utilization distribution and 50% as core areas for ten lizards with more than 12 sightings (see Table 11). For the rest of the lizards (not included in the analysis) the Kernel estimation results were not consistent with their MCP area. The utilization distribution of the males (n= 4, mean= 61.42 m^2±8.9 m^2, range= 36.24-77.21 m^2) was bigger than the females (n=4, mean= 29.61 m^2 ±2.133 m^2, range= 24.62-34.18 m^2), with significant differences (ANOVA test: *F*= 7.962, *n*= 10, *df*= 1, *p-value*= 0.0303). There were no significant differences either for the analysis of the utilization distribution size and age (ANOVA test: *p-value*= 0.0565) or the relationship among UD size and lizards' sex and age (ANOVA test: *F*= 4.499, *n*= 10, *df*= 1, *p-value*= 0.0782).

Table 11: Information of lizards with more than 12 sightings, home range areas, core area per lizard, main activity areas and utilization distribution areas. CODE: identify code, M: male, F: female, A: adult, SA: subadult; SVL: snout-vent length; MCP: minimum complex polygon; UD: Utilization distribution.

CODE	SEX	AGE	SVL.mm.	MCP area (m^2)	Nº core areas	Core areas (m^2)	UD (m^2)
2B	F	A	53,59	18,1753	3	8,7147	34,1867
3A	F	A	49,45	20,3194	3	6,2452	27,7398
4A	F	A	61,75	16,2370	3	5,3705	24,6212
7A	F	A	53,8	23,8759	2	5,4989	31,9143
7B	F	SA	39,89	19,4556	5	9,3761	45,1155
1A	M	A	61,81	56,6169	6	14,3475	62,5853
5A	M	A	61,9	67,3995	5	14,6749	77,2149
6A	M	A	55,44	63,6748	7	12,5939	69,6580
7D	M	SA	48,46	18,4575	3	6,1586	33,4767
9C	M	A	59,14	44,2211	6	8,7440	36,2459

The linear regression analysis among the utilization distribution and SVL measures showed that there were not significant relationship among the animal size and the utilization distribution. (Linear Model test: F= 0.8619, n= 10, df= 8, p-value= 0.3804)(Fig. 31).

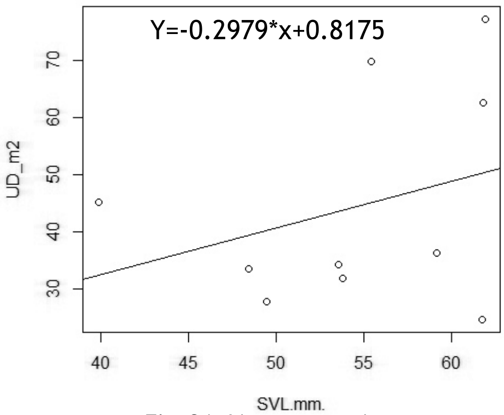

Fig. 31: Linear regression.

4.2.3.3 Activity centres

There were a mean of 4.3 core area per lizard (± 0.53 SE, range= 2-7). Males had more core areas (n=5, mean= 5.4 ±SE 0.75, range= 3-7) than females (n=5, mean= 3.2 ±SE 0.54, range= 2-5, ANOVA test: *F*= 26.40, *n*= 10, *df*= 1, *p-value*= 0.0021). There were not significant differences among the number of core areas and age (ANOVA test: *p-value*= 0.0509), and there were significant differences among the number of core areas by sex and age (ANOVA test: *F*= 24.0545, *n*= 10, *df*= 1, *p-value*= 0.0026). The Tukey test corroborated these results, and showed that the adult males had more core areas (n=4, mean= 6 ±SE 0.40, range= 5-7) than adult females (n=4, mean= 2,75 ±SE 0.25, range= 2-3, Tukey test: *p-value*= 0.002). Also we saw that the adult males had more cores areas than subadult males (n=1, number of core areas=3)(Tukey HSD test: *p-value*= 0.028, Fig 32), for the rest of the groups there were not significant differences.

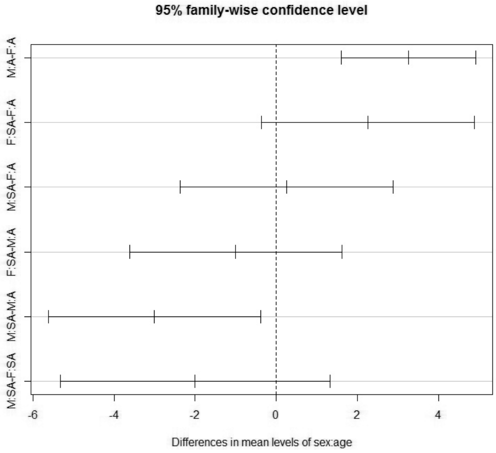

Fig. 32:Tukey HSD test's plot.

There were a significant difference for the analysis of core area size and sex, where the males (n=5, mean= 11.30 m^2 ± 1.85, range= 6.15- 14.67 m^2) had bigger core areas than females (n=5, mean= 7.04 m^2 ± 0.93, range= 5.37-9.37 m^2, ANOVA test: *F*= 9.2496, *n*= 10, *df*= 1, *p-value*= 0.0227). There were not differences between the core areas size by age (ANOVA test: *p-value*= 0.354) and for the analysis of the core area size by sex and age there were significant difference (ANOVA test: *F*= 7.12, *n*= 10, *df*= 1, *p-value*= 0.0371). The Tukey test showed that these differences were among adult males and females, where the core area of adult females (n=4, mean= 6.45 m ^{2}± 0.77, range= 5.37-8.71 m^2) was smaller than the core are of adult males (n=4, mean= 12.59 m^2 ± 1.36, range= 8.74-14.67 m^2, Tukey HSD test: *p-value*= 0.03, Fig. 33).

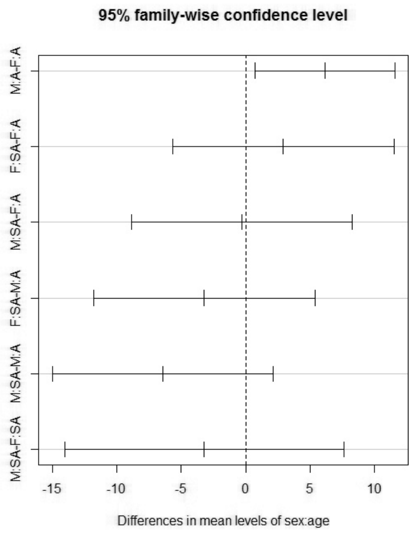

Fig. 33:Tukey HSD test's plot.

The linear model analysis between the core area size and the SVL measures showed that there were not significant association among the variables (Linear Model test: *F*=1.276, *n*= 10, *df*= 8, *p-value*= 0.29).The same analysis among the number of core areas per lizard (4.3±0.538 (mean±SE) with a range = 2-7) and SVL measures showed that there were a positive association (Linear Model test: *F*= 0.4616, *n*= 10, *df*= 8, *p-value*= 0.516) (Fig. 34).

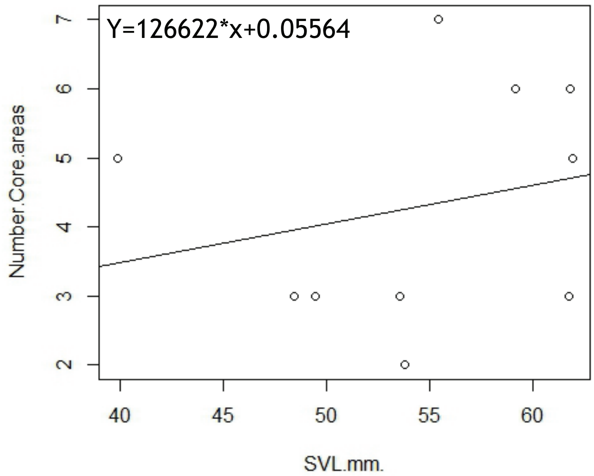

Fig. 34: Linear regression.

