Movement Patterns and Use of Habitat Connectivity Structures in *Lacerta viridis* (LAURENTI 1768) in the Vineyards of Nußberg, Vienna

Master Thesis

For acquiring the academic grade Diplom-Ingeneurin (DI^{in}),
equivalent to Master of Science (MSc)

submitted by

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Vienna, May 2019

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Affidavit

I hereby declare that I am the sole author of this work. No assistance other than that which is permitted has been used. Ideas and quotes taken directly or indirectly from other sources are identified as such. This written work has not yet been submitted in any part.

Acknowledgement

First, I want to thank my Heimo Schedl for the possibility to do my master thesis on the topic of this charming species and for interesting discussions and new insights into applied conservation.

I want to thank Prof. Harald Meimberg for his support and feedback.
Sophie Kratschmer for her help with statistics.
Further I want to thank Prof. Leisch for statistical support, Dr. Sepp Pennersdorfer and Friedl for their support in ArcGIS.
And M&M for their always sympathetic ears!

Thanks to my son Leano, who spent hours for hours in front of the computer in my belly patiently.

Abstract

The critically endangered Eastern Green Lizard (*Lacerta viridis*) is a thermophilic species, which is distributed in Vienna mainly in wine growing areas in the North-West of the city. Based on previous studies since 2011 this survey investigated a subpopulation within the metapopulation system of Green Lizards on the Nußberg, a popular wine growing district, where the lizards inhabit linear dispersed uncultivated slopes between the vineyards. In the last years, connectivity structures between those slopes were established in cooperation with the local wine makers to improve the habitat connectivity in the area.

The current capture-re-capture study worked with individual recognition of scale patterns on the lateral head sides of photographed Green lizards, which were surveyed in the activity season from March to October 2017. The results give an overview of the resident population including population structure, distribution and phenological parameters, and second show the movement patterns of the individuals within the survey area including the connectivity structures. It is determined, that the population shows clustered distributions along the slopes and the sex ratio of the collected data represents a surplus of male individuals. The males covered larger distances and used the connectivity structures to migrate between the habitat slopes. The biggest distance showed a three-year-old male, which moved more than 250 m within the connectivity matrix. Furthermore, was tested statistically if the distances covered by the males correlate with different population parameters. In particular, males´ covered distances correlated negatively with the availability of females in the initially inhabited territory. Thus, low female abundance can cause emigration of males from the habitat patch in other sections. This underlines the importance of the connectivity structures, which help to connect subpopulation clusters within the single habitat sections.

Zusammenfassung

Die bedrohte Östliche Smaragdeidechse (*Lacerta viridis)* ist eine thermophile Art, die in Wien hauptsächlich in Weinbaugebieten im Nordwesten der Stadt verbreitet ist. Basierend auf vorangegangenen Studien seit 2011 untersuchte diese Arbeit eine Subpopulation innerhalb eines Metapopulationssystems am Nußberg, einem bekannten Weinbaugebiet, in dem diese Art linear verteilte, unkultivierte Böschungen zwischen den Weingärten besiedelt. In den Vorjahren wurden in Zusammenarbeit mit den ansässigen Winzern Habitat-Verbindungsstrukturen zwischen diesen Böschungen angelegt, um die Vernetzung der Lebensräume innerhalb des Gebiets zu verbessern.

Die vorliegende Fang-Wiederfangstudie arbeitete mithilfe individueller Erkennung von Schuppenmustern auf den lateralen Kopfseiten von fotografierten Smaragdeidechsen, welche in der Aktivitätssaison von März bis Oktober 2017 erhoben wurden. Zunächst zeigen die Ergebnisse einen Überblick über Populationsgröße, Populationsstruktur, Verteilung der Population im Habitat und phänologische Parameter. Zusätzlich werden die Bewegungsmuster der Individuen im Untersuchungsgebiet einschließlich innerhalb der angelegten Verbindungsstrukturen erfasst und dargestellt. Die Population weist eine geklumpte Verteilung entlang der Böschungen auf und das Geschlechterverhältnis zeigt einen Überschuss an männlichen Individuen. Männchen legten im Durchschnitt größere Entfernungen zurück als weibliche Tiere und nutzten die Verbindungsstrukturen, um zwischen den Habitatböschungen zu wandern. Die größte Entfernung legte ein drei Jahre altes Männchen zurück, welches sich mehr als 250m innerhalb der Verbindungsmatrix bewegte. Weiters wurde statistisch getestet, ob die von den Männchen zurückgelegten Distanzen mit verschiedenen Populationsparametern korrelieren. Die Wanderdistanzen der Männchen korrelierten negativ mit der Verfügbarkeit von Weibchen im ursprünglich bewohnten Habitatabschnitt, folglich führt eine geringe Weibchendichte zu einer möglichen Abwanderung von Männchen in andere Lebensraumabschnitte. Dies hebt die Bedeutung der Verbindungsstrukturen hervor, die dazu beitragen, Teile der Subpopulation innerhalb der einzelnen Habitatböschungen miteinander zu verbinden.

Table of content

1 Introduction

The Eastern Green Lizard (*Lacerta viridis*) is a critically endangered thermophilic species, which is found in Austria at its north-western edge of distribution in climatic favorable habitats. For this thesis, a subpopulation of *Lacerta viridis* was examined in the year 2017 in vineyards of Vienna. The species is listed in the Flora-Fauna-Habitat directive (FFH) of the European Union in annex IV, which are strictly protected animal and plant species of community interest (EU, 1992). For included species a strict protection regime must be applied across their entire natural range within the EU, both within and outside Natura 2000 sites. In the Red List of Austria *L. viridis* is listed under IUCN-criteria "EN" (GOLLMANN, 2007), endangered and in Vienna it is found in category 1 (danger of extinction) (TIEDEMANN & HÄUPL, 1994) . In the Viennese, federal nature protection act the species is listed further as "priority protected species".

Aims of the study were to get an overview of population structure, distribution and abundance of animals as well as to trace movement patterns of adult Green Lizards within the area. The individual movements were of interest to determine the expediency of a habitat connectivity system, which was established in the last years from Heimo Schedl in cooperation with the wine growers in the area to connect parts of the habitat slopes.

In Austria the species is spread in shattered populations along climate favorable regions. In Vienna four isolated populations are found in the North-West and South-West of the city. The examined subpopulation is part of a metapopulation system in the vineyard area of Vienna´s 19th district and inhabits mainly two slopes within the wine growing area of Nußberg, where artificially created connectivity structures are embedded to ensure migration of *L. viridis* between the two slopes. This is an important measure, because small edge populations are more vulnerable to suffer from genetic isolation, increased inbreeding or reduced genetic diversity which leads to smaller fitness in the entire population and therefore a higher risk of extinction in fragmented landscapes (BÖHME et al., 2007, HENLE et al., 2017).

Thus, it is of interest to evaluate this Viennese subpopulation of the Eastern Green Lizards and the expedience of the anthropogenic established habitat connectivity, which is performed in a photographic capture-recapture study for this study.

1.1 Habitat connectivity in conservation management

Due to human activities, fragmentation of landscapes and therefore of habitat systems has gotten an important issue of conservation management at present times. Habitat fragmentation takes place in form of dividing connected habitats in smaller pieces, which loose connectivity and result in isolated habitat patches and loss of habitat area (CÓRDOVA-LEPE et al, 2018). Human activities like urbanization, agriculture or infrastructure like rail- or motorways can be drivers for that phenomenon in landscapes (DENNHARDT et al., 2016). Habitat loss and fragmentation seem to be major drivers of biodiversity loss. Especially (sub)populations in small habitat patches suffer from lower fitness due to lower genetic variability (BÖHME, 2007, HENLE, 2017). Decrease in genetic diversity is caused by inbreeding or genetic drift in small populations, which lead to lower adaptability to alterations in dynamic environmental parameters. Apart from the fact of fragmentation itself, are found additional parameters which influence the status of fragmentation of a landscape, such as total amount of habitat, patch size, patch number and patch isolation towards each other as shown in figure 1. Those lead to decreasing suitability of habitats, which often occurs in a continuous process within the landscape, while patches are getting smaller and more isolated during time (FAHRIG, 2003).

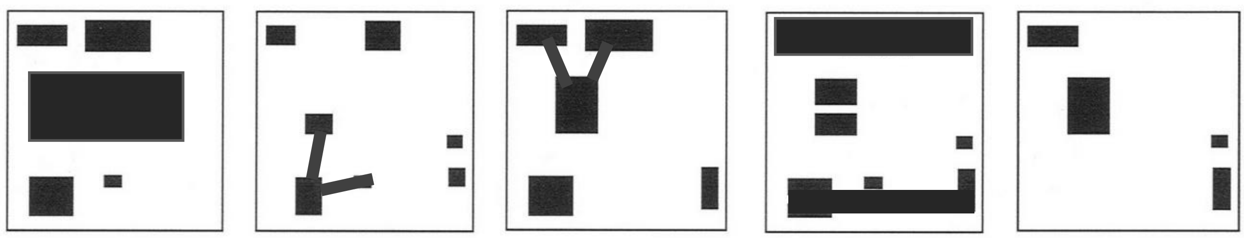

Figure 1: Fragmentation of habitat patches within the landscape in different patterns (from FAHRIG, 2003, own editing)

Even there is no specific threshold, at which certain landscape patches become disconnected from each other for all species concurrently, it is an important issue to create and maintain connectivity structures between those landscape elements (BEIER & NOSS, 1998, TAYLOR et al., 2006). In general, it should be distinguished between mobile species and such with limited mobility and low population density to determine goals in conservation management concerning measures against fragmentation such as creation of landscape connectivity structures (BEIER & NOSS, 1998).

The term *landscape connectivity* basically describes the combination of physical structure of a landscape and an organisms´ reaction, e.g. movement, to that structure. TAYLOR et al. (2006) distinguish between two kinds of landscape connectivity: First, 'structural connectivity', which includes only physical relationships among habitat patches, like existence of habitat corridors and distances between habitat patches, while it ignores behavioral responses of organisms to those structures. Second, 'functional connectivity', which describes an organisms´ response to the landscape matrix and corridors between the patches. If corridors are not used by target species, this kind of connectivity is not provided. It is underlined, that in landscape connectivity evaluation should be always considered the *functional connectivity* as a measure of utility.

Assessing *structural connectivity* in general is easier, as it can be computed and mapped for spatial analysis within a geoinformation system, which is sufficient for evaluating the physical existence of connectivity structures in form of corridors between habitat patches. Whereas *functional connectivity* needs complex and detailed methods for assessment, as it should include observational studies measuring the movement of (individual) animals in connected habitat patches, which needs bigger effort in time and data analysis in general (TAYLOR et al., 2006). This kind of assessments of connectivity structure – utility and use can be performed in studies measuring demographic parameters like habitat patch occupancy, abundance or immigration rate of single individuals etc. (BEIER & NOSS, 1998).

Studies underline the importance of species- specific approach in both creating and assessing existing connectivity structures (BEIER & NOSS, 1998, TAYLOR et al., 2006), even though also studies which use non-species specific models to evaluate fragmentation reveal, that connectivity loss exerts negative effects on populations (CÓRDOVA-LEPE et al., 2018, FAHRIG, 2003).

In this study, the aim was to determine if individuals of *Lacerta viridis* are using connectivity structures among the habitat slopes in vineyards, which consider movement and spreading characteristics of this species, which are key factors to mind in corridor establishment. Studies regarding the use of connectivity corridors, which concentrate on high mobile species like birds or big mammals may consider other spatial scales and need different research methods than studies on smaller and non-mobile species (BEIER and NOSS, 1998). Aim of the study is, to evaluate the utility of species-specific established connectivity structures in form of vegetation strips (grass, shrubs or bushes) for *L. viridis* as a small and intermediate mobile species.

1.2 *Lacerta viridis* (LAURENTI, 1768)

1.2.1 Distribution

The Eastern Green Lizard *Lacerta viridis* is part of the Lacertidae complex which is found in Middle to Western and Southern-/ Eastern Europe in favorable climatic regions.

In 1991 RYKENA divided *Lacerta viridis* in two separate species, which were established in genetic investigations. Therefore, two similar species are found in Europe today, which are able to hybridize (RYKENA 1991, 2001): *Lacerta viridis* which is spread in (south-)eastern regions of Europe and parts of Brandenburg in Germany as well as small populations in Czech Republic (ELBING, 1996, MIKÁTOVA, 2001) and its "sister species" *Lacerta bilineata* which inhabits western parts of Europe from Germany, Italy, Switzerland and France to Spain (figure 2).

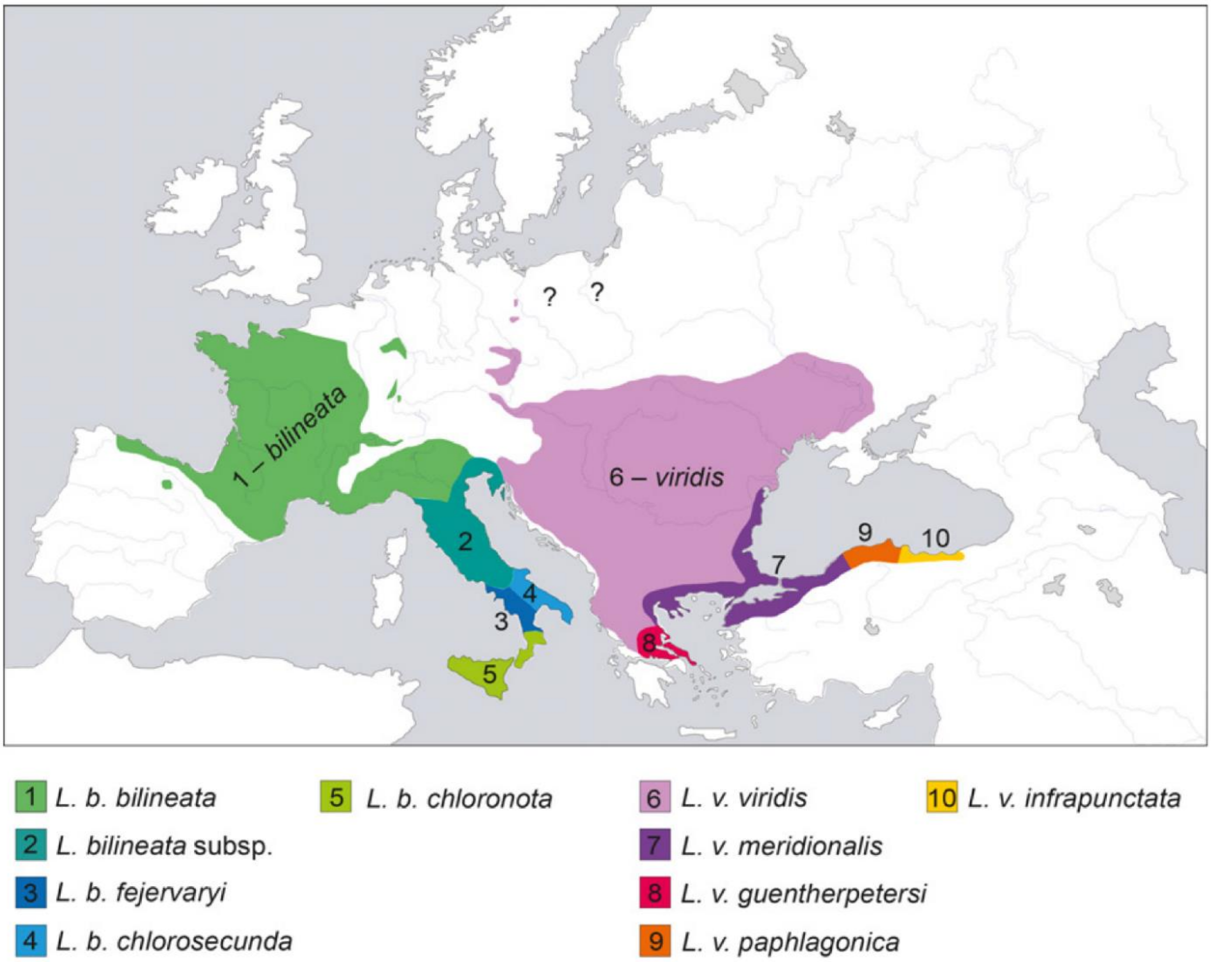

Figure 2: Distribution of the subspecies of the Lacerta viridis complex (MARZAHN et al., 2016)

Potentially a hybridization zone between the two species be found among Slovenia (CABELA & GRILLITSCH, 2001), more recent studies surmise a separated lineage in Slovenia and Adriatic zones (no. 2 in figure 2) (MARZAHN et al., 2016).

MARZAHN et al. (2016) published a study which examined the phylogeography of the Lacerta viridis complex among its entire distribution by processing nearly 400 genetic samples from several countries. They subdivided the two subspecies in further lineages, which are found among southern parts of Europe as seen in figure 2 as well. *Lacerta viridis viridis* populates the biggest part of south-eastern distribution. In Greece, along the Black Sea coast and Turkey are found several subspecies of *L. viridis*.

In Austria only the nominotypical taxon *L. viridis viridis* is found at its north-western edge of total distribution zone in colline and submontane areas with annual temperature sums over 100°C and annual participation less than 1000mm (GRILLITSCH & CABELA, 2001). Its distribution is linked to thermo-favorable low regions like river valleys, wine growing regions and basins. In Austria it is spread in separate populations in basins of Lower-/Upper Austria and Burgenland, along rivers like Danube, Kamp, Drau and Thaya and even some Alpine regions in Carinthia in warm slopes up to over 1100m (PLUTZAR, 1996) or 1300m (FINDEGG & REISINGER, 1950 in GRILLITSCH & CABELA, 2001), 98% of the occurrences in Austria are found below 650m a.s.l (PLUTZAR, 1996) and the most frequent reports (about 40%) where logged between 200m and 300m a.s.l. (GRILLITSCH & CABELA, 2001). According to CABELA and GRILLITSCH (2001) core regions of distribution in Austria are the eastern low lands (Viennese basin, Leithagebirge), Danube- and Kamp valley and Carinthian basin.

In Vienna are found four separate populations of *L. viridis* as seen in figure 3. Three isolated ones are found among the north-western edge of the city in vineyard – and forest edge regions as well as at river Danube. The fourth population is found in the south-west edge, next to the village Kaltenleutgeben (SCHEDL & KLEPSCH, 1999).

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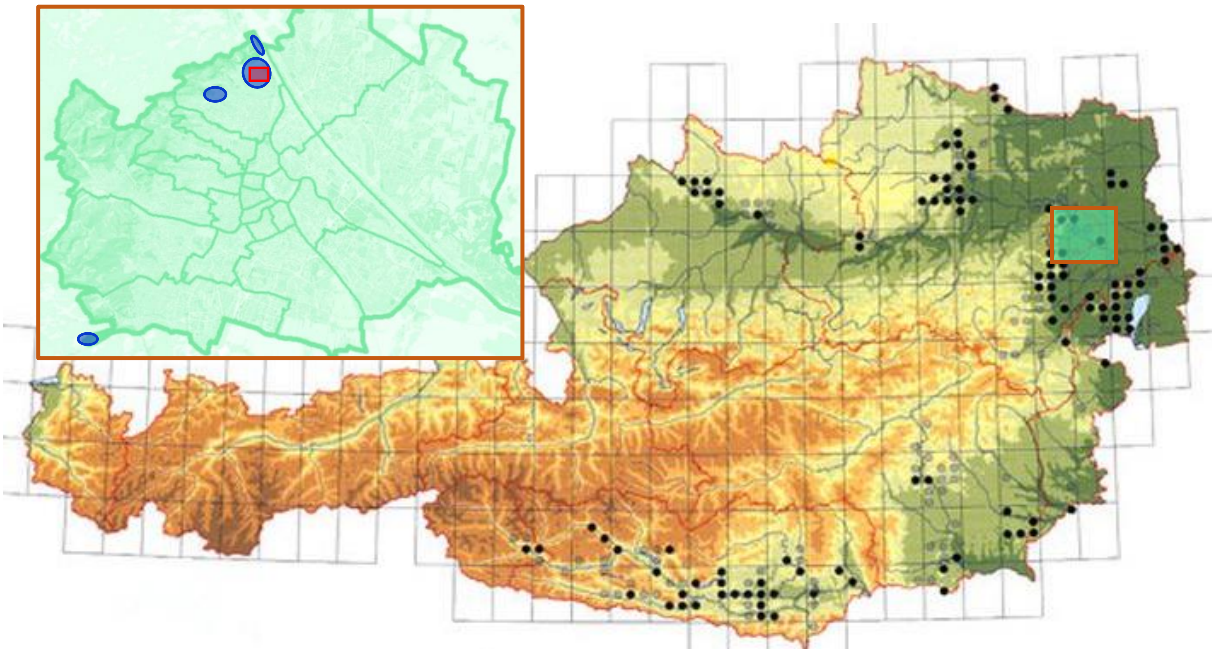

Figure 3: Distribution of L. viridis in Austria (CABELA et al., 2001)
and Populations in Vienna (blue), study area Nußberg in the North of Vienna(red)

1.2.2 Habitat

In middle Europe *L. viridis* is found mainly in areas, which are used for wine growing and agriculture due to their warm and continental climate. In this regions *L. viridis* predominantly inhabits vineyards, ruderal sites, shrubland and vegetation-free areas and areas with forest-steppe character (GRILLITSCH & CABELA, 2001, MIKATOVA, 2001). Often mentioned is the importance of edge situations as habitats, such as way sides, edges of forests as well as stony banks of rail way tracks or stony edges of vineyards with stone walls etc. Important within the habitats are hiding structures like shrubs, woodpiles or stone piles and basking possibilities on stones, walls and open ground areas. (e.g. BÖHME et al. 1986, BÖKER, 1990a, MIKATOVA, 2001, SCHEDL & KLEPSCH 2001). The preferred slope orientation is south to south-east to -west due to favorable insulation and thermal advantages (CABELA et al., 2001).

Most records of *L. viridis* are found in following natural vegetation type zones of Austria: Pannonian- Balkan downy-oak forests (“Flaumeichenwald”), dry warm oak mixed forest (“Trockenwarmer Eichenmischwald”) and oak-hornbeam forests (“Eichen-Hainbuchenwald”) (PLUTZAR, 1996). Due to high rates of agricultural used land in within this climate area also vineyards, forest edges and ruderal areas are inhabited. *L. viridis* occurs in different kinds of structures, more than 51% of all observations in CABELA et al. (2001) have been recorded in forest edges, clearings, hedges and stone fields.

In Vienna *L. viridis* inhabits mainly open, stony areas, forest edges, waysides, bushy grasslands with sufficient cover structures or dry-stone walls in arid warm slopes in south exposition along the Vienna woods in the north-west and south-west parts of the city (TIEDEMANN, 1990).

1.2.3 Ecology

1.2.3.1 Habitus and coloration

L. viridis is the biggest species of the Lacertid-complex in Austria. It reaches up to 40cm total length, whereby body and head make up one third of total length and two thirds the intact tail. Typical characteristic is the green coloration and the males´ blue nuptial colors on head and throat in spring.

Juveniles show brownish camouflage, with darker dots on the body and cream-colored ventral body sides and throat. They hatch with measures from about 32 to 38 mm SVL (ELBING, 2000b*).*

Figure 4: Juvenile in End of September

Subadults after hibernation look like juveniles in next spring. They start to develop more greenish shades in coloration beginning from head and front body. Some animals show a line of white dots at lateral body sides. Figure 5 shows a subadult *L. viridis* in June, where greenish color is already visible on body parts.

Figure 5: Subadult in June, moulting remains on tail, already showing partly greenish coloration

Adult males are green with fine black pattern, the throat is white and ventral bodysides are pale greenish yellow outside the mating season. Young two-year-old adults still show rests of the brown subadult – coloration on the hind legs and tail (figure 6).

Figure 6: 2-year-old male in March with still brownish tail and hind legs, adult green coloration on body

With the first spring moulting, males develop nuptial colors with blue throat and head sides, which contain UV- components as well as visible blue amounts (MOLNÁR et al., 2016). Males show their fully developed adult-coloration from three years on, which contains only green and black color on body and tail, as well as on head and head sides. Only the throat shows whitish coloration in early spring and after mating season in summer and autumn (figure 7). In general, males show bigger and more massive heads than females.

Figure 7: 3-year-old male in nuptial colors in May, tail and whole body show green basic color

Females are green with brownish shades and show a white throat all year around. On their head sides is found a typical pattern of dark and white parts. There is also to note, that younger adults show more brownish components than older ones. In figure 8 is shown a three-year-old female, which already show high amount of bright green color on her body.

Figure 8: Adult 3-year-old female in April

The older the female, the brighter green color is shown on their bodies, four to five-year-old females show deep green body coloration without considerable amounts of other colors on body, legs and tail (figure 9). Other females keep dark color shades on their body, but never as much as males do.

Figure 9: Older adult female which shows only green color on the body with male, end of April (SCHEDL, 2017)

1.2.3.2 Life cycle

After an incubation time of about 80 - 90 days, depending on temperature conditions, the hatchlings appear from mid of August on up to beginning of October (ELBING, 1998, REHÁK, 2015, SCHEDL, 2001, own observations, 2017). ELBING (1998) displays incubation times between 81 and 132 days in Brandenburg, Germany. From beginning of September to mid of October the hatchlings start hibernation in holes and stony structures, while juveniles and subadults stay longer outside than adults (NETTMANN & RYKENA, 1984, RYKENA et al., 1996). From beginning of March, mainly when temperature exceeds 12°C to 15°C (MIKÁTOVÁ, 2001), to mid-April (BÖKER, 1990b, NETTMANN & RYKENA, 1984, REHÁK, 2015) the animals leave their hibernation sites. After their first hibernation, the juveniles are labeled as subadults in their second activity period. Depending on weather and food conditions, they keep a fast growth rate over this period, so it is possible to distinguish young males and females by body coloration from early summer on (SCHEDL, *personal communication*) or in autumn of that year (RYKENA et al., 1996). *L. viridis* achieve their sexual maturity in their second spring, were mating season starts in the beginning of April in very warm years (own observation, 2017) and normally in the end of April and continues until mid of June (BÖKER, 1990, REHÁK, 2015, RYKENA et al., 1996). The eggs are laid from

May to beginning of July, in the study area two clutches per season are the norm, as observed in many other populations of Green Lizards as well (BÖKER, 1990b, ELBING, 1996, GRILLITSCH & CABELA, 2001, NETTMANN &RYKENA, 1984, REHÁK, 2015, SCHEDL & KLEPSCH, 2001). Adult *L. viridis* use summer time for feeding and grow their hibernation-fat deposits until they seek out their hibernation shelters in September or October (KLEPSCH, 1999, REHÁK, 2015, RYKENA et al., 1996, TIEDEMANN, 1984).

In literature, different information about expected lifespan is found. As a fact, they can reach an age over 10 years and more (RYKENA et al., 1996). In populations in Brandenburg were calculated mean life spans from 4,1 to 6,3 years, while only a fractional part of animals reaches maturity and high ages (ELBING, 2000).

1.2.3.3 Reproductive behavior

During the mating season males wear a blue throat with coloration that contains UV components. Some studies investigated in the effects of this color on females and found out, that females of Green Lizards seem to prefer males with higher UV reflection, possibly that coloration can signal male quality (BAYER et al., 2010, MOLNÁR et al., 2016). According to literature, young males, which just reached maturity with two years, tend to be “floaters” between older males´ territories, while older ones stay in one territory to mate with resident females (MIKÁTOVÁ, 2001). Also MOLNÁR et al. (2016) give account of those two different space-use strategies, but depending on UV chroma in nuptial coloration, while males with bigger heads showed duller colors and occupied bigger areas, whereas smaller ones tend to be lighter colored and act as floaters.

In mating season, fights can occur between males, where ritualized display behavior is shown by showing off the spread blue throat skin and flanks. If two males are about the same size, they may start to bite each other’s head and body sides until one opponent leaves the fighting area (RYKENA et al., 1996, TIEDEMANN, 1984).

With the males´ moulting to the nuptial colors, pairs find together and stay in body contact while basking and daily activities as well as they use shared shelters. The actual mating is introduced by display behavior shown by the male while circling around the female. Females show subservience behavior in form of “treteln” (BECKER, 1982) – this describes a special way to move their fore legs up and down without any forward movement. Then the male bites the females´ tail and she starts to walk slowly (“Paarungsmarsch”). Immediately before the mating, the male bites the females´ hips and bends to the cloak region to copulate (RYKENA et al., 1996, TIEDEMANN, 1984).

The pairs normally stay together for several copulations, the time span one pair stays together depends on population- and sex-density in the area. Both sexes are polygamous, males as well as females tend to copulate with different partners in one mating period (ELBING, 1999).

Four weeks after the beginning of mating the females seeks out a warm, soft grounded and sandy place to lay her eggs in a self-dug hole. Before that, she did not allow any further copulation for about ten days. After closing the hole, the female disguises the clutch by running across the surface (ELBING, 1999, RYKENA et al., 1996). When a female has laid her first clutch in spring, the second mating season follows in the same way.

1.2.3.4 Thermoregulation

As a thermophilic reptile species, *L. viridis* relies on warm mesoclimatic conditions, in our latitudes implies that south-exposed slopes or landscape elements and structures in the inhabited regions. Warm and sun exposed structure elements like stones and wood piles are used for basking to reach the optimum body temperature, which vary around the year. So was found out, that the photoperiod influences the selected body temperature in ex-situ experiments, which lied in fall around 28,3°C and 32,4°C and in long-day periods between 32,7°C and 34,2°C (RISMILLER & HELDMAIER, 1982 & 1988). But that values represent freely selectable temperatures in cages, which do not correlate with the possibilities in natural habitats sometimes, e.g. in bad weather periods. After hibernation in spring, Green Lizards were found at the beginning of activity period in March with a body temperature of 12°C; they were able to move and stayed outside their hibernation holes (BÖKER, 1990b).

1.2.4 Threats

In middle and northern-middle Europe, particularly edge populations of *L. viridis* are endangered by anthropogenic and natural influences due to local extinction of isolated small populations. According to literature, the main reasons are loss of habitat due to human activities, and therefore isolation of small populations, shrub encroachment, biocide use and land consolidation. In woody areas, afforestation leads to the problem of shrinking habitats and intensively used agricultural land leads to “landscape clearing” where structure elements like unused edge areas and bushy sections as well as old stone walls are getting removed, an example from the study area is shown in figures 10 and 11.

Furthermore, the loss of open areas which are used as nesting sites seem to be a problem for

Figure 10: Habitat in spring 2017(object 10): dense herbaceous vegetation, bushy parts with Cornus mas, Rosa sp. and small trees along an agricultural track

Figure 11: Same habitat after land consolidation in Dec. 2017 (different perspective): Removed vegetation, totally cleared, bare soil surface left

the species (SCHEDL & KLEPSCH, 2001, SOUND, 2001, TIEDEMANN, 1990). Edge areas of vineyards tend to overgrow by *Clematis vitalba* due to nitrogen input from the adjacent agricultural lands, which leads to changed microclimatic conditions and loss of open ground areas (SOUND, 2001). Further threats in form of predators should also be mentioned due to possible strong impacts on a population, most common predators of *L. viridis* are the Common

Kestrel (*Falco tinnunculus*), house cats and *Coronella austriaca*, which is a specialized predator on reptiles (ELBING, 2016, ZAGAR et al., 2015).

For the sister species *L. bilineata*, which shows same habitat preferences than *viridis*, FRITZ et al. (2001) cite following supplementary threats for a population in the vineyards of Kaiserstuhl and its surroundings in Baden-Württemberg: Succession (see also MIKÁTOVÁ, 2001), which takes place in form of overgrowing by *Clematis vitalba*, *Galium aparine* and intentionally planted bushes on the inhabited slopes. Direct persecution by reptile traders and keepers, which try to capture wild living Green Lizards. Fragmentation and isolation of population parts due to human impacts such as streets, buildings and settlements. Isolated small edge populations are more vulnerable to effects like genetic drift and inbreeding which leads to reduced genetic diversity and therefore to a higher extinction rate (BÖHME et al., 2007).

2 Research questions and hypothesis

The main research demand in the area of Nußberg concentrates on movement patterns and utility of connectivity structures.

For its size, *L. viridis* is a remarkably mobile reptile species which can move distances up to 500m from its home biotope (MIKATOVA, 2001), that leads to questions about the usage of habitat corridors which connect habitats. Gathering basic information about the population, which included population size, sex ratio, distribution within the habitats and movement characteristics of the species were essential for further investigations.

2.1 Research aims and hypotheses

Regarding the information mentioned above, the following research hypotheses were established for this study:

1. **Population structure**

a) Population size: An important parameter for assessment of population stability is the population size, which is estimated at around 100 adults in the examined population.

b) Sex ratio in adults: Stable populations should show balanced sex ratios in most cases, we expect that within the population on Nußberg.

c) Distribution within the survey area: In literature are found reports of clustered distributions of Green Lizards populations, which occur around favorable habitat patches. Due to inhomogeneous distributed habitat structures in the survey area, clustered population distribution is estimated as well.

2. **Movements of *L. viridis* within the area**

a) Efficacy of connectivity structures: It is estimated, that individuals of *L. viridis* use the connectivity structures to migrate between the habitat patches.

b) Individual use of connectivity structures: There is estimated a difference between age classes and sexes, e.g. younger males acting as “floaters” may rather use the connectivity structures to migrate between the habitat slopes, than older territorial males.

c) Influence of sex on movement patterns: Males tend to cover bigger distances than females in average. Males, which inhabit patches with low female abundance possibly tend to cover larger distances than males which live in patches with high female density.

3 Material and Methods

In this survey, a non-invasive capture-recapture method was chosen to get an accurate estimate of the surveyed *L. viridis* population size. In previous studies capture-recapture in Lizards often was performed by invasive marking methods by capturing the animals and marking them by scale clipping, branding, tattooing or toe clipping i.e. the removal from a unique combination of toes in each marked individual (SACCHI et al., 2010). ELBING (2000) used in her dissertation the unique scale pattern on each *L.viridis´* head sides to distinguish the animals visually in the three investigated populations. She captured and recaptured them by noosing and assigned them by their scale patterns individually or did not capture them if it was possible to recognize the pattern in situ (ELBING, 2000). SCHEDL (2001) and KLEPSCH (1999) used only photos to assign the found Green Lizards in Vienna individually by scale pattern.

In this study, it was also performed by photographing the Green Lizards in their natural environment using a Bridge camera with 100x zoom which showed best results in a distance from approximately 3m. This exceeded in most cases the flight distance of the photographed Lizards and if both head sides were available, the record of one single animal took about one minute, which is to point out as a fast, cheap and non-invasive method to survey a population. In this way, the capture-recapture method could be processed fully without actual capturing and marking, which would lead to stress or injuries like inflammation etc. (SACCHI et al., 2010). The used method allows to trace each recognized individuals´ movement and it is applicable for dense populations without bigger effort than for populations with low density (in areas which are the same size). SOUND & VEITH (2001) used implant-radio telemetry to follow 25 adults of *Lacerta bilineata* in the vineyards of Rhine in Baden-Württemberg, which lead to exact results in habitat choosing in a few individuals, but it cannot be performed for a whole population, first due to high financial effort, second, for reasons of possibility to catch all adults from one population and third, also important reasons of ethics in conservation research.

3.1 Study area

The Green Lizard habitat slopes are situated in a south-east to south-west orientated hillside in the vineyards of Nußberg. This area, located in the Northwest of Vienna, is embedded between the Danube River on the east side and the hills of Leopoldsberg and Kahlenberg in the North and West. The vineyards show an open southern orientation, at the bottom of the hill lies the residential district of Nußdorf composed of private houses and small blocks of flats, all with a relative big proportion of green space.