4.2.4 Overlaps

4.2.4.1 Home range

There was high degree of overlapping among the 21 lizards with five or more sightings (Fig. 35). The home ranges were straggly along the stone wall. As it saw in the map the left part of the stone wall it seem with more overlaps than the others parts.

Fig. 35: Lizards' home ranges map

There were not significant differences among the number of overlaps per sex (ANOVA test: *F*= 0.0536, *n*= 21, df= 1, *p-value*= 0.8193). With a mean of 6.38± 0.579 overlaps per lizard (range= 2-11; Table 12), the average of females' overlaps (n=9) was 6.22 ± 0.99 (range= 2-11) containing adults and subadults, and for males' overlaps (n=12) was 6.5 ± 0.72 (range= 2-10) (adults and subadults).

Table 12: Overlaps among lizards. Label: Lizard Identify code, overlap= "x".

	1A	2A	2B	5B	5A	4B	4A	3A	5C	5D	6A	6B	8A	7D	7C	7B	7A	8D	9B	9C	1D	Overlaps
1A				X	X		X	X				X			X		X	X			X	9
2A			X		X	X				X	X			X	X	X						8
2B		X			X					X	X					X						5
5B	X						X	X				X						X			X	6
5A	X	X	X					X		X	X			X	X	X	X					10
4B		X									X											2
4A	X			X				X				X			X		X	X			X	8
3A	X			X	X		X					X			X		X	X			X	9
5C																			X	X		2
5D		X	X		X						X			X	X	X						7
6A		X	X		X	X				X				X	X	X				X		9
6B	X			X			X	X										X			X	6
8A																			X	X		2
7D		X			X					X	X				X	X						6
7C	X	X			X		X	X		X	X			X		X	X				X	11
7B		X	X		X					X	X			X	X							7
7A	X				X		X	X							X						X	6
8D	X			X			X	X				X									X	6
9B									X				X							X		3
9C									X		X		X						X			4
1D	X			X			X	X				X			X		X	X				8

According to the age groups (Table 13), the average of the adult males' home range overlaps (n=8) was 7.125± 0.971 (SE) per lizard; for adult females' overlaps (n=6) was 6 ±1 (SE) per lizard; for subadult males' overlaps (n=4) was 5.25±0.75 (SE); and for subadult females the mean of the home ranges overlaps (n=3) was 6.66±2.603 (SE) per lizards. There were not significant differences among the groups (Chi^2 test: *X-squared*= 3.89, *df*= NA, *p-value*= 0.92).

Table 13: Home range overlaps among sex and age groups. M: adult males, F: adult females, Msa: subadult males ans Fsa: subadult females.

	M	F	Msa	Fsa
M	22	15	9	11
F	15	10	7	4
Msa	9	7	2	3
Fsa	11	4	3	2

4.2.4.2 Activity center

There were many lizards' core areas overlapping, and most of these overlaps are concentrated in specific areas of the stone wall, namely the high areas. (Fig 36).

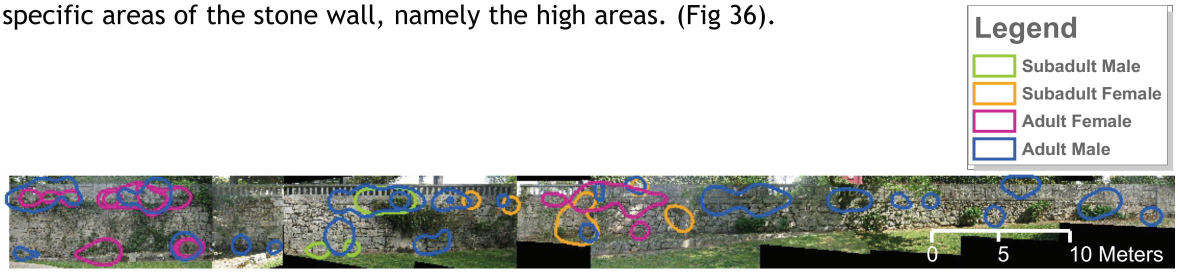

Fig. 36: Lizards' core areas map.

There were a mean of 2.6 core area's overlaps per lizard (± 0.371; Table 14). The average of females' core areas overlaps (n=5) was 2.6 ± 0.2449 (range= 2-3) containing adults and subadults, and for males' core areas (n=5) was 2.6 ± 0.0.748 (range= 0-4) (adults and subadults) thus, there were not significant (ANOVA test: *F*= 0, *n*= 21, *df*= 1, *p-value*= 1).

Table 14: Overlaps among lizards, represented by the "x".

	9C	7B	7A	6A	5A	4A	3A	2B	1A	7D	Overlaps
9C											0
7B				X	X			X			3
7A							X		X		2
6A		X			X			X		X	4
5A		X		X				X		X	4
4A							X		X		2
3A			X			X			X		3
2B		X		X	X						3
1A			X			X	X				3
7D				X	X						2

According to the sex and age groups (Table 15), there were not significant differences among the overlaps of the core areas (Chi^2 test: *X-squared*= 8.32, *df*= 9, *p-value*= 0.5014).

Table 15: Core area overlaps among sex and age groups. M: adult males, F: adult females, Msa: subadult males and Fsa: subadult females.

	M	F	Msa	Fsa
M	2	5	2	2
F	5	4	0	1
Msa	2	0	0	0
Fsa	2	1	0	0

5 DISCUSSION

5.1 FIRST STUDY CASE: SYNTOPIC SPECIES

5.1.1 Spatial distribution pattern

One of the main goal of this work was to see if there were significant spatial patterns among the species, sex and by climatological parameters. Both species were spatially segregated: each species selected different areas, as identified by LISA analysis (Fig.15). In fact, *P. hispanica* was distributed throughout the study area, presenting clusters in some walls (e.g. the southern wall) and in the big rock of the beach, namely formed by females. On the other hand, *P. bocagei* was more numerous than *P. hispanica*, with a larger distribution and more clusters. These clusters occupied almost all the walls. In the beach area, namely in the ground, *P. bocagei* males had an isolated spatial pattern. *P. hispanica* clusters were located in the stone walls with high values of ambient temperature, low values of substrate temperature and low values of humidity, predominantly. When isolated, this species used areas with high values of temperature and humidity. Clusters and isolated individuals were spatially segregated (Fig. 20). *P. bocagei* clusters helped to identify the environmental spatial pattern of the study area: the most hotter part was the north-western corner (a higher stone wall), and the colder area was located in the south-eastern corner, where a shorter wall allowed more vegetation, and therefore more shadow. Although, *P. bocagei* clusters were widespread along the walls, a time-space analysis might show a more clear spatial pattern: under cooler conditions, the individuals would be located in hotter areas, and under hotter conditions, in colder areas, making behavioural adjustments (Cowles and Bogert 1944). However, in any of the two species, males and females locations were not clustered or isolated.

These results indicated that *P. bocagei* out-competed *P. hispanica*, this interspecific competition could be a possible reason of the low abundance of the *P. hispanica* in this area (McGinley and Caley 2008a). Thus, *P. hispanica* occupied the less favourable areas. Only in the big rock of the beach, it was able to get more suitable habitats, because it is a rock specialist (Sá-Sousa et al. 2002). This is the reason why clusters and isolated individuals presented different spatial patterns: only isolated individuals were able to stay in better environmental conditions.