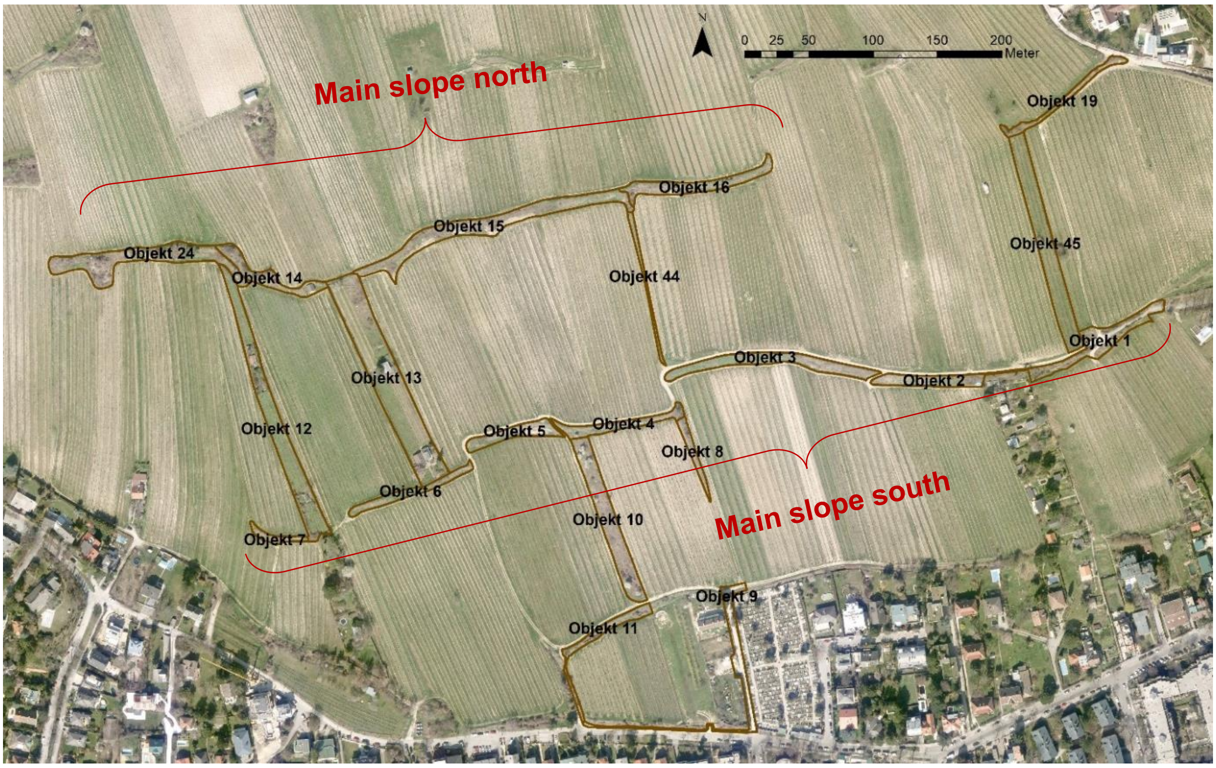

Figure 12: Study area: vineyards of Nußberg, embedded habitat slopes and object numbers (KRENN, STADT WIEN, 2017)

The total area of the examined vineyard slope is about 22,9 ha, in which the habitat structures are embedded. The habitats themselves are about 2,5 ha in size, which extend mainly on two linear slopes ("Main slope north and south"), which are situated hillslope-parallel with west-south-west to east-north-east alignment in a width from 2 to 5m (figure 12). They divide the winegrowing area in three terraces by levels of 2 to 3m up per habitat slope. Furthermore, there are some rectangular located habitat connectivity structures, which are mostly herbaceous plant structures or linear fallow lands between the cultivated areas. Some of them are established to build connection bridges from the southern slope to the northern slope. All in all, the linear dispersed habitats show a total length of 2300m, whereby the two "main slopes" are 600m (northern slope) and 760m (southern slope) long. This means in effect, that about 1360m of *L.viridis*-habitats are represented in the "main slopes" and about 1000m are situated in habitat connectivity structures between the two main slopes. There is to differentiate between "linear" structures, which only show a width of two to five meters and some which show more spatial extension like the fallow lands, which are at least around eight to ten meters wide and over 100m long. For the survey, we defined habitats as "linear", which are only surveyed from a linear path from the outside, so we had only insight to the edges of them, some of them are very bushy, others more open and it was possible to gaze a little deeper. The defined extensive

habitats were walkable, so it was possible to gain access to animals which used the whole area of the habitats. The two main slopes run parallel in a distance from about 130 to 200 meters.
For better workability, the entire area was divided in object numbers which defined each part of the study area (figure 12). The established fictive border lines between the object numbers were structures like paths and ways as well as some naturally given ones, like changes in land use etc. My particular research area is composed of 19 object numbers, not in order from 1 – 19 following a prescribed order of the numbers from the preceding work of Heimo Schedl. The surveyed area is included in a much bigger research area which is part of a conservation project for the whole 19th district of Vienna (due to that there are also found the object numbers 24, 44 and 45 in the present study, which numbers are out of order).
The focus of this survey was laid on the definitely by Green Lizards inhabited structures, no investigations beyond casual observations were done in the vineyards themselves.

In chapter 4.2 the different sections of the habitat-slopes are listed for an overview of geographical, topographical as well as vegetational and structural character of the objects. A bigger map is found in Appendix I.

3.1.1 Habitat connectivity

In figure 13 shown blue structures represent habitat connectivity structures in form of unmown grass and vegetation strips, which connect the habitats at the upper and the lower part of the vineyard slope. Those structures were established in the last years by Heimo Schedl in cooperation with the wine growers and private landowners for better linkage of the two relatively separated habitat main slopes ("Main slope north and south").
Figure 14 shows some examples of these structures. Once in form of an unmown grass strip between the vineyards (object 44) and the second example shows one along a fence (object 13), which is also a grassy structure with some upcoming bushes (*Rosa sp*.).

Figure 13: Connectivity structures in blue, which connect upper and lower slope as well as habitat patches in the South and East of the survey area (KRENN, STADT WIEN, 2017)

Figure 14: Examples of connectivity structures: object 44 (left): unmown grass strip between vine rows, object 13 (right): unmown grass strip along a fence of a private garden to ensure cover structures for migrating Green Lizards (KRENN, 2017)

3.1.2 Solar insulation

The south-exposition of the survey area leads to a high solar insulation throughout the year. Following graphs demonstrate different insulation situations along changing daytime on the example day April 15th.

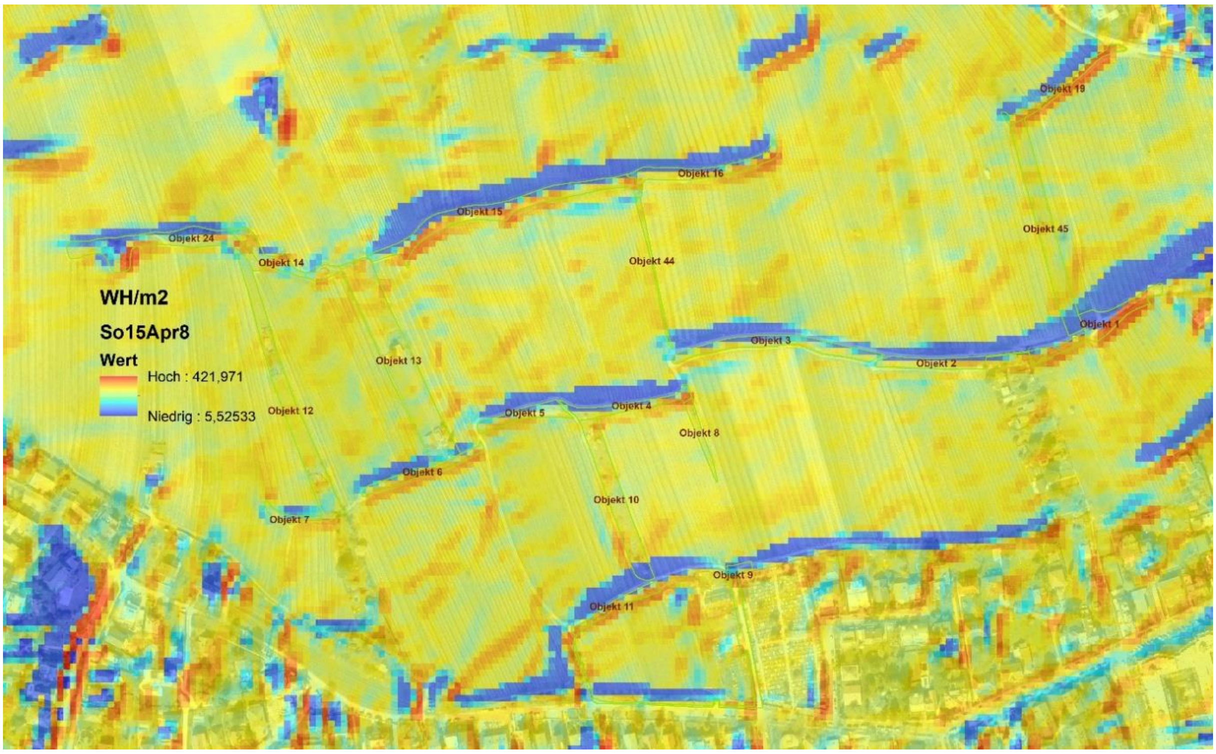

Figure 15: Solar insulation on April 15th 08:00 morning, blue patches show areas with low insulation around 5 WH/sqm, orange and red parts show high insulation up to 422 WH/ sqm. Created with ArcGIS

That particular day was chosen because in mid of April, *L. viridis* showed high activity in the survey area. The illustration was created to represent the different insulation and thus, the responding temperature situations in the slopes. The high values in reddish color shades represent the inhabited slopes, the blue parts parallel behind show the flat sections, which are the base parts of the vineyard slopes, which are not as steep as the habitats. The first illustration 15 shows the morning situation, where south-eastern exposed parts already show higher (red) insulation values in Watthours/ sqm than other expositions. In figure 16, it is seen, that the habitat slopes heat up quickly during daytime and lead to high insulation values in the south-exposed steep habitat areas at 11:00 noon. The graphs were plotted in ArcGIS ® with the tool "Solar Insulation".

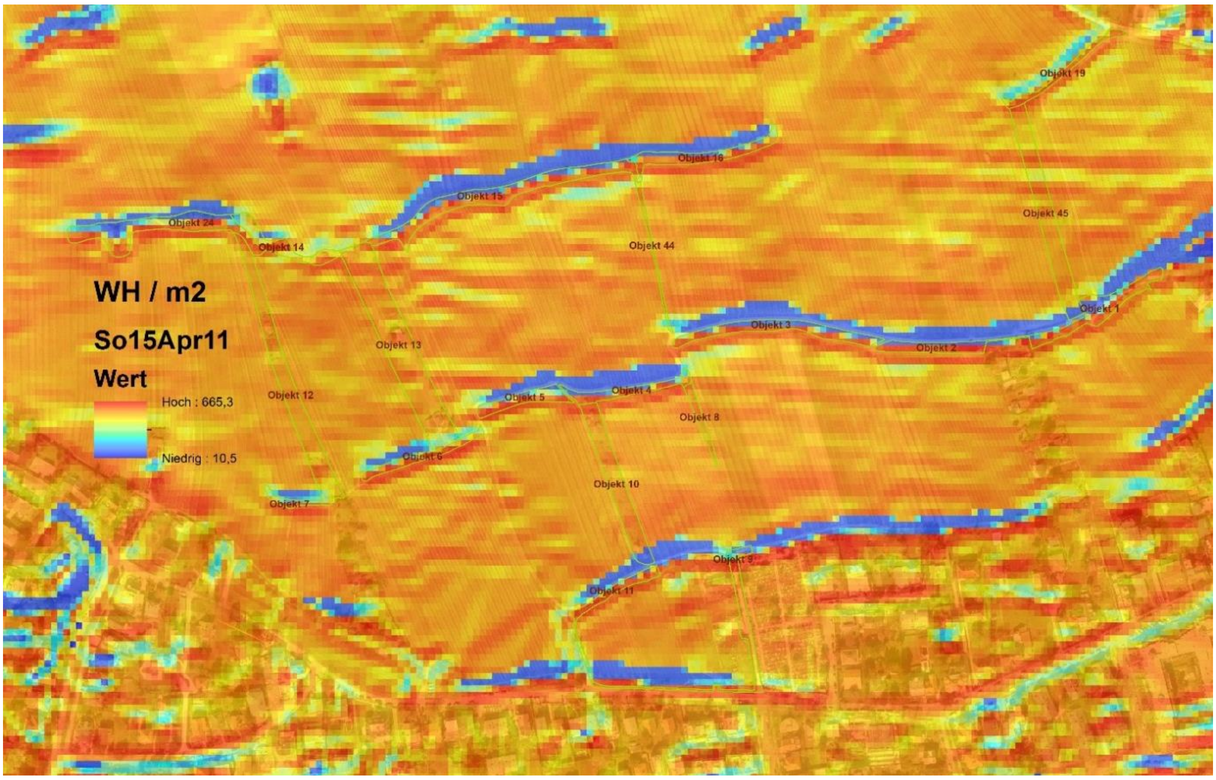

Figure 16: Solar insulation on April 15th 11:00 noon, blue patches show areas with low insulation around 10 WH/sqm, orange and red parts show high insulation up to 665 WH/ sqm. Created with ArcGIS

3.2 Objects

As mentioned above, the study area was divided in sections called objects for better manageable data collection. Below a detailed description of the 20 examined objects within the habitat slopes. Numbers 1-8 build the “southern main slope”, 14-16 and number 24 build the “northern main slope”. Northern and southern slope are connected by objects 12, 13 and 44 in form of connectivity structures. Other objects 9, 10, 19 and 45 are found in the periphery.

3.2.1 Main slope South

The total length of this slope is about 760m and it is divided in seven object numbers. At all parts except object 6 and 7, an agricultural road runs along the upper edge of this slope- bound.

Object 1

Object Number 1 is located on the very east edge of the study area, it lies protected to the north-west due to its different wall-structures which are orientated from south-east to south-southeast. It´s heterogeneous structure includes woody structures, such as woodpiles and bushes, shrubs and some trees, four stone walls and some stony structures as well. The walls are between 12 and 40m long and form two terrain levels between the lower part, the agricultural road and the upper part in the north-east of object 1. It also includes a concrete retention pond where a woodpile is found surrounded by some small shrubs (*Lycium barbaricum*). In the lower part two big and one small woodpiles are placed in front of the western stonewall, which lead to a very warm and protected microclimate in this part. Total habitat length: 170m.

Object 2

Object 2 joins object 1 at its western edge. It´s eastern part is built from a 25m long dry-stone wall placed at the base of a steep slope which is orientated directly to the south. There are *Lycium barbaricum* hedges in the upper part which is bounded by the agricultural road. The around 8m wide slope is overgrown with some *Clematis vitalba* scrub, grass and another bush (*Sambucus nigra*) in the middle part, where are also found parts of a small dry-stone wall which is overgrown by herbaceous vegetation. Total length: 120m.

Object 3

This object is also located in the linear slope, west from object 2. It mainly consists of an around 9m wide herbaceous overgrown slope-bound which is also orientated to the south and includes five stone-walls with a total length from 72m that build the terrain level to the upper part where the agricultural road runs. The longest wall with 30m is built with bonders, in general there are very few dry-stone walls in object 3. Besides that, there are found two stony structures that come mainly from destroyed wall-parts. Next to the eastern stony structures is found a nut tree, *Juglans regia* and further in the west is a *Euonymus verrucosus* at the lower edge of object 3. Total length: 165m.

Object 4

Object 4 mainly consists of a nearly 80m long stone wall which is partly overgrown by *Clematis vitalba*. It is about 3 m high and orientated to the south side. There is found a stone pile in the western part consisting of big stones, rusty metal bars and some vegetation, next to it a *Prunus domestica* subsp. *syriaca.* The east edge is composed by some trees (*Prunus avium*), a few big stones and a big wood pile. The west edge is a scrubby slope and some flat parts overgrown by *Clematis vitalba.* Total length: 95m.

Object 5

Object 5 is the further extension of object 4 on the west side of it in the southern main slope. Here is found a big stone pile in a ground dip which is overgrown by some herbaceous plants and filled with earth/ sand in some parts. The continuum of this slope is characterized by low undergrowth, herbaceous vegetation and in the western part by a few woody plants (*Sambucus nigra, Prunus dulcis*). Total length: 75m.

Object 6

It is the extension of object 5 to the westside. This slope is composed by *Clematis* scrub, some bushes like *Rosa sp*. in the eastern part and grassy sections in the middle. There is found homogenous scrub vegetation without any further structures in the middle to western part of object 6. To the north side it is connected to object 13. It´s orientation is south-southeast. Total length: 105m.

Object 7

It builds the west end of the southern main slope and contains grassy and shrubby structures as well as some parts overgrown by *Vitis sp*.. Low *Cornus mas* and *Rosa sp.* shrubs are found in the middle of this object that is orientated to south-southwest which leads to relatively long solar insulation in the later parts of the days. It is one of the smallest objects and is connected to object 12 on the eastern edge. Total length: 51m.

3.2.2 Main slope North

The total length of the northern slope is about 600m and it is divided in four object numbers. There are grassy agricultural tracks on the upper and lower edges of the slope.

Object 24

Object 24 is the western edge of the whole study area, it´s a big object that shows overall heterogeneous structures. The eastern part is built from shrubby vegetation and open part, as well as a stone pile which is situated on the west side of an old earth deposit, which leads beside the southern orientation also to habitat parts with eastern and western orientation on both sides of this deposit that is overgrown mainly by grassy and low shrubby vegetation (*Acer campestre, Rosa sp*.). Followed by some parts with trees (mainly *Acer campestre*) and open soil on a short steep part of the slope. Then there are found some different stony and wood structures which are situated on a tree-shaded stone-field ("Steinriegel"). In the western part is found a big cairn-hummok ("Steinriegel") with rubble surface and some trees (*Prunus sp*.). This "Steinriegel" has also eastern, western and southern orientation. Total length: 165m.

Object 14

It joins object 24 in the east side with a woody section that opens to the east side with shrubs (Acer campestre, *Rosa sp*.) and parts of wood piles which are situated in dips. There is some grassy vegetation found as well as *Clematis* scrub in the east part of object 14. In the very eastern part is situated a little stone hut which is not used for are special function, in front of that is found an about 7m long dry-stone-wall. Total length: 96m.

Object 15

Object 15 builds the longest defined object on a more or less equally narrow slope section that is orientated to the south and south south-east side. In parts it´s overgrown with *Lycium barabaricum* on big sections which leads to partially very dense vegetation. There are also some stony, woody and grassy section which provide basking habitats for Green Lizards. One part next to a stone pile has been opened in spring 2017 due to management measures by Heimo Schedl and some students from the BOKU, so that it developed open ground areas with rubbles on the surface. The eastern part is composed by more open areas with grassy structurs and shrubs in the east end. There is also found a stone pile that is partially connected to some low *Prunus spinosa*. These shrubs build a structure to the south which provides baskings places orientated to the west side as well. Total length: 220m.

Object 16

This object builds the eastern edge of the northern slope. It is overgrown with shrubby parts in the west which open up in eastern direction to a Rubus sp. – scrub slope. The following part is overgrown by different low vegetation like *Clematis vitalba*, grassy vegetation and other herbs. Between that are found some old stone wall segments which are destroyed partly and a sandy brake-off-edge that runs parallel along the slope edge for about 13m. The eastern edge is built by a dry-stone wall which is overgrown by *Clematis vitalba* in some areas. Total length: 125m.

3.2.3 Connectivity structures

Object 8

This object also is established as a connectivity structure, which joins object 4 in the east end to the south side. It´s composed by some tree and shrub structures in the north which lead to a narrow vegetation strip which is slightly sloped to the west. It is overgrown by herbaceous plant and *Clematis*-scrub, as well as some little bushy structures in the south (*Rosa sp*.). It is one of the smallest and narrowest objects. Total length: 70m.

Object 10

This object is a fallow land – connectivity structure from north to south in the western part of object 4 to object 11. It is consisting on a mosaic of shrubs (*Cornus sp*.), trees (*Prunus sp, Acer sp*.), *Clematis*-shrubs and herbaceous vegetation on a total area of 1750m2, whereby around 240m2 are represented by bushy structures and around 160m2 are overshadowed by trees. There are found some scattered wood piles in the whole object. In the upper part is a square shaped concrete area, maybe the fundament of an old house which is surrounded by scrub and bushes as well as some woodpile.

Unfortunately, object 10 was totally grubbed up to (re-)establish a vineyard in December 2017. Total length: 140m.

Object 45

This abandoned vineyard joins object 1 in the north and forms object 45. It consists of four vine rows which are not used anymore, that leads to very high herbaceous plants in the vegetation period. The vegetation was only mown once in 2017. So it consists mainly of living herbaceous vegetation, in the middle are found two structures out of bushes, trees and also deadwood parts. Some of the vine rows are partially overgrown with *Hedera helix.* Object 45 builds a north-to-south connectivity structure between object1 and object 19. Total length: 175m.

3.2.4 Objects outside the main slopes

Object 11

Object 11 is on a separate slope in the south of the two main slopes. Its plant cover is characterized by parts of scrub, bushes and a few little trees. There is one part on the west side that leads along an agricultural road rectangular to the slope-part of object 11. This was grubbed up in the beginning of 2017, so it was an earthy slope covered by some herbaceous plants in that year. Total length: 80m.

Object 19

It is located in the north-east edge of the study area and it’s a strung-out, narrow slope. The structures are some woody ones like shrubs, bushes and deadwood piles as well as a stone pile in the east end. The middle part consists from herbaceous vegetation and a 10m long dry-stone wall. Object 19 is orientated to south-east which leads to early solar radiation in the mornings and object 45 connects it to object 1 from north to south. Total length: 110m.

3.3 Habitat structure types

It was distinguished between 12 different structure types within the habitats of *L.viridis* in the survey area. Following table 1 shows the distinguished structures of this survey.

Table 1: Habitat structure types

STRUCTURE TYPE	DESCRIPTION
WALL	Two types: either dry stone wall or built with some binder like cement, between these two is not distinguished in the record data base.
STONE PILE	Often found next to vineyards in some not utilized edge areas. It is built of stones, which were found in the vineyards and had been removed to allow cultivation.
WOOD PILE	Located in the edge areas and created by unused posts, timber, removed vine branches etc.
HEDGE	Wooden vegetation structures along paths or fences are defined as “hedge”, characterized through a dense, wooden vegetation and linear appearance.
HERBACEOUS VEGETATION	Grass or herbs
WOODY VEGETATION	Tree, bush
CAIRN SLOPE	„Steinriegel“, characteristic structure, built by removed gravel bricks, which formed big accumulation over time
CEMENT STRUCTURE	Fence posts or retention pond
SLOPE	“slope” is defined as a slope, which is overgrown by herbaceous plants without any further structures like bushes, stones, wooden piles etc.
CUT-REMAINS	Plant material, cut vegetation
BREAK-OFF-EGDE	Sandy slope, which broke off partly and formed steep sandy habitats
CLEMATIS THICKET	Dense *Clematis vitalba* carpet, which suppresses upcoming of other species

3.3.1 Substrate

This parameter describes the substrate, where the Green Lizard was observed on. It was distinguished between 7 types of substrates in this survey. Table 2 shows the detailed description.

Table 2: Substrates used by Green Lizards

SUBSTRATE	DESCRIPTION
SOIL	Bare soil, heats up quickly in the morning
STONE	Relatively high thermal conductivity (KRISCHAN, 2018), good heat store capacity (not for basking in the morning, after sunset used)
WOOD	High specific heat capacity and low thermal conductivity (used in the morning and during sunshine for basking)
GREEN VEGETATION	Living, green vegetation, shrubs
DRY VEGETATION	Dead plant material, e.g. grass
SAND	Sandy surface
DRY LEAVES	Often found next to bushy vegetation or trees

3.3.2 Secondary structures

This parameter was listed if the recorded Lizard was detected on a habitat structure which was embedded in a bigger one, which also seems to have a significant influence on appearance of *L.viridis* in the survey area. E.g. a Lizard was found on a stone pile which is located directly (± 1m) in front of a stone wall, the stone wall would be recorded as “secondary structure”. Commonly used structures in this case were slope, wall and woody vegetation, for all options see 4.3.1.

3.4 Field Work

The surveys were done on 82 days between March 4th and October 13th in 2017. The used method of individual recognition of *L. viridis* was the photographic identification by head scale pattern, ornamentation and shape on lateral head sides (e.g. ELBING, 2001, KLEPSCH, 1999, SACCHI et al., 2010, SCHEDL, 2001). For that reason, we used a Sony DSC-HX 400v Bridge-camera with 50x optical and 100x digital zoom, which showed best results in a distance of approximately 3m from the target object. That seemed to be an appropriate distance to cause no disturbance to the photographed Green Lizards unnecessarily, which was also included in the intention for non-invasive survey methods.

3.4.1 Data collection

As mentioned, most of the objects were surveyed on linear paths from the outside. First, for reasons of avoiding invasive methods, which could change the behavior of *L. viridis* in bigger flight distances due to high survey frequencies and second, for reasons of impossible walkability of the steep slopes (it would lead to destruction of the habitats and their structures in many cases). The existing tracks were used as survey paths to detect Green Lizards in the slopes and take photographs. This was done by photographing each head side and if possible, the habitus of the animal to detect indications of animal-age (coloration, habitus), eventual injuries (like autotomy of tail) or scars etc. The used paths were walked slowly and carefully to detect Lizards before their individual flight distance was reached. For each individual were also recorded exact place and time, sex, approximate age, sun intensity and sun exposition, cover ratio, behavior (like "basking" etc.), substrate, habitat type as well as secondary structure. The age classes are seen in table 3:

Table 3: Designations of age classes

Designation	**Estimated age**
S	Subadult, 1 year
2	Adult, 2 years
2-3	Adult, 2-3 years old
3	Adult, 3 years or older

If the animal escapes before it was possible to take a picture, all other parameters were still collected. In case the Green Lizard escaped unseen, we recorded A for adult or S or subadult (according to the flight noise) with still listing the remaining parameters. The surveys were done between sunrise and about an hour after sunset two to eleven hours a day. For surveying the whole study area around two to three hours of slow walking and photographing were needed. On most days in spring the habitats were inspected more than once a day in different orders. To avoid walking the surveyed habitats in same temporal sequence always, we started the research days in different objects to keep the movement pattern through the whole area differently. For an overview of the commonly used paths in the survey area see figure 17, the mostly used routes (<10 up to 60 times surveyed) are illustrated in yellow and for the sake of completeness less than ten times used paths in purple.

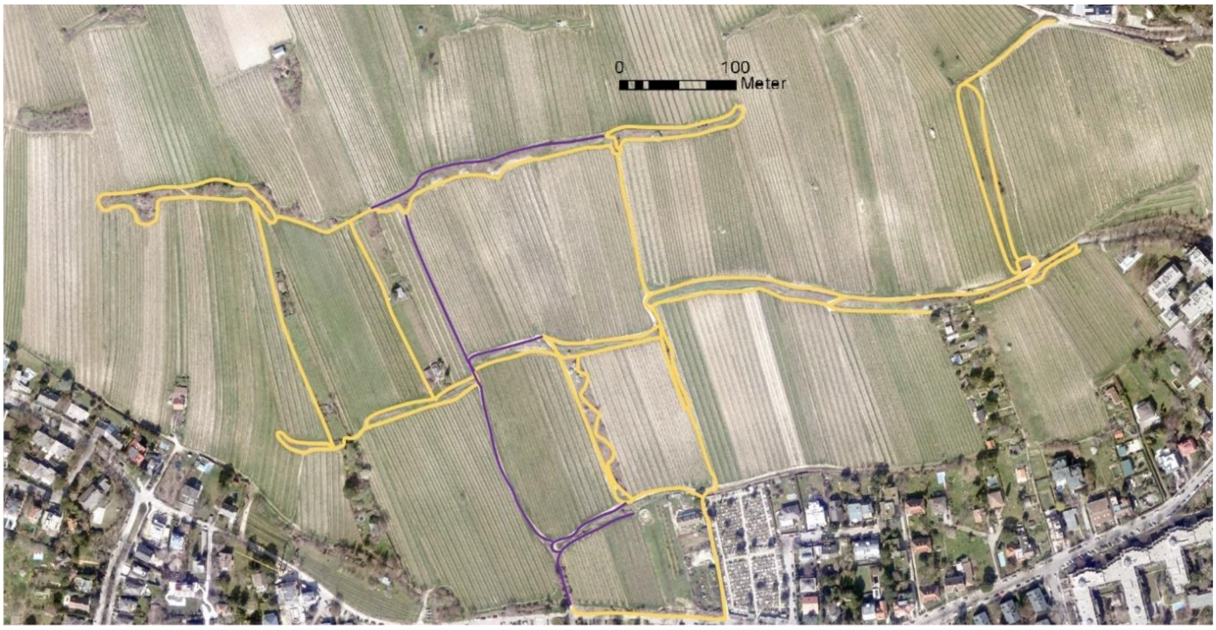

Figure 17: Common routes (yellow), routes walked less than 10 times (purple)
(STADT WIEN 2017, own editing)

3.4.2 Noosing of individuals

In addition to data collection by photo documentation, some of the Lizards were captured by noosing for further research of Heimo Schedl. Animals were caught while basking or resting using a transparent nylon noose on a wooden rod. They were captured carefully and kept for max. 20 min to do the probings, which included taking a genetic sample by buccal swap, weighing and measuring, as well as taking habit and head pictures. To measure the lizards, a transparent plastic ruler was used for determining snout-vent-length, head- and tail length. If a regenerated tail was detected, the original and regenerated parts were measured and recorded separately. For weighing, the lizards were put in a white paper bag which was attached on a spring balance with 1g accuracy. Furthermore, the general condition of the individual, moulting status, lost toes or ticks were checked and noted. To mark a captured animal, we put red nail polish dots on the back, vent or neck. This was done in different patterns to distinguish the animals by those marks until its next moult, which was expected max. four weeks after noosing. The animals were released at the exact same place where they had been caught. For each caught animal, a new noose was tied, unused medical gloves were worn and new paper bags for weighing were used to minimize any risks of disease transmission.

3.4.3 Survey Frequencies

Due to order and location within the study area it wasn´t able to survey all objects in the same frequency. If an object was surveyed less than 10 times, the data were not included to any calculations.

3.5 Data Analysis

3.5.1 Photo processing

The raw material (figure 18) was reviewed and the best photos of each animal record were processed further. A picture was added to the database after cutting and rotating it to display only the horizontally shown head side on the final picture (figure 19). If both head sides were photographed, both sides were put in the database after cutting and rotating the appropriate picture section.

Simultaneously the taken photographs of the surveyed specimens were labelled following a precise scheme, which allowed to identify selected details about the displayed animal. Subsequently shown an example of an adult male, which was found in object 9 as the first male (M1) of that specific day, the shot head side ("re" for right), the estimated age (three years in this case) and the date as well as the original photo number given of the camera:
9_M1re_3_01-04-2017_DSC04799 .

Figure 18: Original photo of adult male

Figure 19: Edited photo in database: cut, rotated for optimal image detail

3.5.2 Database

The database was established in Microsoft Excel, all mentioned parameters were imported to that file in chronological order. Each record of an animal is one data set. The photo code was integrated in the Excel database as well to connect the photos virtually to the related data set.
The data base was created in chronological order of inspection of the objects. In this way, zero reports of Lizards in objects were integrated in the database as well to get an overview of the chosen survey routes in the area.

3.5.3 Individual identification

As proven in previous studies by different authors (ELBING & RYKENA, 1996, ELBING, 2000a, KLEPSCH, 1999, PERKINS & AVERY, 1990, STEINICKE et al., 2000, SCHEDL 2001, SACCHI et al., 2010) it is possible to distinguish Lizards individually by the scale pattern on their head as well as on their throat. There are given two indications for individual identification, first, the actual shape of the scales and second, the color pattern within these scales (figure 20). In particular, the shape of scales, respectively the connection points among scales and the number is individual like a fingerprint for each specimen of *L. viridis* (SACCHI et al., 2010). In juveniles or subadults it is not possible to use the color pattern within the scales for recognition due to changing colors on the whole animal until it reaches about two years age. For that reason, on young Green Lizards only the scale shape is used for recognition. Due to a high amount of non-assessable subadult photos (due to limitations in camera resolution), it was not possible to evaluate all subadult sightings and assign them individually in this study. Ambiguity of individual identification is much higher for subadults, therefore this age class is not included in the results.

Figure 20: Pholidosis: Temporalia (purple), Supratemporalia (black), Labialia (orange), Subocular (yellow), Supranasalia (red), Nasalia (blue), shown on young female

The following data base photo represents an example of individual identification and recognition on a two to three-year old young adult male. It was spotted from March to September 2017 within objects 4, 5 and 8, the photos below show examples from the pool of records. It shows a kidney-shaped light pattern on his right head side which has a high recognition factor. It was captured for the genetic studies in May 2017 as catch number 58, figure 21 shows both head sides during the handling while caught. In each individual, well shot photos from both head sides were used to identify both head sides in one joined picture doubtless.

Figure 21:8MB-4MA-5MB, a young adult male (2-3 years): data base photos taken during capture show left and right head side showing the scale pattern, coloration and shape

The following picture shows exemplary records from March to June. In March and beginning of April it was found in non-nuptial coloration and in May and beginning of June it shows typical blue mating season coloration on throat and head sides (figure 22). The photos were taken without disturbing its natural behaviour.

Figure 22: Examples of records of male 8MB-4MA-5MB: each vertical picture pair shows one record of this individual - two records in early spring and non-nuptial coloration, and two records in nuptial colors in May and June

3.5.4 Individual designation

The photos of identified animals were collected in folders and every individual was designated by a scheme that included a letter and the objects where the animal were recorded. In every object, the first male or female was MA or WA (W for *Weibchen*, female), this was proceeded in alphabetical order for all individuals within one object, following an example from object 1: 1MA, 1MB, 1MC etc. This procedure was applied within all single objects and after all single objects were finished, then animals were compared stepwise between objects. As shown in figure 23 we started a pairwise comparison between objects 1 and 2, where animals, which were found in both objects, get one designation which included both object names e.g. male C from object 1 which was the same as male A from object 2 got a new designation: 1MC-2MA. This way, we went further stepwise including more and more objects. The final name included all found objects, beginning with the one, where the individual was recorded the first time.

To avoid too complex comparison amounts, the whole study area was clustered in several parts, which included four to six different objects each.

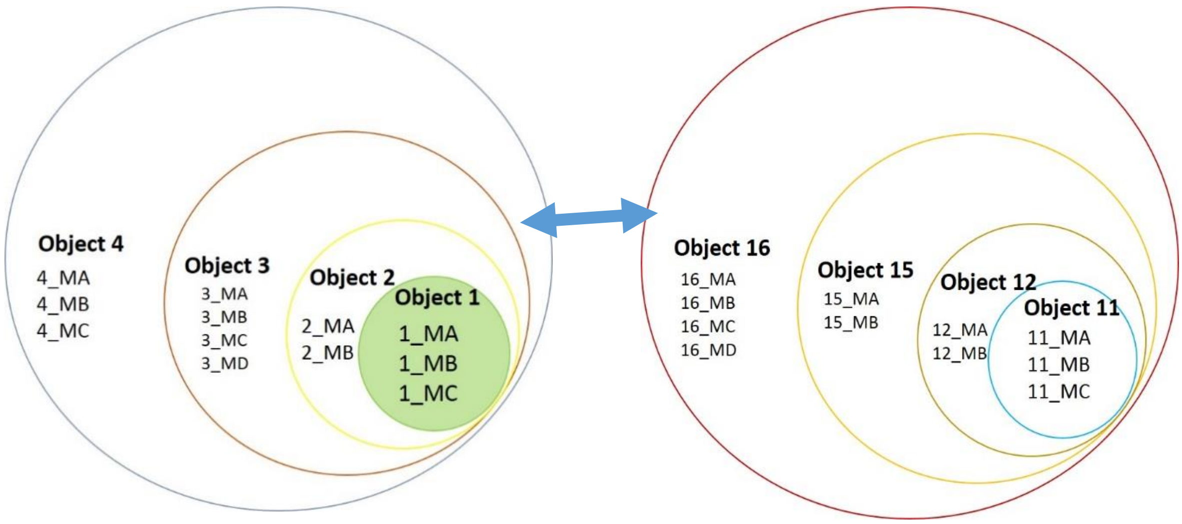

Figure 23: Stepwise comparison scheme: starting in one object and including more objects stepwise. Designations of repeated found animals were amalgamated

So finally, this stepwise comparison led to an inclusion of all objects in the study site and an overview of the population size, which could be used for further calculations of population parameters.