5.1.2 Home range and overlap

We saw that the home range of *P. hispanica* were bigger than the home ranges of *P. bocagei*. Also, bigger lizards of *P. bocagei* had smaller home ranges. This last result could be explained because the bigger lizards had their home range situated in the best places, therefore they did not need to move looking for resources, or they had a more intensive use of their small area. Moreover, as the density of lizards is very high, this behaviour may be advantageous, because it avoids to fight frequently to defend the territory. As I referred in the introduction of this dissertation, the home-range size does not necessarily increase with group size (Macdonald 1983). These results confirmed again that *P. hispanica* was confined to the worst areas: it can be assumed that in these areas the *P. hispanica* has to move more in order to find resources or the best locations (e.g. basking). *P. hispanica* overlap their home ranges more times than *P. bocagei*, namely the males, as a consequence of its larger home ranges. This last evidences reaffirming the dominance of *P. bocagei* on *P. hispanica* and proves that *P. bocagei* was more territorial than *P. hispanica*.

P. bocagei males had bigger home ranges than females. This result is common in other lizards (Gil et al. 1988). Males need to overlap more times with females in order to increase the possibility of being chosen as mate.

5.2 SECOND STUDY CASE: BOTANICAL GARDEN

5.2.1 Spatial distribution pattern

P. bocagei was widespread along the stone walls. Each sex selected different areas of the wall. LISA analysis found clustered pattern of the females in the higher walls, scattered in the high and lower zones, specifically in the areas with more vegetation which could be used as refuges. The cluster pattern of males presented less dispersed distribution than females, in areas with high or low vegetation, and also in the lower walls. The possible cause of these differences between both sexes could be the requirement of the females for the walls with more refuges. The adult lizards clustered pattern were related to the higher walls and in the high areas of the lower walls, with more vegetation. These areas may have better environmental conditions, namely for basking behaviour. The subadult lizards clustered were related to the lower wall and in the place with more human disturbance, such as the oriel of the wall. The dominance of adults over subadults (intraspecific competition) was evidenced by the exclusion of subadults to the less favourables areas (McGinley and Caley 2008b). May and June were the month with more lizards sightings. The isolated pattern between sexes were more evident than the clustered pattern in June: in the others months the pattern distribution were mostly clustered for males and females. Even we did not investigated the reproductive behaviour of these species, Galán (1999) studied the population dinamic of *P. bocagei* in the north-west of Spain (area with a climate similar to our study), where the courting behaviour and copulation were observed from early April to early July. Which could probably explain the high activity and also the high number of sightings for the month of May and June. Thus, in this month the males and females were more widespread (with more isolated spatial pattern) looking for mate.

5.2.2 Home range, utilization distribution and core areas

Contrary to the results obtained in the study case of the syntopic species (above), the relationship of the home range size and lizard size in *P. bocagei* was positive, where bigger

lizards had bigger home ranges (Schoener and Schoener 1982). There were not significant differences between the home range size and the sex, although the analysis related to the utilization distribution size by sex (for the ten lizards with more than twelve sightings per lizard) showed that the males had a bigger UD than females. This discordance may be due to the low number of sightings per lizards (five or more) used to calculate the home range with the MCP method. In any case, is explained in the first study case, males need larger home ranges in order to increase the possibility of being chosen as mate (Gil et al. 1988). Bigger *P. bocagei* had bigger UD as in the case of the home range analysis.
We saw that males had more core areas than females, namely adult males had more core areas than adult females and subadult males. And also, the core areas sizes of the adult males were bigger than the adult females. As the home ranges of males are bigger, in consequence, there are more core areas and the core areas are also bigger. However, the structure of the habitat (a long wall) may influence in the form of the home range, and consequently in the form and number of core areas. As the wall is a longitudinal structure, home ranges are longer, increasing the possibility of having more core areas.

5.3 Advantages and disadvantages

In the first case of the study, the major problem that we had to deal was the loss of colour inks of the lizards, very quickly. The only way to continued with the field work were to recapture the lizards, but we did not marked it with permanent marks for visual identification of the individuals, and thereby, we stopped the work. Notwithstanding, we were able to record more than one thousand points during eight days by using the handheld GPS, which provided us to record of all information related to the individuals, improving our performance in the field. This allowed us to record more sightings for the study of the home ranges than other methods, such as the experimental plot (Gil et al. 1988). The GPS did not allow us studying the distribution pattern of the lizards with a height component, as the majority of the walls of the study area were short; thus, the vertical error (altitude) of the GPS was higher than the horizontal error, and the accuracy was not enough for our study.
In the second study case we used a different method to record the lizards positions, i.e. a reference mosaicked image. Therefore, we were able to study a lizards population on the vertical stone wall with a GIS. The main disadvantage was that the reference system was a non earth connected reference system, thus, we had some problems in the use of the ArcGIS software with the calculations of the home ranges areas. However, these problems were solved with some unit conversions.
We used the I^3S software to identify each lizards by chest photograph. Therefore, the problem related with the lost of the colour ink of the lizards (first study case) was solved. We did several recaptures and I identified 100% of the recaptured lizards. However, the lizards started to understand the process of the captures and from the third days of recaptures became more difficult to capture the individuals.

5.4 Conclusions

There is a lack of information related to the home ranges and spatial distribution of small Iberian lizards, namely *P. bocagei* and *P. hispanica,* from a spatial point of view. This work is innovative by the using of handheld GPS receivers. To my knowledge, until today there is no any research using this kind of techniques for tracking of small lizards, and for home ranges studies. In a similar way, there was not any work which applies the reference mosaicked image described above.

We used LISA analysis for some qualitative variables, such as the species, sex and age, when LISA is a test for measuring autocorrelation of continuous variables. The results of some of these analysis agreed with the expected, although In other cases, results can be considered as not completely correct.

Finally, it is important to highlight that this is the first study in using geomatic tools, namely GPS of very high accuracy, GIS, and spatial statistics, to analyse and identify the home ranges of animals. Here, we have applied a holistic spatial point of view.

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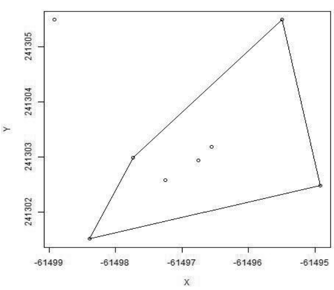
Appendix A (FIRST Study case: Syntopic species)

Home ranges (MCP) of the 35 lizards with five or more sightings, created by R software. (Each graph have the identification code of the lizard).

BBB



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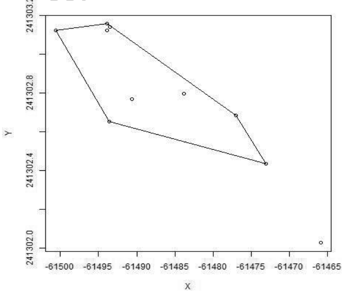

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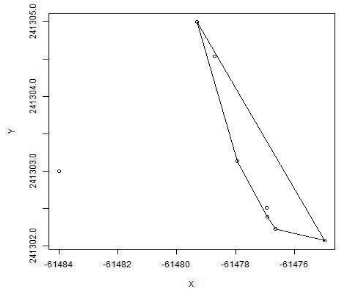

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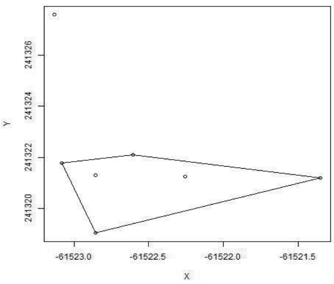