3.5.5 Geo information system (GIS)

The location of all recorded Green Lizards was transferred in ArcGIS 10.4.1 (ESRI, 2017) for visualization and measurement of relevant parameters. This was done manually with exactly documented record locations to keep highest possible precision (figure 24). The data points were connected via *Join-and-relate*-tool to the Excel database to get all relevant information including individual name, sex, date of record, used structure etc. for each single *L. viridis* record in the GIS-map. In that way, it was possible to show e.g. all data points for one specific individual to retrace its movement during time in the area in ArcGIS. For each individual Green Lizard was measured the exact covered distance in linear parallel projected movement due to linear arranged habitats with ArcGIS. The record points of each individual were connected step by step, always using the record point in minimum distance as next one. In this way, it was possible to represent the covered distances per individual finally (figure 25).

Figure 24: Record points of L. viridis in ArcGIS, adults: males(blue) and females(red) in object 4

Figure 25: Calculated covered distances of males, each line represents an individuals´ movement, projected parallel for better visibility, same map detail as figure 25.

3.5.6 Statistical analysis

For gaining statistical results in this population investigation, the statistic software R (R CORE DEVELOPMENT TEAM, 2016) for Windows® was used with the package R commander (FOX, J. & BOUCHET-VALAT, M., 2017). For finding differences in males and females covered distances was first generated a boxplot and then the distance values of both sexes were put in a Wilcoxon rank sum test due to non-normal distributed values in this measurement. These two operations were done first with all collected distance-data and second, with data cleared from outliers, to test, if the results are influenced by extreme values.

To determine if other animals in one males´ home range influence its covered distances (and therefore movement pattern), a statistical test was applied for every male´s covered distance to detect any correlations between other individuals´ presence in *home range* (radius of 50m, see below) and *total activity range* and individual covered distance. To test the parameters, which may influence the males covered distances, a General linear model (GLM) was applied. As parameter and dependent variable for movement was used the individual covered movement distance for each male. The input-parameters were age class (3 classes), number of other males and females in radius of 50m at the point of first record ("home range/ origin") and number of males and females in the whole activity range. The scheme is illustrated in figure 26. In this scheme, the radius of 50m is shown for "male 1" at its point of first record, colored dots represent four other individuals in this range. The entire covered distance (activity range) is represented by the red line which includes record points of six other individuals as well.

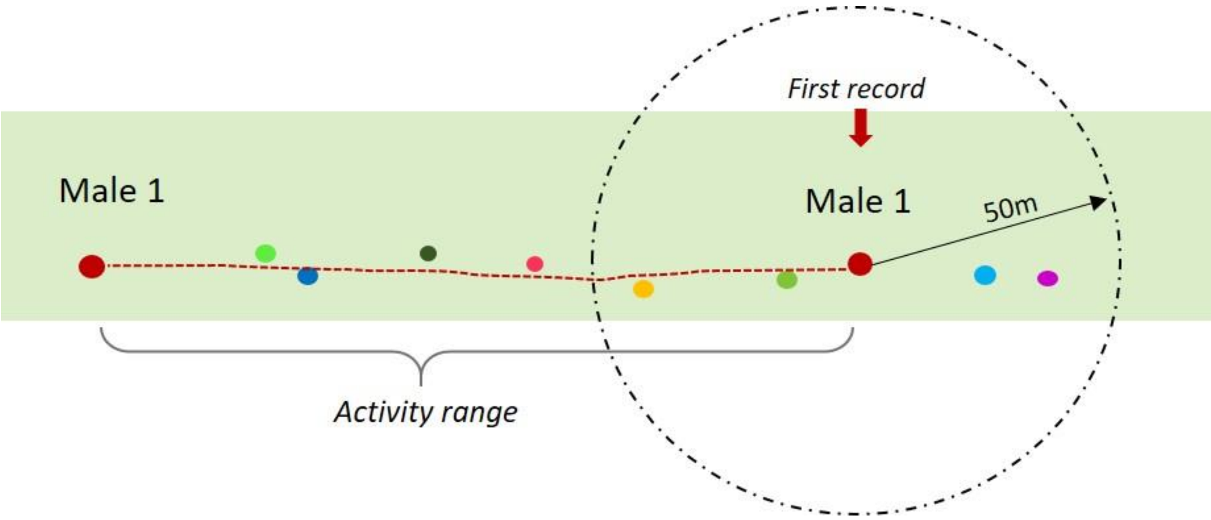

Figure 26: Scheme for GLM input: right position of male 1 represents the point of first record, red line the covered distance = activity range. Dots represent other individuals, which stay inside male 1´s activity range

To preclude correlations within the GLM, a Pearson product-moment correlation-test was applied and subsequently, the GLM was generated again without the correlating parameters. Finally, the best GLM model was selected by the basis of the AIC values.

An additional GLM was applied with data of captured males to include more potential influences in the model. The same GLM as shown above was calculated with the additional parameters Snout-vent-length (SVL) and number of sightings of the captured animals. Possibly an older and therefore bigger male tends to stay in one territory without moving a lot and smaller males are pushed around as “floaters” between older males´ territories, which lead to larger covered distances in younger age classes.

Furthermore, another model was calculated, which included only the parameters SVL and sighting number to describe their correlation with the males´ covered distances.

4 Results

4.1 Recorded animals and population size

Overall 1107 observations of *L. viridis* in the investigation period lead to the following estimated population structure: 77 adult males and 57 adult females which represent the minimum adult population of the survey area. Table 4 presents the total numbers of records in age classes.

*Table **4**: Total numbers of records in all L. virdis sightings*

Age class	**N of records**
Adults	630
Subadults	415
Juveniles	49
[Rest: dead, re-sighting within one day]	13
Total	**1107**

In total, 630 adult Green Lizards were recorded, including males, females and sightings, which could not be assigned sexually because the animals vanished without being reliably identified. 415 subadults were recorded by sighting or photographing, whereby no photographic identification was applied in this study due to different factors as explained in chapter 4.5.3. From the first hatch in the end of August on 51 Juveniles were recorded (table 5).

Table 5: Records, photos and assigned animals in all records

Class	**Records**	**Photos**	**Assigned Photos**	**Individuals**	**Ø Sightings/ Individual**
Adult ♂♂	376	335	322	77	4,9
Adult ♀♀	164	137	132	57	2,9
S	415	163	/	/	/
J	51	22	/	/	/
A	93	/	/	/	/

376 male sightings were recorded within 335 were photographed of which 322 could be individually assigned. The ones, which were not individually registered were either not photographed due to flight or pictured in too bad quality to recognize them. Those results lead to 77 male adult individuals, which represent the minimum abundance of male adults in the survey area. Individual assigned adult males made up 28% of all sightings and 85,6% of all male sightings. The mean number of sightings of an individual male was 4,9.

164 female sightings of which 137 could be photographed were recorded in the surveys. 132 of them were individually assigned, out of those 57 female adults were emerged. This number can also be seen as the minimum abundance of female adults of *L. viridis* on the Nußberg. Those individual assigned females made up about 12% of all sightings and 79,0% of all female records. The mean number of sightings in female individuals was 3,1.

In total 82,3% of all sighted males and females were identified and assigned individually. 98% of photographed adults could be assigned individually. For a detailed list of registered photographic animals see appendix II.

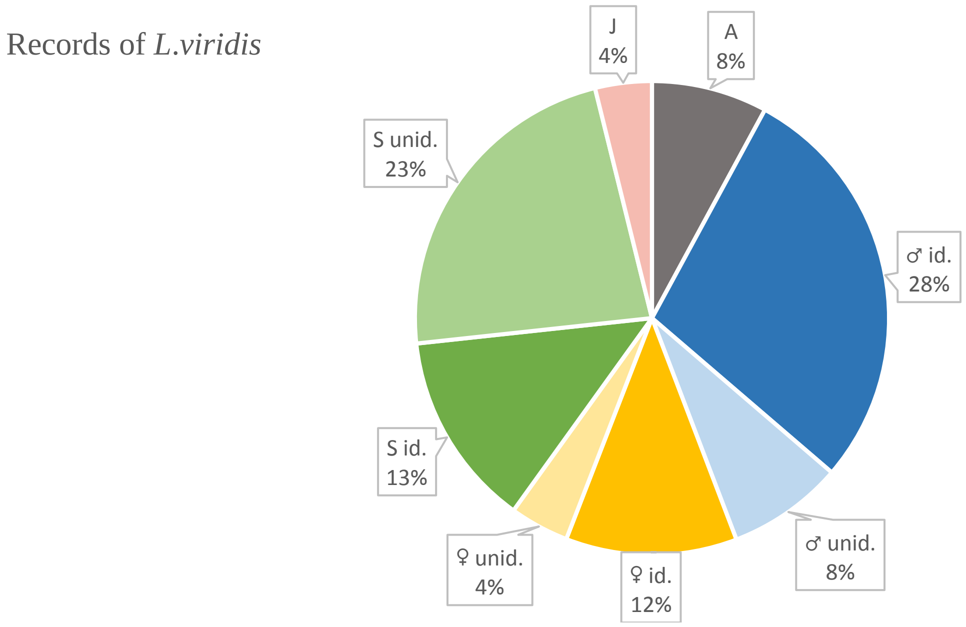

Figure 27: Recorded L.viridis: ratios of identified (id.) and unidentified (unid.) individuals. Adult males and females, J: Juveniles, S: Subadults, A: unidentified adults

In figure 27 are shown the ratios of identified and unidentified recorded Green Lizards per sex and age category. Identified adult males and females ("♂ id., ♀ id.") show the ratios of photographed lizard sightings which were assignable to an individual, unidentified animals are not photographed or photographed in bad quality with no possibility of assignment. Adult ("A") shows the percentage of recorded adult *L. viridis*, which could not be assigned to any sex due to flight or bad visibility. The degree of photographed subadults is lower, more than one third of subadult records were photographed.

The remaining sightings which are not included in the numbers above contain repeated sightings of the same animal within one day, dead found ones (two records) and animals which could not be assigned to an age class in autumn (five records).

4.1.1 Survey frequencies

Below is found a graph which shows the survey frequencies in % of all 82 survey days 2017. Object 11 was surveyed less than 10 times, due to that it was not included in any calculations (figure 18).

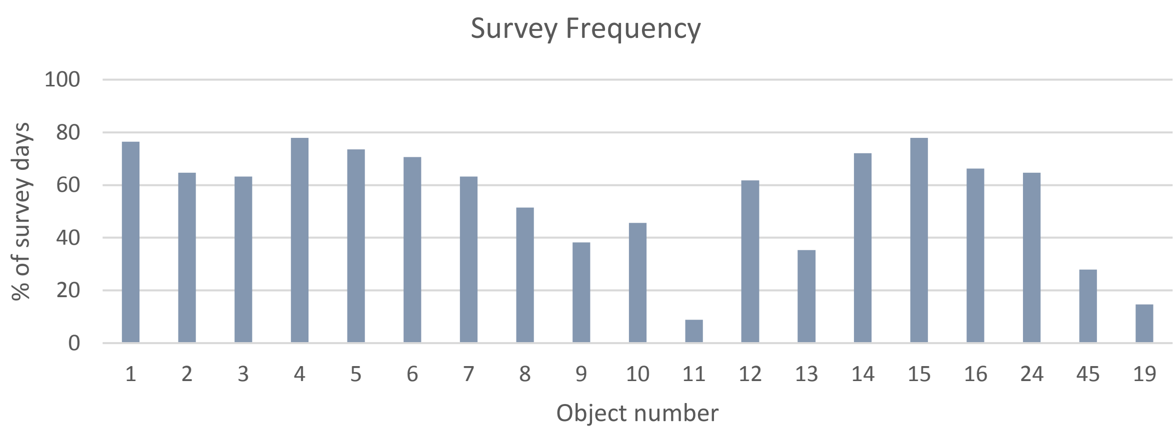

Figure 28: Survey frequency in objects

4.1.2 Recorded data points

The following maps show the entire data points of recorded Green Lizards, divided in adult records of males and females (figure 29) and subadult/ juvenile records (figure 30). The distribution within the habitats occur in inhomogeneous patterns, which will be presented in chapter 5.2.2. Furthermore, it is apparent that males and females do not distribute in the same pattern, in some sections nearly no females were recorded, while in other parts of the slopes appeared cumulative sightings of females.

Data points of recorded subadults are spread more scattered in every object than the adults´ ones, but show in general a comparable distribution pattern within the entire area. Juvenile sightings occur interspersed in the examined population at some local points.

Figure 29: Entire record point of males (blue) and females (yellow)

Figure 30: Entire record points of subadults (turquoise) and juveniles (pink)

4.2 Population structure

4.2.1 Sex and age ratio

The recorded animals show a sex ratio of 1 : 0.74 (m:f) in individual recorded 77 males and 57 females.

Figure 31 shows the distribution of age and sex range categories in the survey objects in all sightings (entire sighting numbers). It shows differences between the objects in abundance and in distribution of males and females. Generally, more male than female sightings were recorded in nearly all objects. Furthermore, subadult animals were found in every object, in connectivity structure object 44 were recorded only subadult sightings (4 records) and one juvenile.

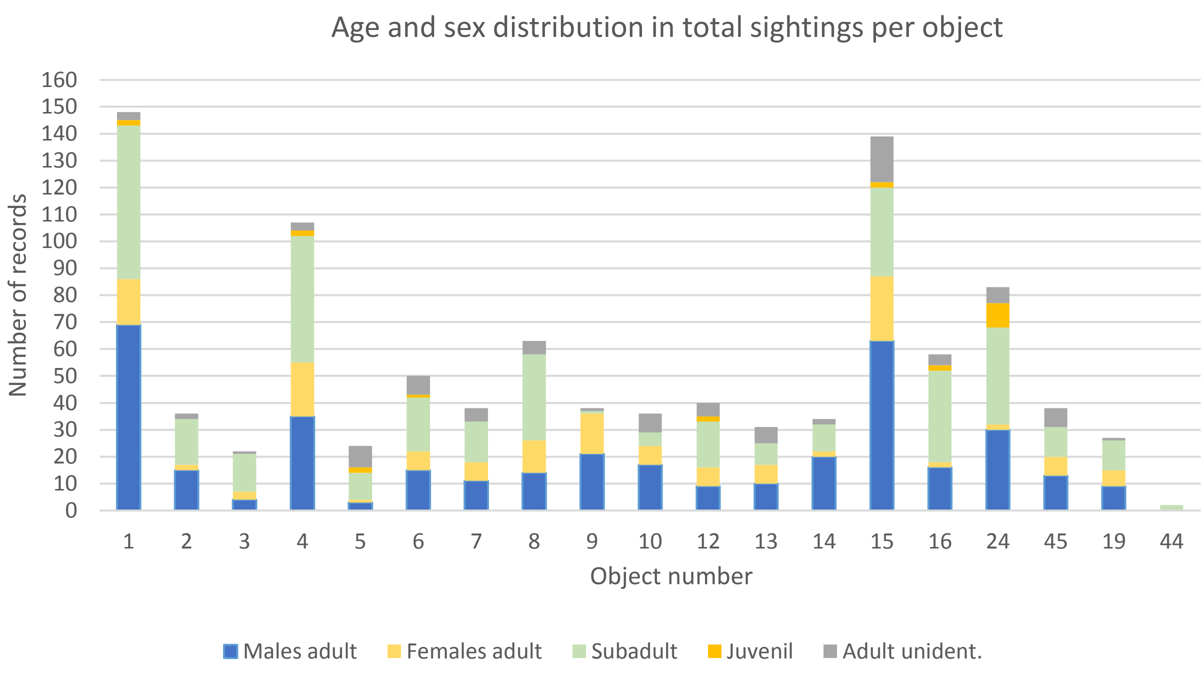

Figure 31: Age and sex ratio in all sightings

Values in figure 31 show a relation of 1,5:1 of adult to subadult sightings in all records of *L. viridis*. Due to big data amount and a high amount of non-assessable subadult photos (due to limitations in camera resolution), it was not possible to evaluate subadult sightings and assign them individually.

Most animals were recorded in object 1 (nearly 150 records). Followed by object 15, where about 139 Green Lizards were recorded during the entire study period. Subadult *L. viridis* were found in all objects and show a relative high abundance in total records of this study. The ratios of seen subadults follow the sighting numbers of adults in the objects. See chapter 5.4 for the phenological appearance of the age classes.

4.2.2 Distribution

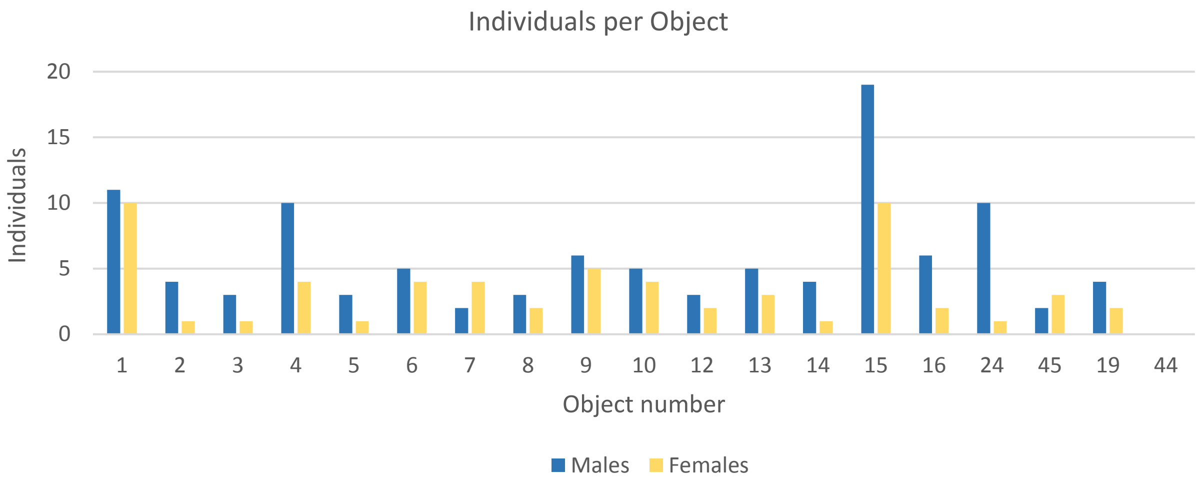

Figure 32: Sex ratio and distribution of adult L. viridis in objects

Figure 32 shows the distribution of adult male and female individuals in the objects. Here is shown that the sightings numbers of Lizards (figure 31) correlate with the actual abundance of animals in most sections. The highest numbers of individuals occurred in objects 15, 1, 4 and 24. The sex ratios differed a lot between the area parts. In this diagram, animals which were recorded in more than one object are included in every single object where they were seen, so in those numbers occur double and triple records of individuals.