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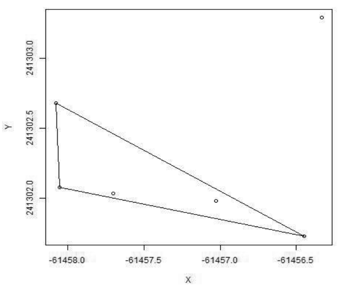

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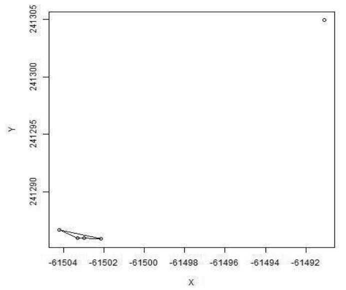
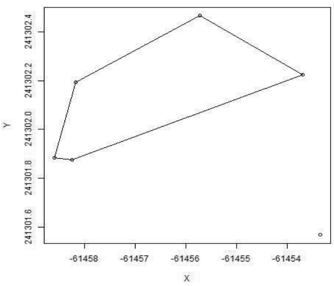


BRB



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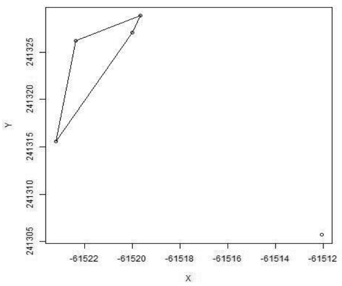

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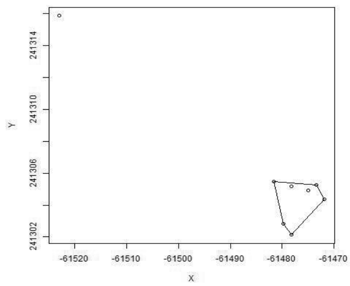

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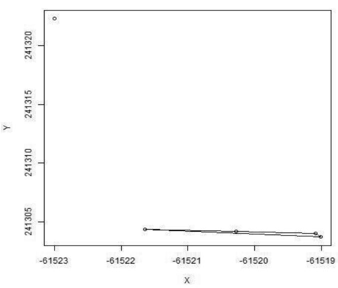

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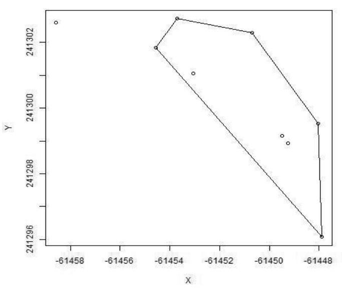

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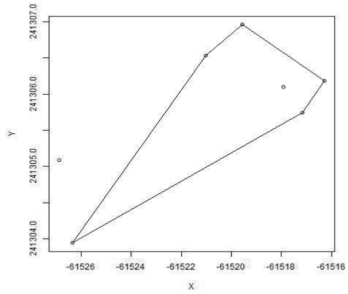

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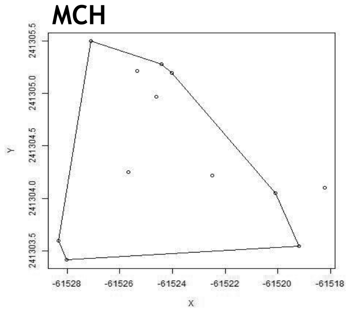
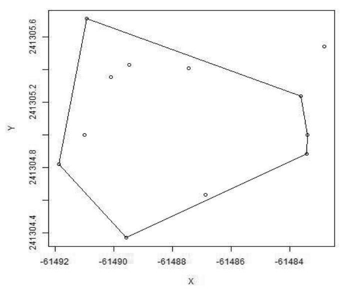


RBB



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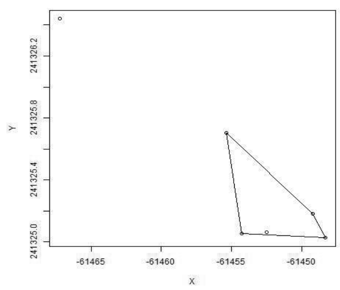

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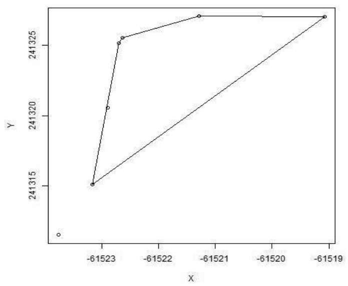
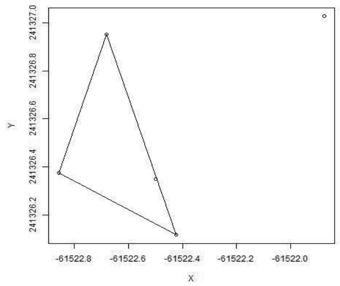


RRYY



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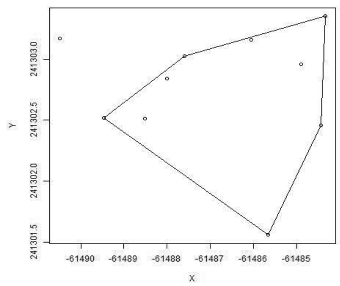

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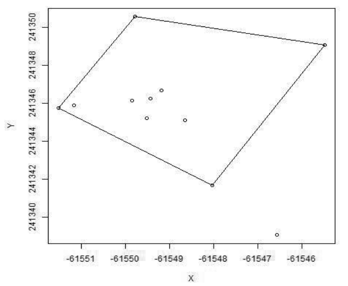

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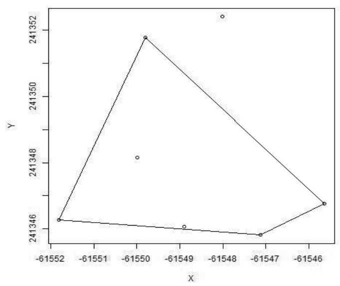

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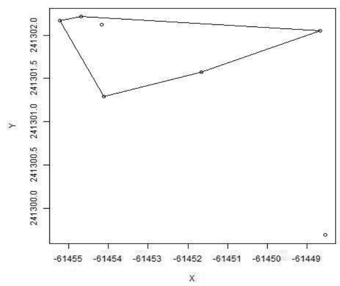

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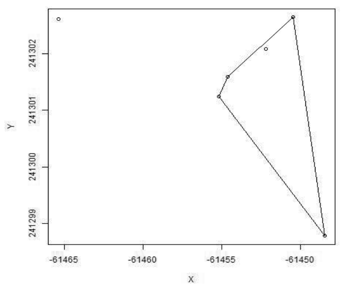

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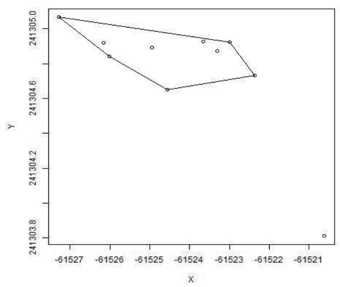

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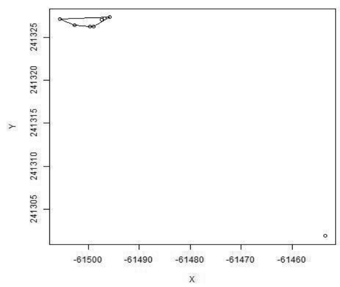

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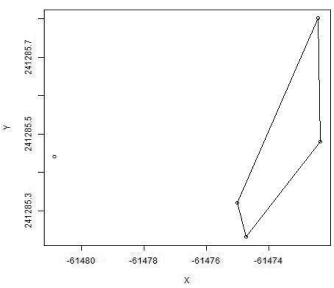

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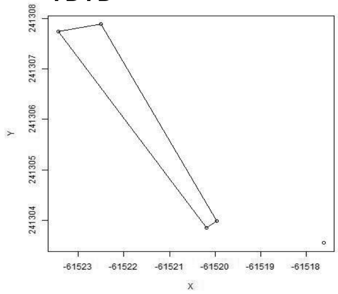