Figure 33: Distribution and sex ratio illustrated in area map (KRENN, 2018)

The map (figure 33) shows the spatial distribution of adult males and females within the survey area. The lizards occur in clusters and not evenly distributed within the habitats.

Object 1 in the very East as well as object 15 at the upper part of the slope are densely populated, whereby the latter shows a big imbalance in sex ratio m:f (1:0,53). Edge regions in the North-East (object 19) as well as object 7 in the South-West show smaller abundance in individuals as well as some objects in the mid region of the area like objects 2, 3 or 5. The connectivity structures 8, 10, 12, 13 and 45 show presence of adult males and females in all cases.

4.2.3 Density

The estimated population density for the entire survey area of 2360m habitat length is 5,25 adults/ 100m, whereby some sparsely populated slope sections occur within the area as well as densely populated areas. Subadults and Juveniles are not included in those numbers, for approximate relations between adult, subadult and juvenile sightings see chapter 5.2.1.

The following table 6 displays detailed densities within the objects.

Table 6: Detailed adult densities in all survey objects

Object-number	**Object length**	**Number of ♂♂**	**♂♂/100m**	**Number of ♀♀**	**♀♀/100m**	**♂♂ and ♀♀/ 100m**
1	170m	11	6,5	10	5,9	**12,4**
2	120m	4	3,3	1	0,8	**4,1**
3	165m	3	1,8	1	0,6	**2,4**
4	95m	10	10,5	4	4,2	**14,7**
5	75m	3	4	1	1,3	**5,3**
6	105m	5	4,8	4	3,8	**8,6**
7	51m	2	3,9	4	7,8	**11,7**
8	70m	3	4,3	2	2,9	**6,2**
9	245m	6	2,4	5	2,0	**4,4**
10	140m	5	3,6	4	2,9	**6,5**
12	175m	3	1,7	2	1,1	**2,8**
13	225m	5	2,2	3	1,3	**4,5**
14	96m	4	4,2	1	1,0	**5,2**
15	220m	19	8,6	10	4,6	**13,2**
16	125m	6	4,8	2	1,6	**6,4**
19	110m	4	3,6	2	1,8	**5,4**
24	165m	10	6,1	1	0,6	**6,7**
45	175m	2	1,1	3	1,7	**8,8**

4.2.3.1 Statistically processed densities

Specific densities of other males and females for further statistical analysis were collected like demonstrated in chapter 4.5.6. Those values refer to individual males and their covered distances:

1. <u>Animals per radius of 50m at point of first record</u>

One density value was evaluated for other males and females in a 50m radius at the point of first record (“origin”) of each individual male (figure 34).

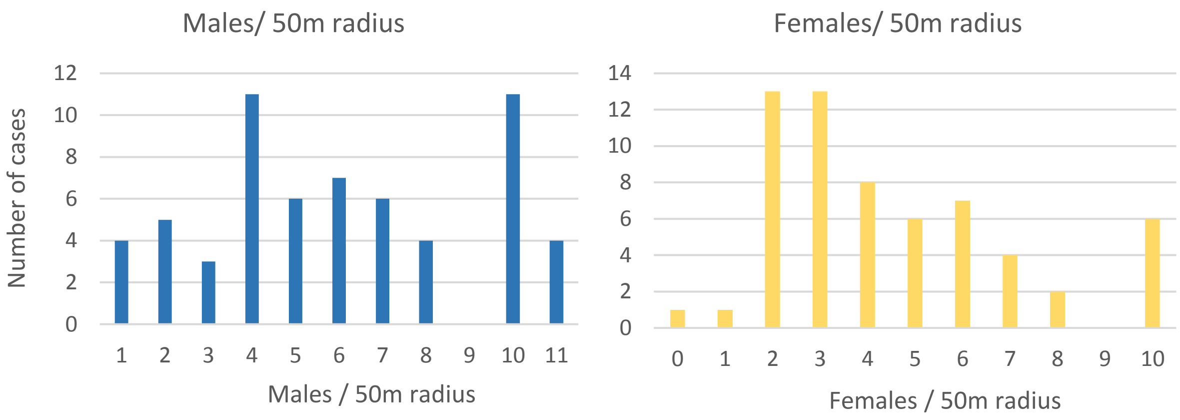

Figure 34: Male and female densities/ 50m radius at males´ origins

The mean number in males is 6,02 animals / 50m radius and the mean for females 4,50 animals/ 50m radius in one individual males´ origin. The maximum male density is 11 males/ 50m radius in 4 cases, the maximum of females was 10 females/ 50m radius in 6 cases of observed males´ origins.

2. <u>Animals per activity ranges</u>

The second value, which was determined for statistical analysis, are the numbers of other individuals within one males´ entire activity range, like shown in chapter 4.5.6. Following tables illustrate the results. In mean, one male found 4,87 other males and 2,75 females in its entire activity range in the whole activity period. Peaks are found in 4 and 5 other male individuals and in 2 and 3 female animals per activity range.

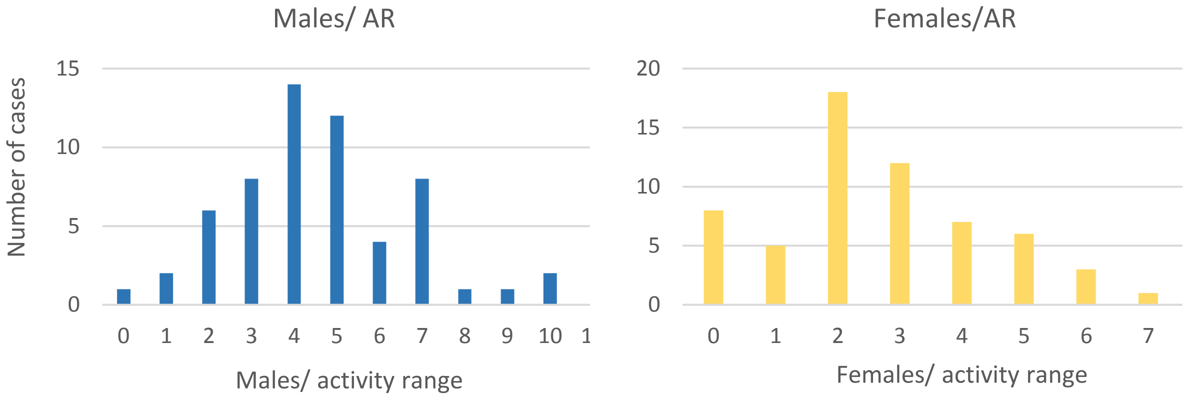

Figure 35: Male and female numbers per activity ranges of males

4.2.4 Influence of insulation

In figure 36 is shown that *L. viridis* prefers south-eastern to south-western exposition within areas of high solar insulation (red parts). High values and high animal sighting numbers are found along steep sections like slopes and stone walls in the area. The blue parts quite behind the inhabited structures represent the flattened slope-parallel parts in the lower sections of neighbouring vineyards. Nearly no Green Lizards were recorded outside areas with highest insulation values along the main slopes. In connectivity structures are found lower maxima of insulation.

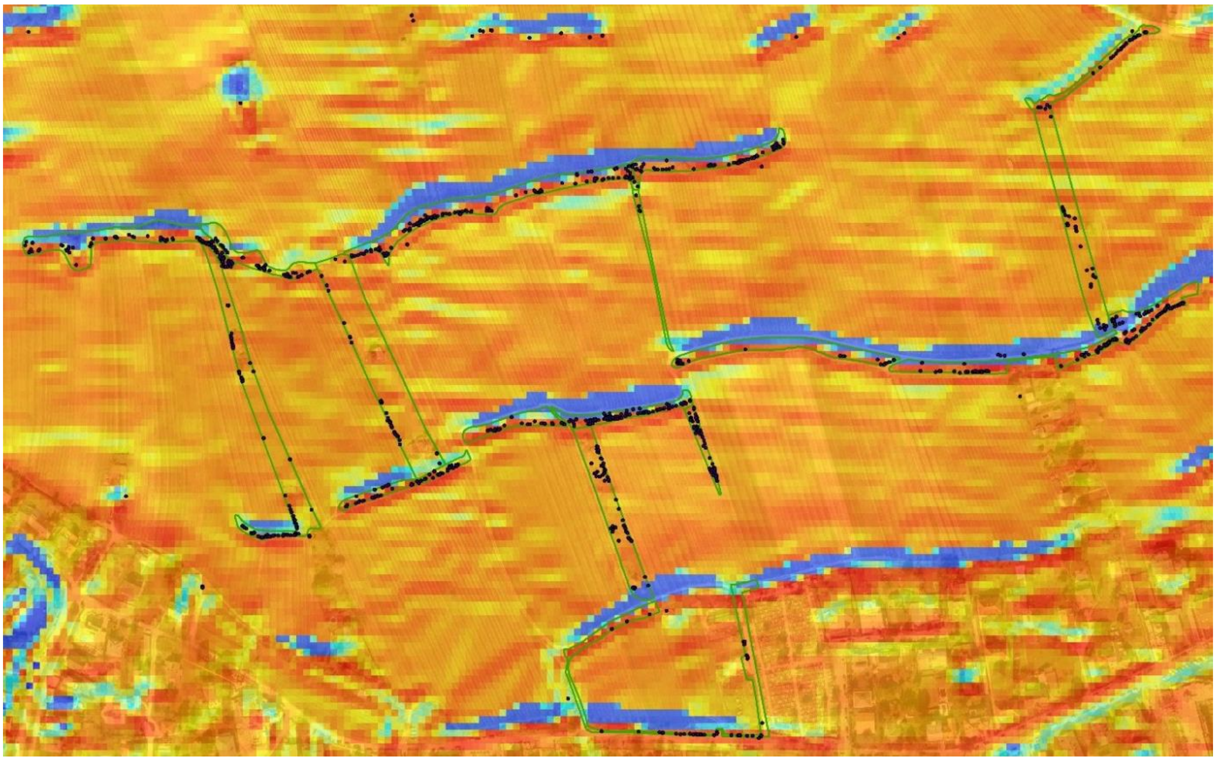

Figure 36: All record points of L. viridis shown in solar insulation map of the area (blue: low insulation, red: high, green: object shapes)

4.3 Movements

Covered distances vary between individuals as well as sexes of *L. viridis*. This chapter presents the results of recorded movements and covered distances of the species in the study area. For detailed covered distances of all individual males and females see appendix III. For these results only animals, which were recorded more than once could be included in calculations.

4.3.1 Sex specific movements

Movements were traced from 61 adult males (that were photographed more than once). 21 recorded males used more than one object as habitat. The mean covered distance was 59,1 m. 86,6% of those males moved less than 99,9 m. 13,3% moved between 100 and 255,1m.
The maximum distance was covered by a two-year-old male, which used 4 objects and covered a distance of 255,1m (table 5).

Females covered smaller distances, which is also shown in the box plot figure 37. Distances could be traced from 29 adult female lizards which covered a mean distance of 22,0 m. Most of them stayed within one object and 3 were found in two. The maximum recorded distance covered by a surveyed female was 64, 5 m within two objects.

Table 7: Covered distances in males and females

Distances	**♀ (n= 29)**	**♂ (n= 61)**
Mean	22,0 m	59,1 m
Min.	0,3 m	1,3 m
Max.	64,5 m	255,1 m

In total, the recorded males covered bigger distances than the females as shown in the boxplot figure 37. The result was tested statistically with a Wilcoxon rank sum test due to non-normal distributed distances. It shows significant differences between males and females.

Wilcoxon rank sum test: p-value = 0.0002472

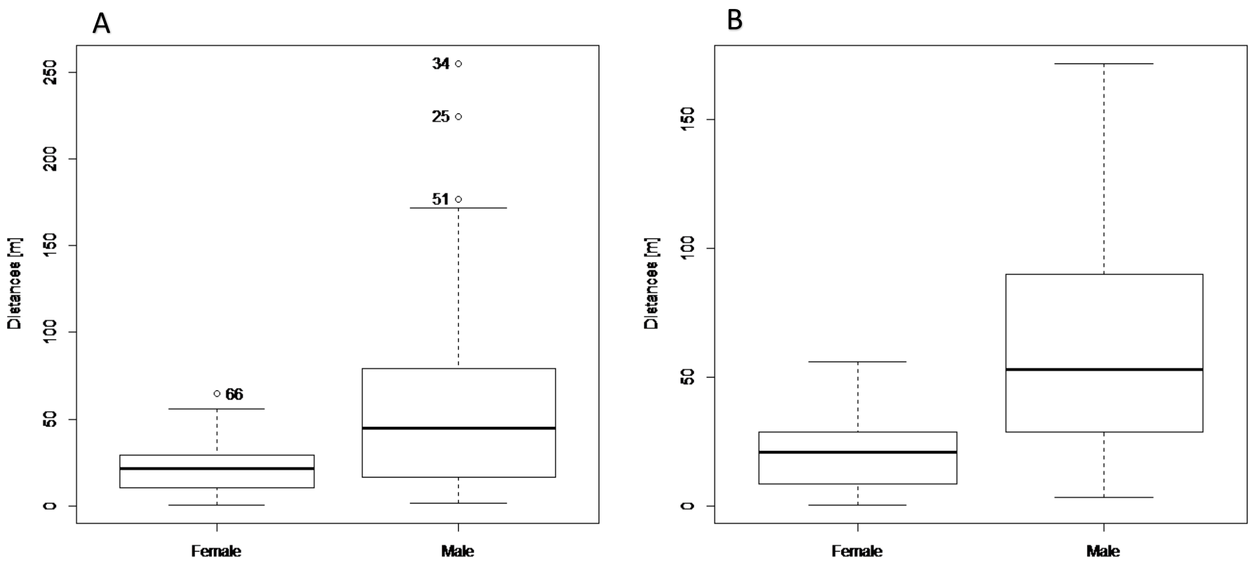

Figure 37: Boxplots of covered distances in both sexes: A)including all distances (males n=61, females n=29) B) distances excluding outliers (males n=58, females n=28)

To assure to avoid wrong results caused by outliers, the boxplot was also generated without outliers for both sexes (figure 37B). It shows the same results within even higher significance in differences shown in the Wilcoxon rank sum test below.

Wilcoxon rank sum test: p-value = 7.072e-06

4.3.2 Movement within objects

Figure 38 shows an example of males´ covered distances in object 15. Some individuals are found only in a small area, some others covered large distances all along the slope. In the picture also structures such as stone piles, bushes and woody structures are mapped. It is obvious, that the males conglomerate around areas with heterogeneous structure mosaic. That is the case in the western part of object 15, where a partly overgrown stone pile is found next to some woody structures, bushes and wood piles. Here are found overlapping activity ranges of up to five males at one point. In the eastern border Object 15/ object 16, where stones, bushes and grassy vegetation builds a habitat mosaic for lizards the overlapping activity ranges of six males are found.

Figure 38: Males´ movements object 15, each colored line represents the covered distance of one male

Another example of movements within one object and a conglomeration around heterogeneous structures is shown in object 4 (figure 39). Activity ranges cluster around some stone and wood piles in front of a stone wall with southern orientation. Here are found the overlapping activity ranges from up to eight males at one location, the lines represent the projected individuals´ covered distances (for better visibility and clarity spread parallel). Furthermore, the females´ record points are mapped as well to show their presence in this part of object 4, here were recorded three females in the entire study period. 4WA (yellow) was recorded 11 times, always staying on an overgrown stone pile or close to it in this area. 4WB (orange) moved along the basis of the stone wall about 25m and 4WC (green) was recorded only once. Some males were found staying only around the cluster like males 4MB, 4MC, 4MD, 4MJ. Others covered larger distances and used bigger habitat parts of object 4. Male 8MB-4MA-5MB was found in two neighboring objects to object 4 (objects 5 and 8), it covered about 170m. It was found in March and September in front of the stone wall in object 4, in April and May in object 8 and in June in object 5.

Two males were also recorded in object 10, which builds a connectivity structure to south: 4MG-10MC, which was found in object 4 March and April and in object 10 paired with a female in May and 10MD-4ME-5MC-8MC, a two-year-old male, which was found in four objects from March to June, while it covered an area from about 225m length.

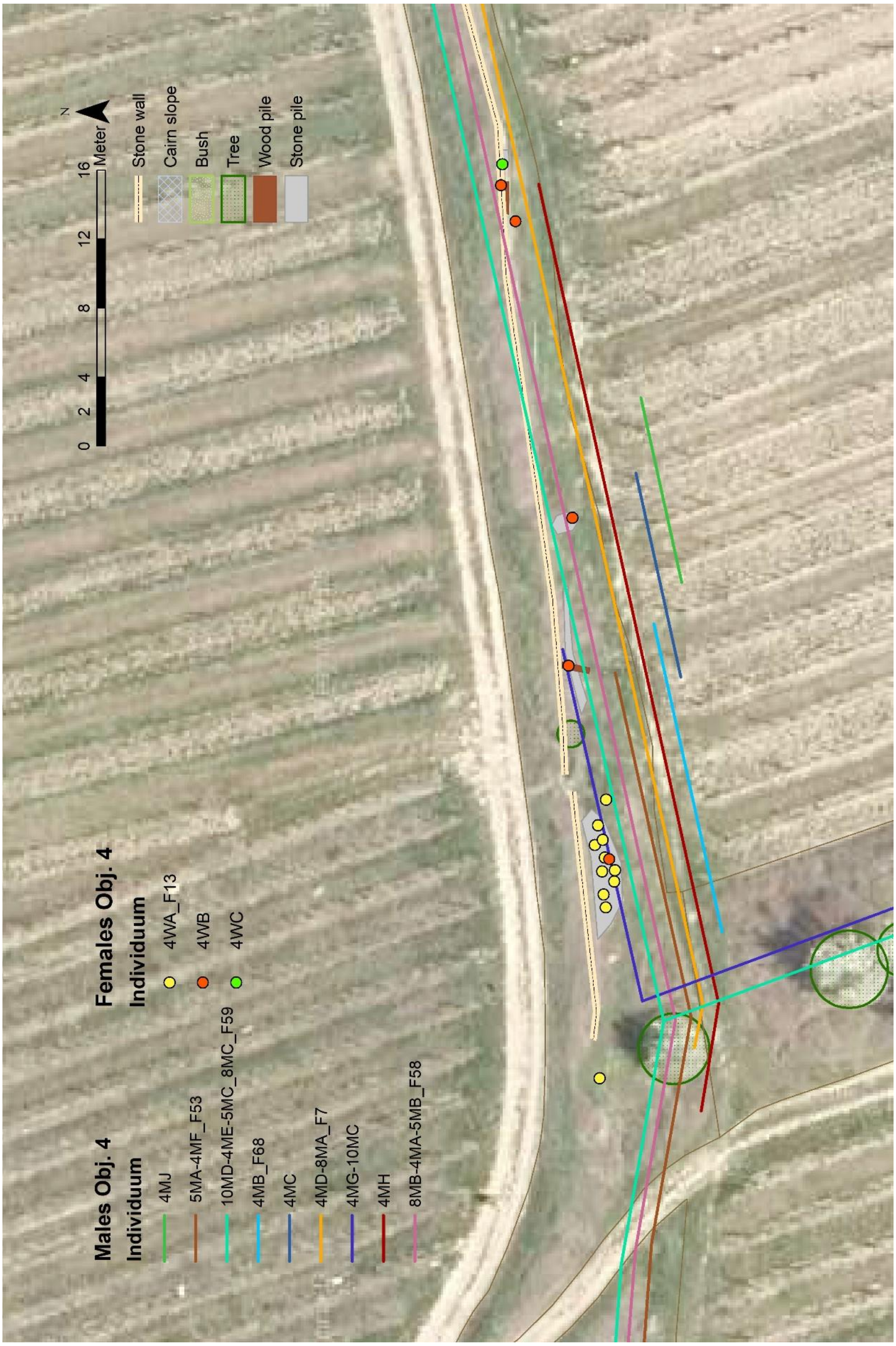

Figure 39: Detail of object 4, males (lines) and females (dots)

4.3.3 Movements between objects

Figure 40 shows the number of objects, which were used by adult males and females.