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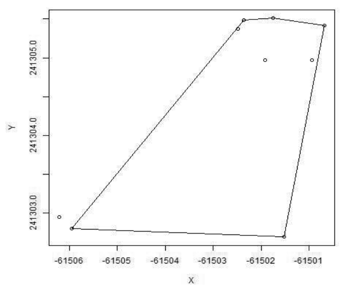

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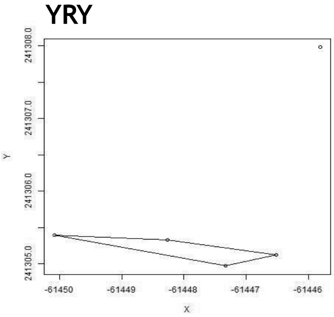

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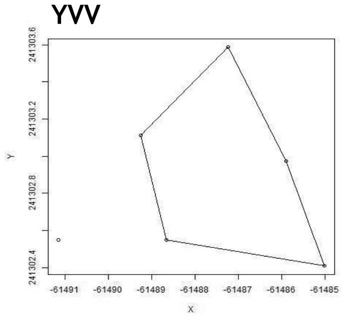

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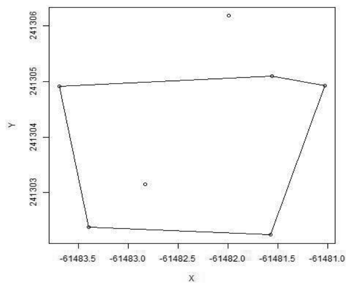

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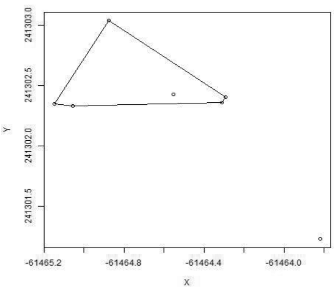

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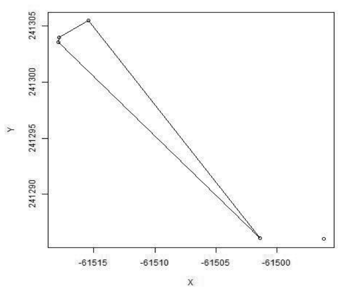

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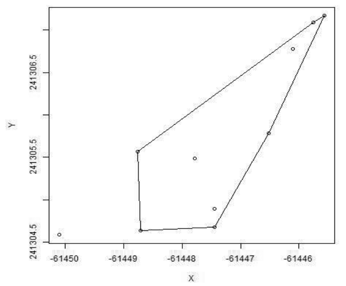

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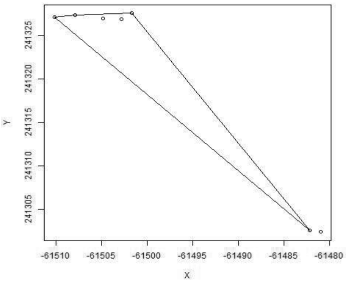

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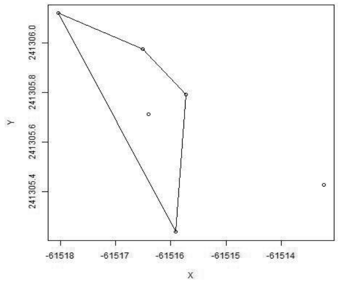


Appendix B (FIRST Study case: Syntopic species)

Table of the overlaps among lizards. Label: Lizard Identify code, overlap= “x”

	BBB	BBR	BBV	BYP	BRB	BBYY	BBY	BYR	BYV	BYY	HD	MCH	RRYY	VVYY	YBYB	YYB	YYY	YYVV	YYV	YYBB	YRR	YRY	YVV	YVYV	YBR	VYY	VYV	VVY	VBY	VBV	RYY	RBB	RBY	RRR	BBP	Overlaps
BBB									X																										X	2
BBR								X																											X	2
BBV				X																														X		2
BYP			X																															X		2
BRB							X			X																		X								3
BBYY																																				0
BBY					X																															1
BYR		X																						X											X	3
BYV	X											X			X																					3
BYY					X									X														X								3
HD												X			X		X										X									4
MCH									X		X				X												X									4
RRYY																																				0
VVYY										X																		X								2
YBYB									X		X	X																								3
YYB																																				0
YYY											X																									1
YYVV																								X		X						X			X	4
YYV																						X														1
YYBB																																				0
YRR																																				0
YRY																			X																	1
YVV																															X				X	2
YVYV								X										X														X			X	4
YBR																																				0
VYY																		X																		1
VYV											X	X																								2
VVY					X					X				X																						3
VBY																														X						1
VBV																													X							1
RYY																							X												X	2
RBB																		X						X												2
RBY																																				0
RRR			X	X																																2
BBP	X	X						X										X					X	X							X					7

Appendix C (SECOND Study case: Botanical Garden)

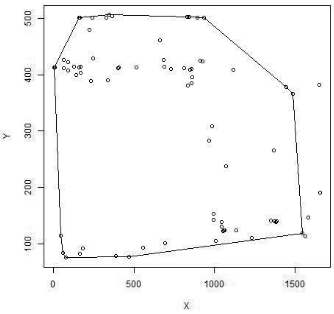
Summary of the information related to the captures and recaptures of the 39 lizards. Date of the capture, umber of sightings per lizards, final and temporal code, temporal code of each recapture lizards for the five recaptures field works (24/5/12, 19/6/12, 11/7/12, 9/8/12 and 4/9/12) already identify with the I^3S software.

DATE	AGE	SEX	Sightings	FINAL CODE	CAPTURE CODE	CODE 1st RECAPTURE (24_05)	CODE 2nd RECAPTURE(19_06)	CODE 3rd RECAPTURE (11_07)	CODE 4th RECAPTURE (9_08)	CODE 5th RECAPTURE (4_09)	NUMBER OF CAPTURES
10_05	A	M	75	1A	PPB		WBB	BRP		RRB_2c	4
10_05	A	M	28	2A	PRB	WBW	WBW				3
10_05	A	F	38	3A	PWB		GBP		PYB_31b		3
10_05	A	F	17	4A	PYB	WGB	GWB	BWP		RBR_3c	5
10_05	A	M	85	5A	PGB		YPB	BPG	PPB_11b	RYB_5c	5
10_05	A	M	60	6A	PBP		YGB	BWG		RGB_1C	4
10_05	A	F	47	7A	PBR		GBR	BWY	PBR_21b		4
10_05	A	F	5	8A	PBW		GGB	BRY			3
10_05	A	F	0	9A	PBY						1
10_05	A	M	0	1B	PBG						1
10_05	A	F	41	2B	PBB	WBY	YBW		PBP_33b	PBP_33b	5
10_05	A	F	4	3B	RPB						1
10_05	A	M	6	4B	RRB		YYB	BRG			3
10_05	A	F	10	5B	RWB	WBG	YBR	BYP			4
10_05	SA	M	5	6B	RYB		GRB				2
10_05	SA	F	29	7B	RGB		BPR	BWB			3
10_05	SA	F	0	8B	RBP						1
10_05	SA	M	9	9B	RBR		GBW				2
10_05	A	F	0	1C	RBW		YBG				2
10_05	SA	M	4	2C	RBY		BPY				2
10_05	SA	M	0	3C	RBG						1
10_05	SA	F	2	4C	RBB						1
10_05	SA	F	6	5C	WPB		BPW				2
10_05	SA	F	0	6C	WRB						1
10_05	SA	F	21	7C	WWB			BWR	PGB_02b		3
24_05	A	M	1	8C		WYB	YBY	BYW			3
24_05	A	M	29	9C		WBP	GPB		PWB_01b	RWB_12c	4
24_05	A	M	8	1D		WBR	GBY	BPB			3
19_06	A	M	0	2D			YRB				1
19_06	A	F	0	3D			YWB				1
19_06	A	F	3	4D			YBP	BRB			2
19_06	A	M	9	5D			YBB			PBB_4c	2
19_06	SA	M	0	6D			GYB	BRW			2
19_06	SA	M	25	7D			GBG	BWW			2
19_06	SA	M	12	8D			BBW				1
19_06	SA	M	2	9D			BPP				1
11_07	A	F	0	1E				BRR			1
11_07	SA	M	3	2E				BYR	PBW_32b		2
9_08	A	F	0	3E					PRB_41b		1

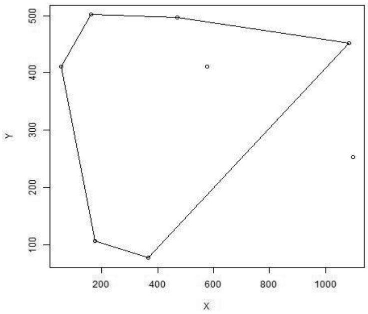
Appendix D (SECOND Study case: Botanical Garden)

Home ranges (MCP) of the 21 lizards with five or more sightings, created by R software. (Each graph have the identification code of the lizard).

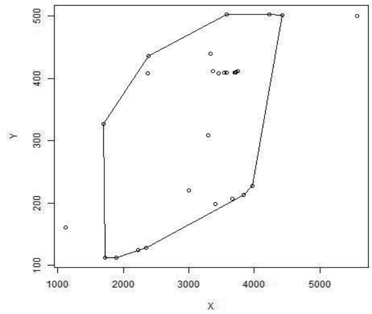
1A



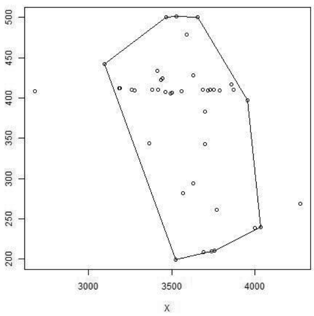
1D



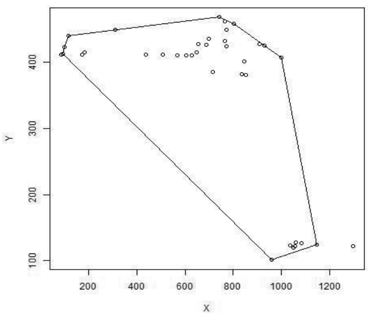
2A



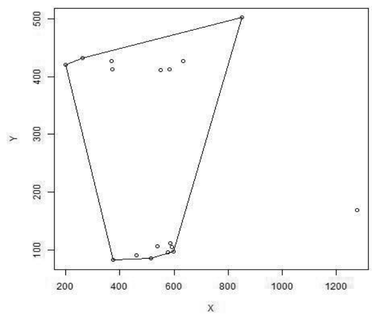
2B



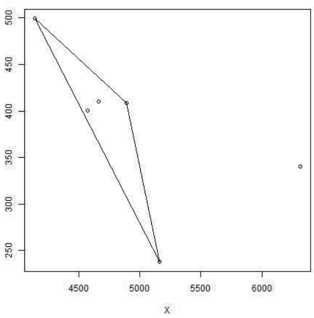
3A



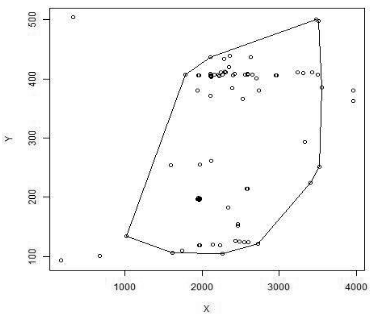
4A



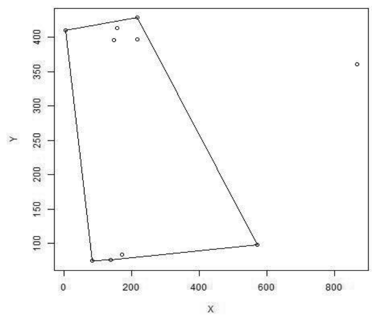
4B



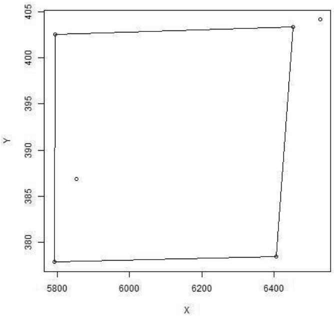
5A



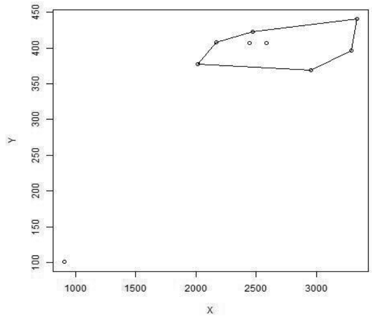
5B



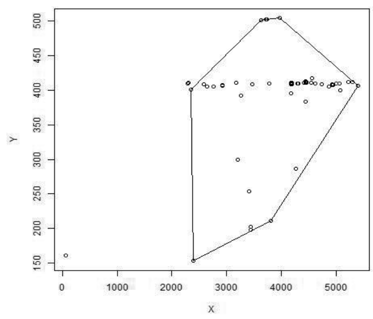
5C



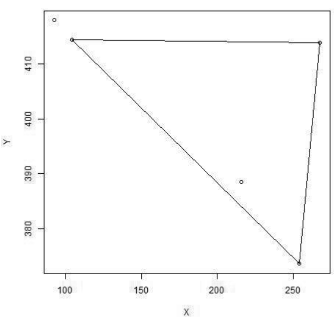
5D **1A**



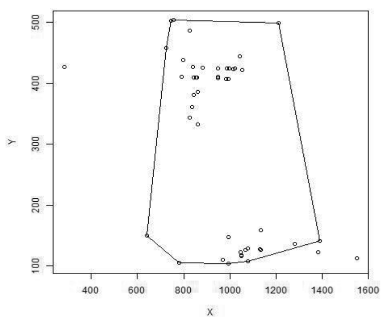
6A



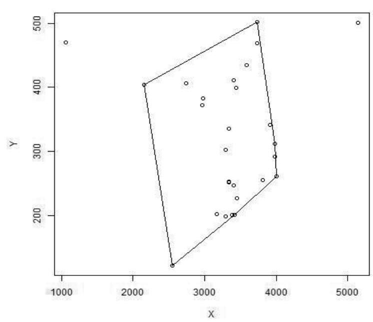
6B



7A



7B



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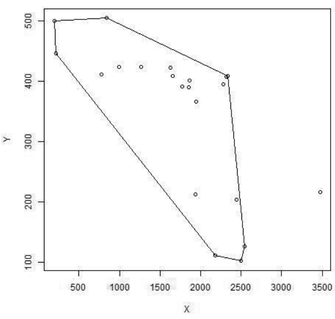
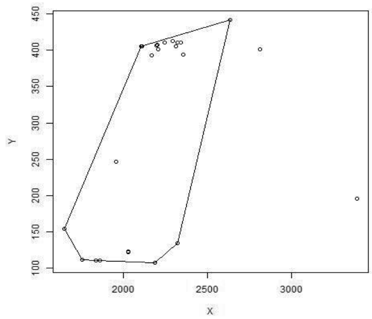
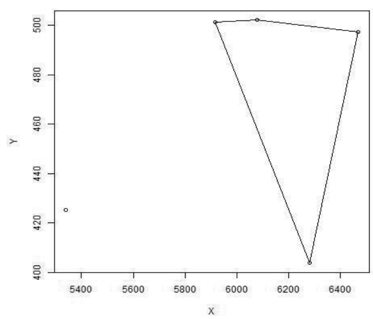