15 males moved within two objects, four used to stay in three objects and only one young adult male was found in four objects, while it covered a total distance of 225m. All animals, which were found in more than one object were found in neighboring objects to the origin.

Females covered mostly distances within one object, we found 26 animals which did so, three females were recorded in two objects.

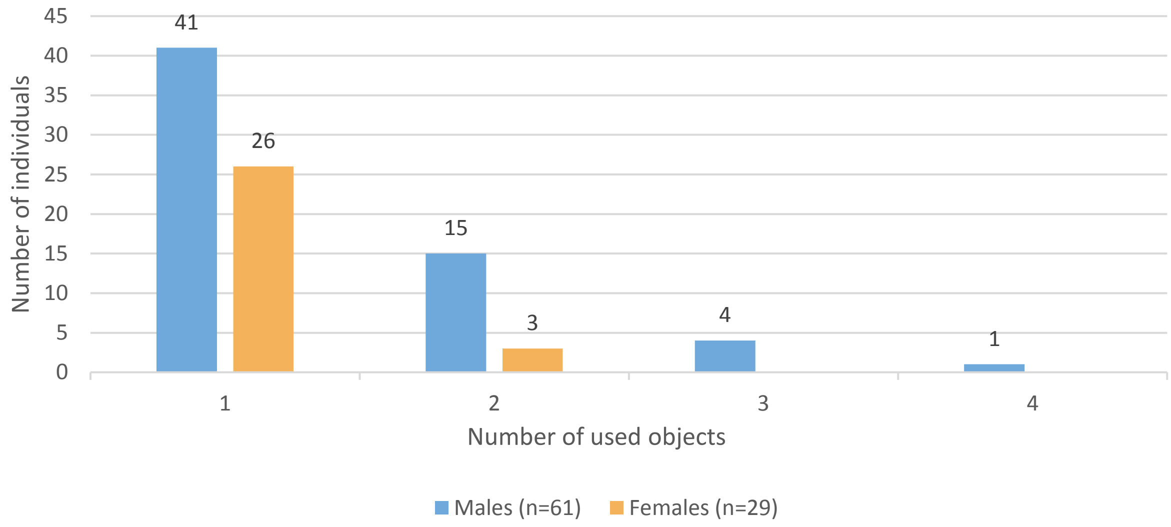

Figure 40: Used objects in all sightings

As an example, the movement patterns of males in the object-complex 4-5-8-10 are shown in figure 41, the mentioned male, which used all 4 objects is illustrated in turquoise (10MD-4ME-5MC-8MC). Further, following males were recorded in more than one object in this area: 5MA-4MF, 4MD-8MA, as well as 8MB-4MA-5MB, a young adult male, which used to stay in three objects. It is shown, that some males cover big distances and seem to be explorative while others tend to stay in a smaller area. Object 4, which is part of the main slope south, inhabits more individuals than the connectivity structures object 8 (east side) and object 10 (west side).

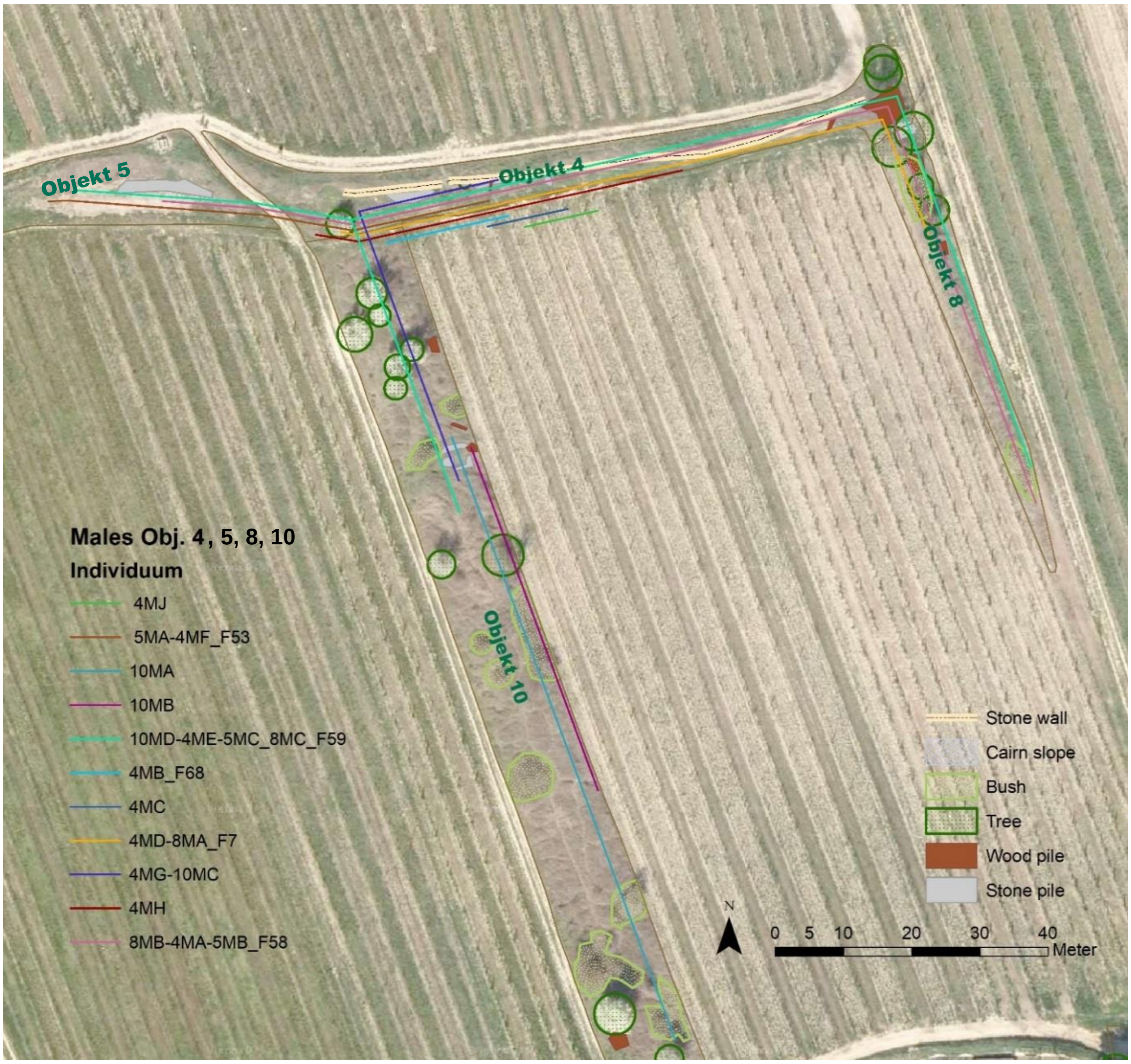

Figure 41: Movements of males in objects 4, 5, 8, 10

4.3.4 Use of connectivity structures

Green Lizards, which included connectivity structures in their movement were recorded at different parts of the study site. Bigger covered distances within that structures were recorded in males only, females were found solely at local points. Below, three examples of males´ movements in the two connectivity structures objects 12 and 13 are given. In figure 42 are illustrated the movements of three males between upper and lower parts of the slope. The only animal, which was found on upper and lower main slope (main slope north and south) is Male 24MB-13MA-6ME, a three-year-old male (yellow in figure 43). It moved from main slope north to main slope south, while covering the biggest detected distance in all animals of more than 255m. The data point in the middle between upper and lower slope in object 13 represents a point, where he was recorded paired with a female in May. Connectivity structure object 13 is an unmown grass strip with some bushy structures along a fence (see photo figure 14 chapter

4.1.1). The other two illustrated males were the same age class than the mentioned one. Male 12MB-24MI moved from the middle part of the slope, where he was found the first time on March 25th and paired with a female (12WA) on April 10th in a garden hedge, up to object 24 in the upper main slope and used a small grass connectivity strip for that movement. The third male 12MA-7MA moved from the lower part up to the garden, where the mentioned animals were found and used a small grass strip along an extensively cultivated vineyard for that movement. Where the distances join up, a female (12WB) was found on a pile of cut remains in a hedge, where she was paired with male 12MA-7MA on May 12th. That male wandered down again and was found in June there.

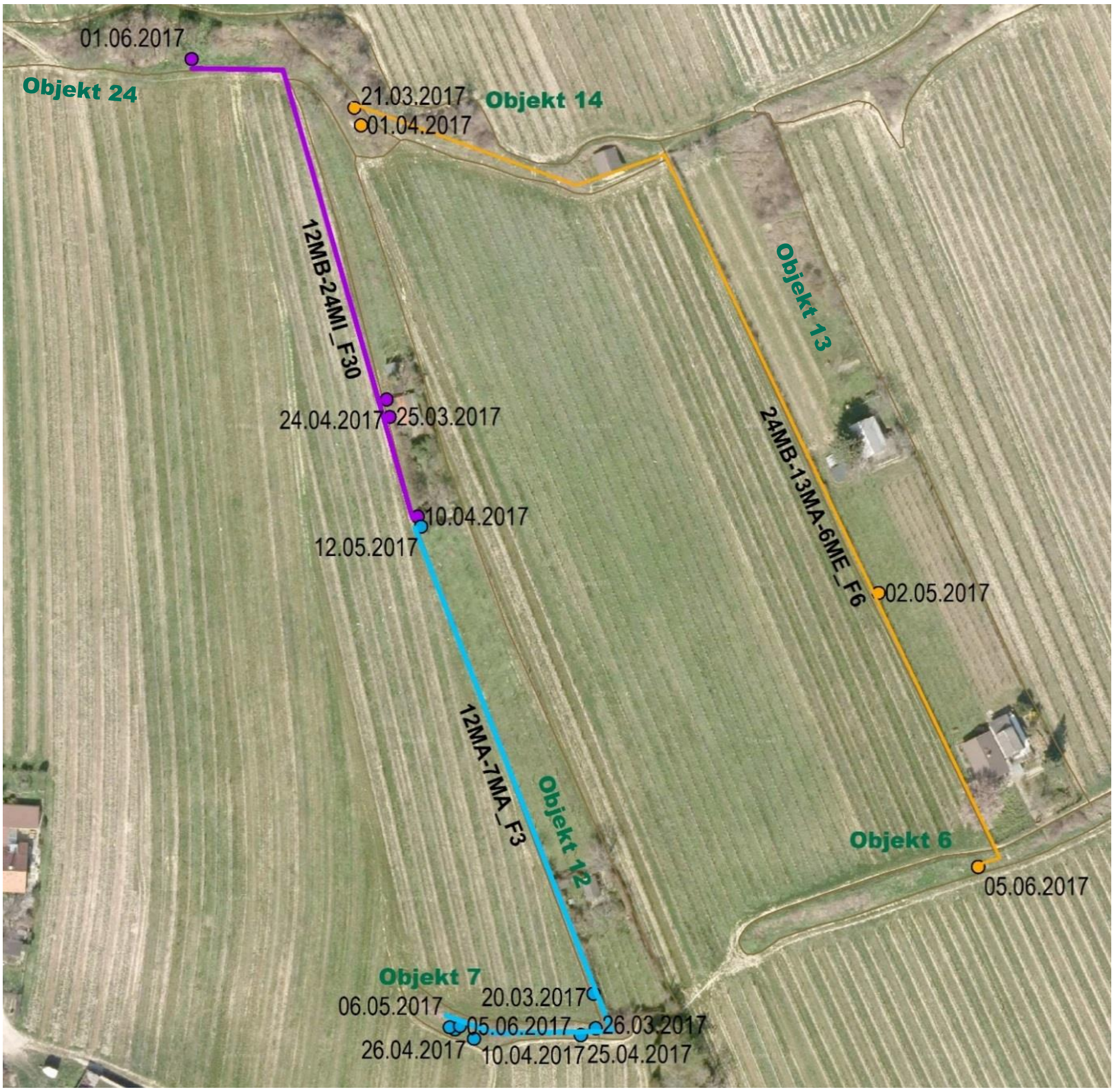

Figure 42: Connectivity structures objects 12 & 13 used by adult males.
Each color represents the covered distance by an individual including the record dates

4.3.5 Movement motivation

For males, a General Linear Model (GLM) was applied to determine eventual motivation for moving in the habitat (figure 43, further operation description is found in chapter 4.5.6 and data sets in appendix III).

The independent variables were the following: age class (3 classes), males and females (individual numbers) within a radius of 50m at the point of first record, males and females (individual numbers) in the whole activity range, as dependent variable the covered distance values of the males were put in the model. The results of density and animals per activity range are shown in chapter 5.2.3.

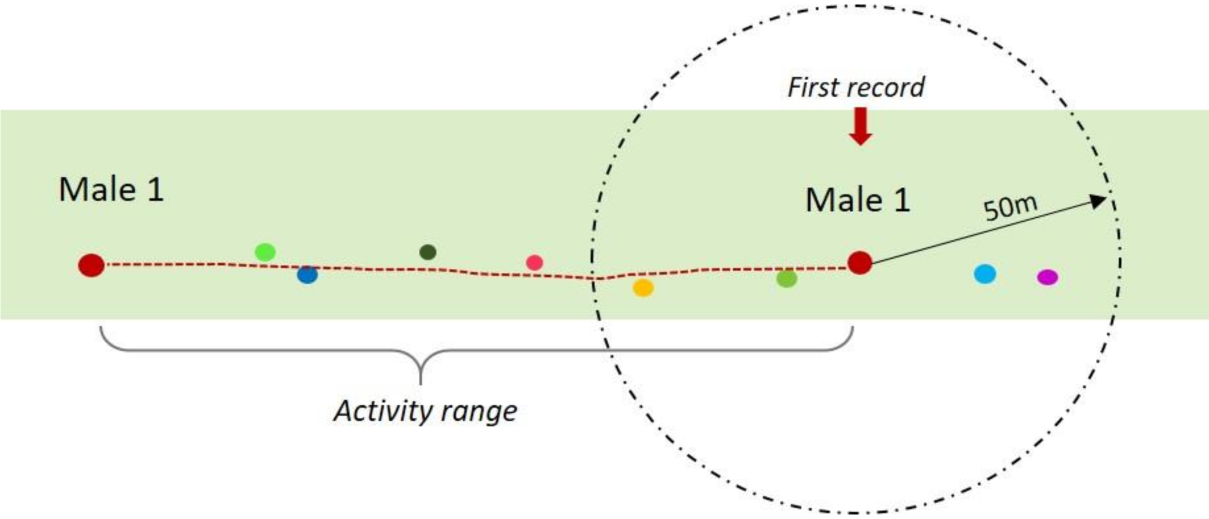

Figure 43: Scheme of GLM as shown in chapter 4.5.5

Even if the Pearson´s product-moment correlation suggests a correlation of males (m/50m radius) and females (f/50m radius) at point of first record (p= $1{,}086e^{-7}$), the AIC value was higher in the model which included both parameters (AIC: 610). The GLM, which was calculated without m/100m showed also significant results, but a smaller AIC value (AIC: 608,13).

<u>The used GLM with all parameters showed the following significant results</u> (table 8):

1. "*Females per 50m radius at point of first record*" showed significant negative correlation (-11,0621) with the covered distances of males with p= $4{,}82e^{-5}$ ***.
2. "*Females in activity range*" showed significant positive correlation (21,0741) with the males covered distances with p=$2{,}41e^{-7}$***.

Table 8: GLM of covered distances (males), including all parameters

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	39.5601	13.3883	2.955	0.00466	**
Age class 1[2014-2015]	-5.8668	10.3222	-0.568	0.57218	
Age class 2 [2014]	-25.4626	17.2189	-1.479	0.14512	
Age class 3[2015]	-11.8915	11.9006	-0.999	0.32222	
m. 50m radius	0.8254	2.4235	0.341	0.73477	
m. Activity range	2.7393	2.8887	0.948	0.34730	
f.50m radius	-11.0921	2.5062	-4.426	4.82e-05	***
f.Activity range	21.0741	3.5587	5.922	2.41e-07	***

Other values do not show any significant influence in the model. Neither age nor other males in the activity range seem to influence the covered distances in this model.

In the second model (table 9) were used data from captured males (n=25) to check the influences of sighting number and SVL (Snout-vent-length) on the covered distances. It represents the following: neither SVL nor sighting number showed any significances in the model. The parameters regarding female numbers showed significant influences as well. A slight negative influence of SVL on covered distance was detected in the model and the sighting number did not show any considerable effect.