7D



8A



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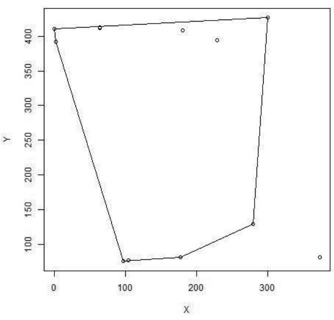

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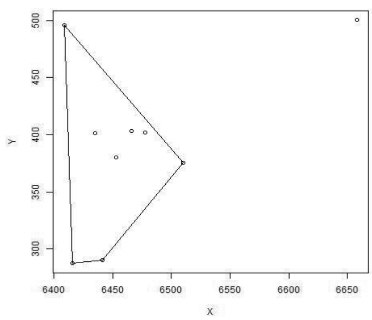
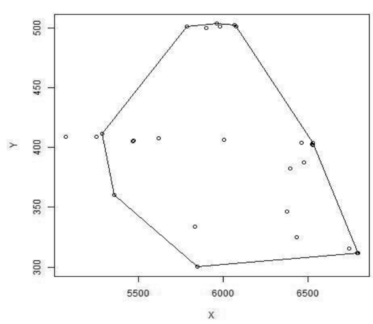
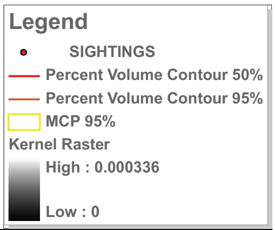


9C

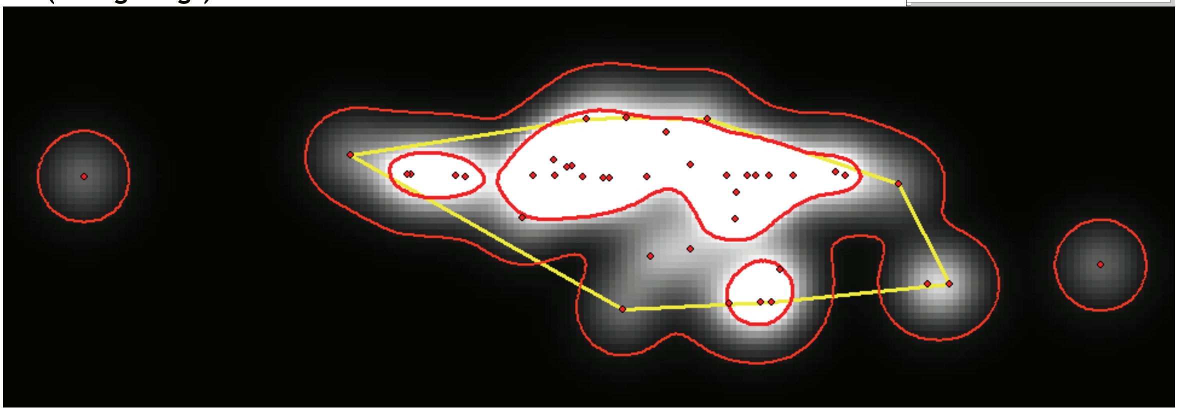


Appendix E (SECOND Study case: Botanical Garden)

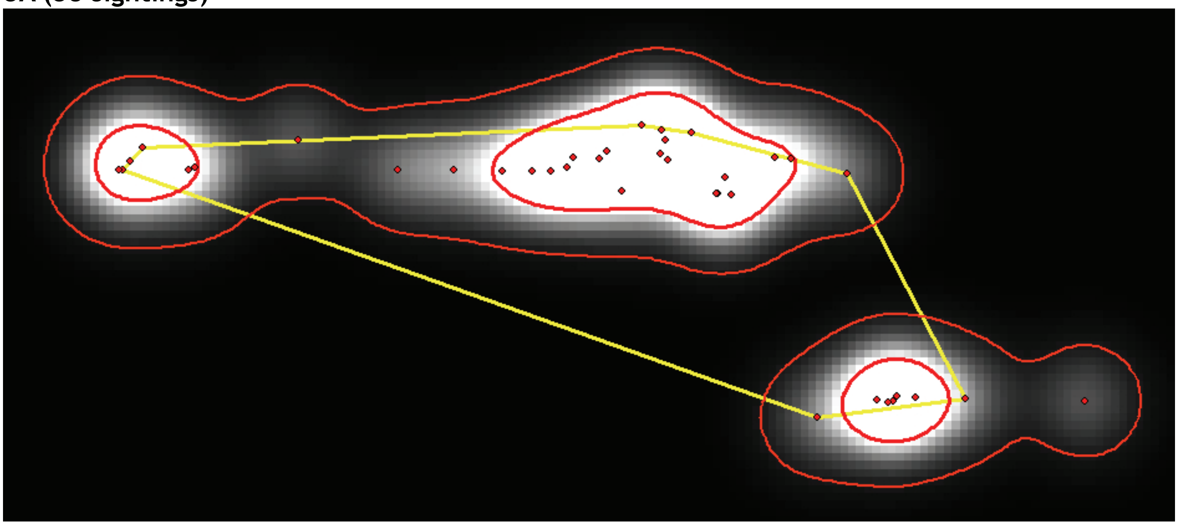
Maps of the home range, utilization distribution and activity centre of 9 lizards with more than 12 sightings.



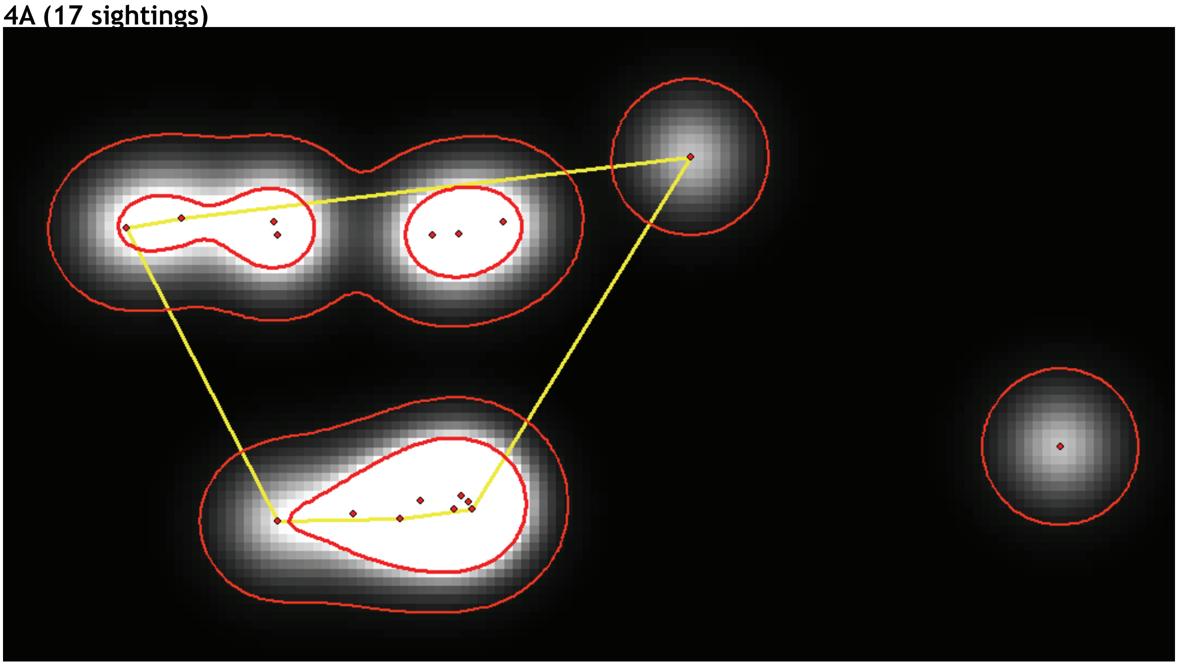
2B (41 sightings)



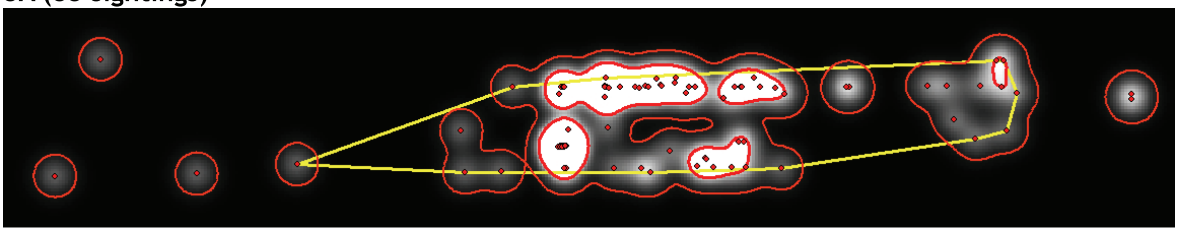
3A (38 sightings)



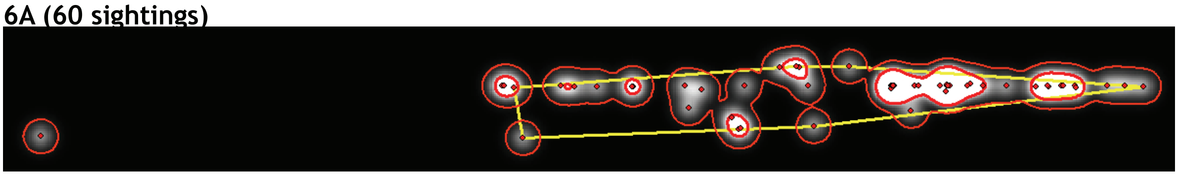
4A (17 sightings)



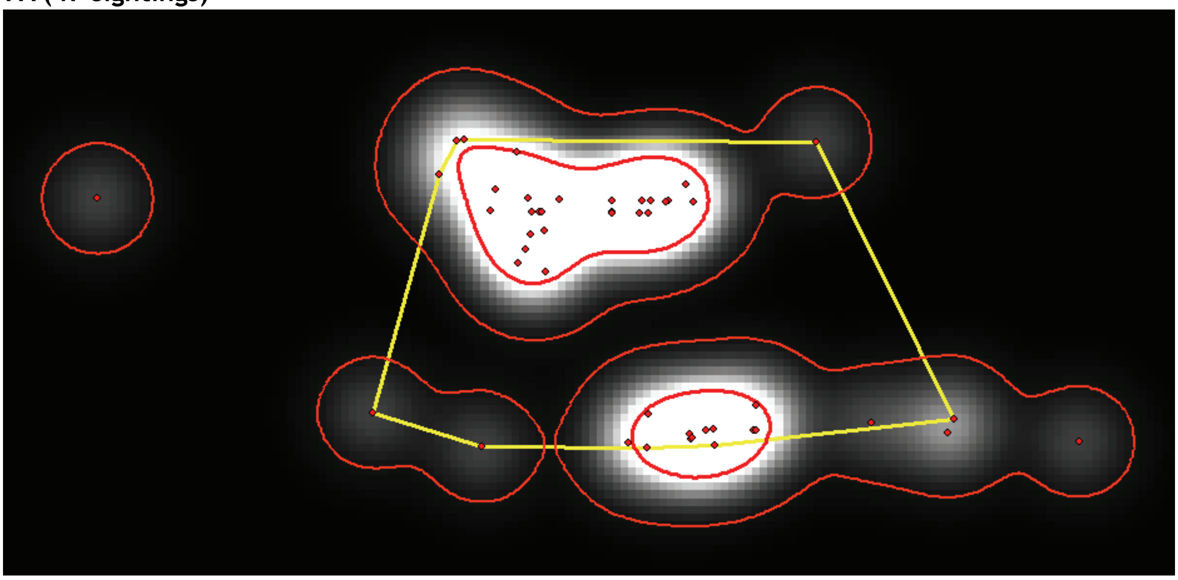
5A (85 sightings)



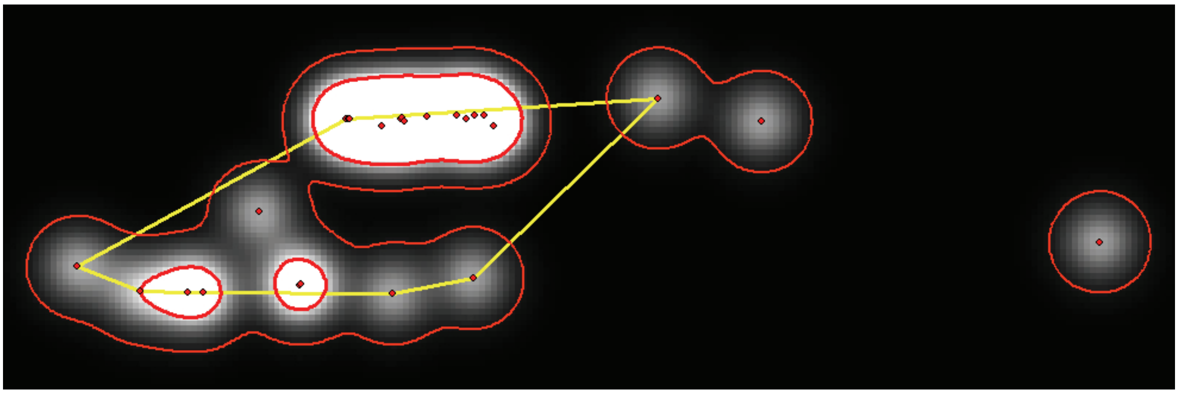
6A (60 sightings)



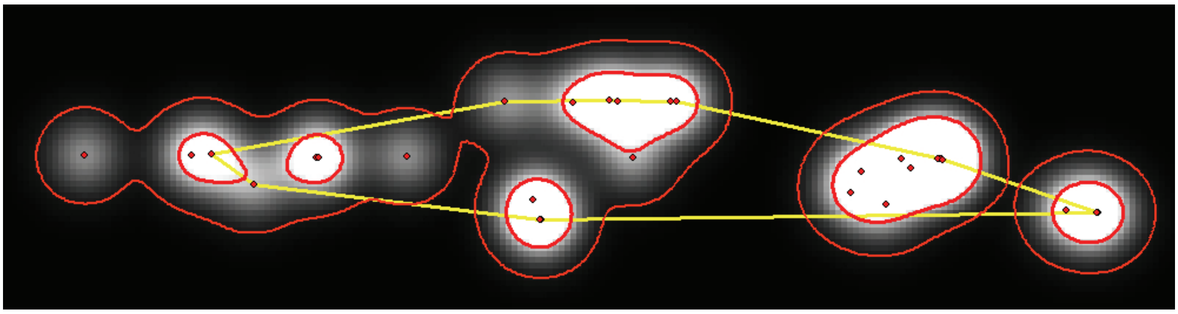
7A (47 sightings)



7B (29 sightings)



7D (25 sightings)



9C (29 sightings)