Table 9: GLM of captured males including sighting number and SVL

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	183.793	123.879	1.484	0.155202	
m. Activity range	7.235	5.264	1.375	0.186127	
Sighting number	**0.412**	**2.854**	**0.144**	**0.886833**	
SVL	**-12.980**	**10.434**	**-1.244**	**0.229420**	
f.50m radius	-18.465	4.310	-4.285	0.000446	***
f. Activity range	24.355	7.112	3.424	0.003025	**

Another model (table 10) including only sighting number and SVL also showed no significances on the covered distances of captured males:

Table 10: GLM including only sighting number and SVL

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	106.841	203.258	0.526	0.605
Sighting nr.	2.835	4.296	0.660	0.517
SVL	-3.669	17.600	0.208	0.837

Summary: The results displayed in the applied General Linear Models show influences of female abundance in males' activity ranges in two ways: First, a negative correlation between males´ covered distances and female densities at one males' origin (point of first record within a 50m radius), and second a positive correlation between males´ covered distances and females per entire activity range.

4.4 Phenology

The phenological consideration of the sighting numbers shows peaks of *L. viridis* records in March, April and May (figure 44). The first male was recorded on March 4th basking on a stone wall. The first female was seen 13 day later, on March 17th basking on a stone pile, from that day on females occurred regularly.

Most males were recorded in April, then March and May follow. In March only 15 females were recorded, then the number of sightings increased until May, where about 75 female sightings took place. From beginning of June on all sightings decreased, in August in September followed a slight increase in subadult records. In August, the first juveniles were seen, this age class occurred until October. No Green Lizards except 4 juvenile sightings were recorded in October.

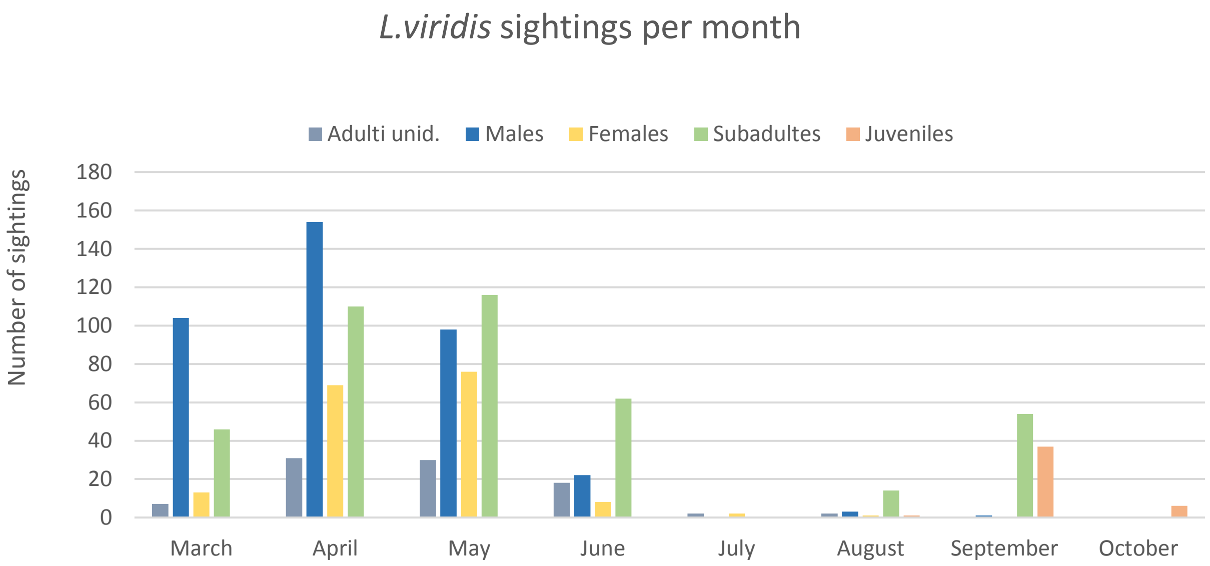

Figure 44: Sighted animals per month

About one month after the occurrence of the first males, the mating season started with the first moultings of males and the simultaneously occurring pairs basking together. On April 3rd, we observed the first mating between a three years old female and a male about the same age.

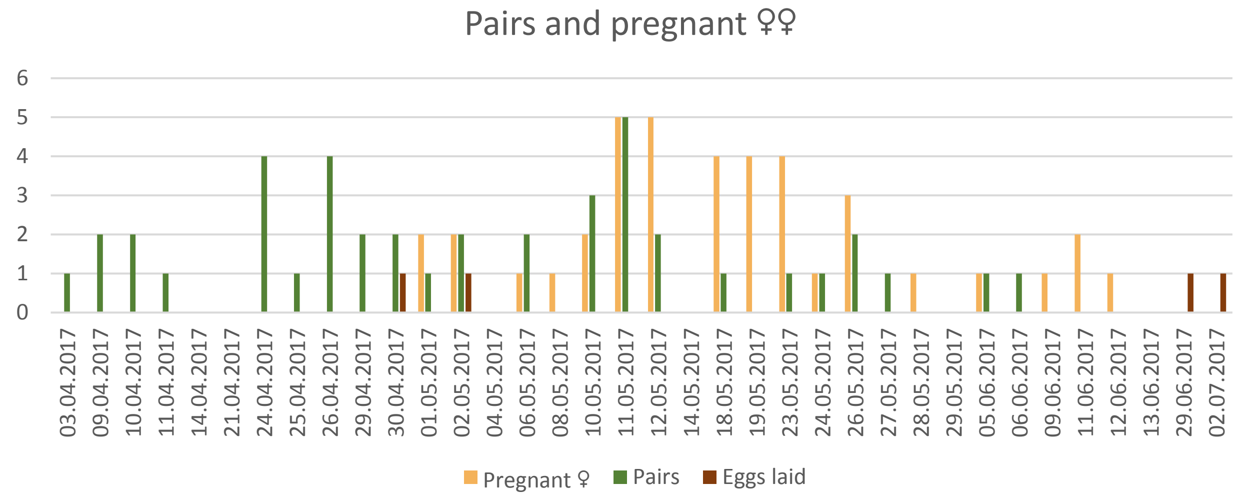

Figure 45: Records of pairs in the whole mating season

Pairs were recorded from April 3rd to June 6th, there can be seen two peaks around April 25th and May 11th (figure 45). Pairs are defined by one male and female lizard, which stay in body contact and are following each other if one animal started to move. From beginning of May on pregnant females were frequently observed until July 13th. A peak was seen here also around May 11th which lasted until May 26th. In this period, every field day were recorded four or more pregnant females. The first female, which had laid its eggs was recorded on April 30th, this was recognized by lateral skin folds at the females´ body sides. The last females with lateral folds were seen around beginning of July, but the last two pregnant ones were recorded on July 13th, so there must have been also females, which laid their eggs later. The first juvenile was recorded on August 29th and from that day on they occurred regularly in the area until the last survey day on October 13th.

4.5 Used habitat structures

For all records of *L. viridis* were also collected data about the structure and substrate the animal was found on as described in chapter 3.3. Below, the results of this analyzed data of structures and substrates, Green Lizards were found on.

4.5.1 Used structures

Figure 46 presents the results of the analysis. Nearly a third (30%) of *L. viridis* were found on herbaceous vegetation, which includes dry vegetation as well as fresh green vegetation. Nearly one quarter was found on wood piles which are commonly found structures in the study area Nußberg. 11% of all records were done on walls, mostly dry-stone-walls and in some cases walls built by using cement as well. Another 11% of sightings were done on slopes without any further structure, mostly overgrown by herbaceous vegetation (detailed description in chapter 4.3). The remaining third is made up by records on or in woody vegetation, stone piles, clematis thicket and hedges as well as some seldom used structures like cut-remains, cairn-slopes, break-off-edges and cement structures.

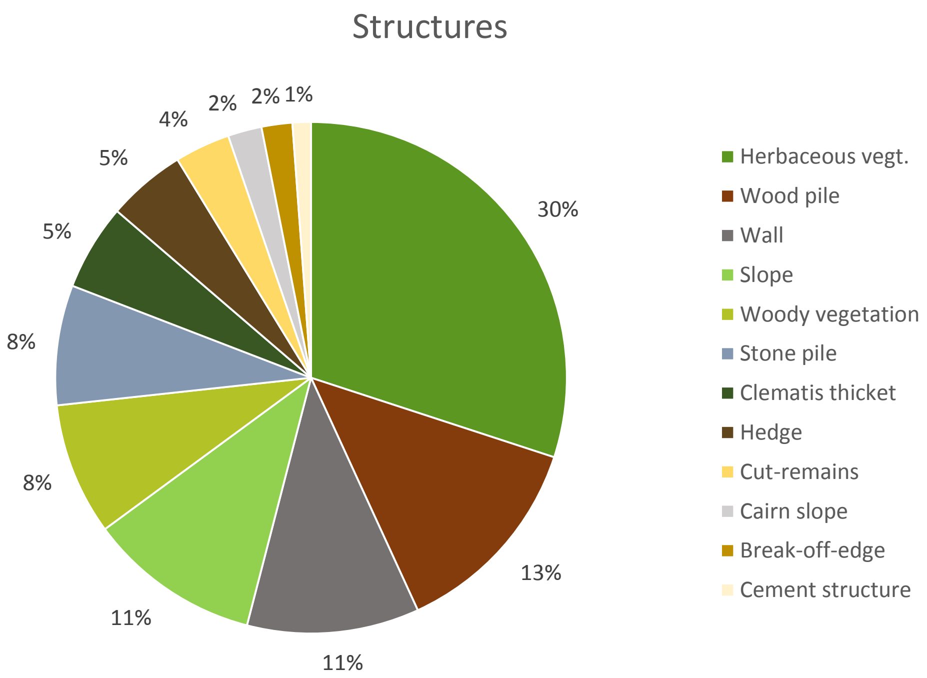

Figure 46: Used structures of recorded L. viridis

An example of a conglomeration is found at the east end of object 15 at its border to object 16 (figure 47). Here is found a bushy structure which extends V-shaped some meters to south direction, which provides possible basking orientation to east, south and west side. This part is structured heterogeneous, it is composed of stones, a dry-stone wall, a big wood pile and some bushy structures as well as grassy parts. Here were found seven males around the survey period, whereby one particular older male (male 15MD-16MB, orange) was very site-related, it was found by Heimo Schedl the first time in 2014 at this location (SCHEDL, *personal communication 2017*). Three more male were found in direct vicinity of this part without being recorded elsewhere, as the movement pattern in the map show.

Figure 47: Conglomeration of males at the border of objects 15/16

4.5.2 Used substrates

As described, in addition of structures, data regarding the substrate, the animals were found on, had been collected. Hereinafter are shown the results of the analyzed data.

The results in figure 48 represent the importance of vegetation, as well as stone and wood as substrate in Green Lizards´ habitats. Half of the recorded animals were found either on green or dry vegetation or a mix of those. Mixes occur, if an animal was found sitting on two substrates with its body length. Woody and stony substrates made up more than one third of used substrates with 34% including mix structures. The remaining 15% are made up by bare soil, sand and dry leaves and mix of soil.

6% of recorded animals were found on mixed structures, it occurred mainly in small-scale patches or in animals which were found in or next to cover structures.

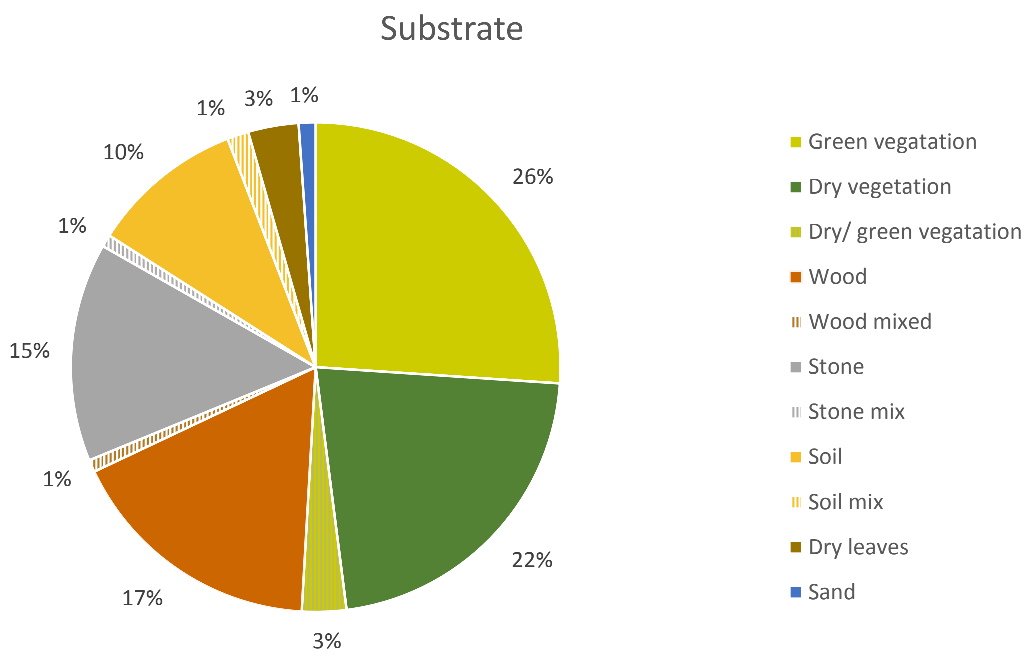

Figure 48: Used substrates of recorded L. viridis

5 Discussion

5.1 Photographic recognition

In previous studies, photographic methods of scale pattern recognition for individual assignment was used in different ways. In some studies, the pectoral scales of Lacertid species were used for recognition. STEINICKE et al. (2000) applied this in a capture-recapture study of the species *Podarcis muralis* (Common Wall Lizard). The lizards were caught to photograph their pectoral region, those pictures were compared to each other to re-identify animals, which had been caught and photographed more than once. SACCHI et al. (2010) used the same body region in *Lacerta bilineata* (western Green Lizard) and *Podarcis muralis* for recognition of individuals by a computer program. The animals were captured and the taken photos had to fulfill some requirements to operate the computer program, which uses pattern recognition algorithms to detect similarities between photographed individuals. That was possible if the surveyed animals were captured and pictured in a camera parallel position to get flat, non-skewed photographs of the entire target region on the animal surface.

In the case of this study, animals were photographed in their natural environment, even if there was only seen a small part of the lateral head while hiding in vegetation. Due to this factor, most of the pictures could not be processed by a computer program due to inhomogeneity in the picture quality.

Studies in *L. viridis* also used photographic recapture methods, which were applied on lateral head scale pattern (ELBING, 2000, KLEPSCH, 1999, SCHEDL, 2001). The animals were captured by noosing and photographed on head sides and pileus to identify unique scale pattern and shapes. Afterwards the lizards were marked with color (mostly nail polish) to identify recaptured animals for a period for about 4 weeks (up to the next moulting). In smaller populations, it was possible to distinguish the animals just by sighting on basis of the scale pattern and markings (ELBING, 2000a). ELBING (2000a) used additionally to scale pattern the counted number of lateral head scales for identification in recaptured animals. KLEPSCH (1999) and SCHEDL (2001) identified the animals after capturing, photographing and nail polish marking in a re-sighting with the markings or by recapturing them, followed by identifying the animals directly by a carried photo database of individuals. Before recapturing, every animal was photographed additionally for safety reasons, in case of an unsuccessful capture. Some of the already captured animals were identified only by photographing them in a re-sighting or directly through binoculars (SCHEDL, 2001).

All these mentioned studies were based on physical capture of Green Lizards, which of course, leads to stress and changed behavior in the moment of capturing. SCHEDL (unpublished) introduced a method for identifying recorded *L. viridis* only by photographing the head sides by using a bridge camera with high zoom factor. That brought the possibility to identify the animals without capturing or marking them, just by assessing the pictures (either in situ or in retrospect). In that way, the animals in most cases were uninterrupted in their natural behavior, while staying in their habitat and being recorded by the researcher. This method was also applied in my study for investigating in this big area of about 2300m habitat length, which leads to the possibility to overview a larger area and population because it is a big time-saving factor, if the animals do not have to be captured physically at all. Furthermore, it is an inexpensive and efficient method for population monitoring as well as more detailed investigations like movement studies as shown in previous chapters. It is efficient, which is shown by the identification rates of nearly 80% in all recorded males and nearly 75% in females. A slighter low rate is detected in re-identification of female sightings because they show a much more secretive way of life and better camouflage, so some of the females vanished before it was possible to take a qualitative picture. In smaller study areas, due to high inspection frequencies it is possible to identify 85% to nearly all recorded adult animals (cf. SCHEDL, 2001).

5.2 Population and population structure

The examined *Lacerta viridis* subpopulation on Nußberg is part of the population inhabiting the wine growing area around Nußberg, Kahlenberg and adjacent areas like Burgstall and Steinberg as well as some private gardens in the area (SCHEDL, unpublished). The survey area is inhabited by identified 77 adult males and 57 adult females. It is located in the core-area of Nußbergs´ vineyards and shows an average density of 5,25 adults/ 100m. In literature are found densities from 1 adult/ 100m (ASSMANN, 2001), 1,6-2 adults/ 100m (LAUBE in ASSMANN, 2001) and 2,1 adults/ 100m (KLEPSCH, 1999). NETTMANN and RYKENA (1986) indicate densities from 1 -5 adults/ 100m in suitable habitats. LAUBE in ASSMANN (2001) found clusters within the *L. viridis* population in the Danube valley in Passau, which reached maximum densities of 4 animals/ 100m. Due to a non-evenly distribution in the area of Nußberg occurred clusters of animals as well, which reach densities up to 11 males/100m and 10 females/100m. Including both sexes and therefore very high densities compared to other areas with maxima up to 14,7 animals/ 100m were found (see chapter 5.2.3). Here is to point out, that the inhabited slopes are very narrow at some sections and reach a width from only three to four meters in some cases, which leads automatically to a very concentrated occurrence of Green lizards at habitat edges. It seems, that the populations of *L. viridis* tend to occur in agglomerates and clusters within habitat sections with favorable conditions (BÖKER, 1990b, ELBING, 2000a). ELBING describes "non-random, unequal and mainly cumulative" distribution pattern between sections with opportune habitat structures and ones with more unfavorable conditions (ELBING, 2000a, p. 87). In edge areas of the research area were found sections with smaller abundance of individuals. In object 19 at the north-eastern edge were found only four adults, which concentrated around the eastern edge of this narrow slope. Outside the research area the habitat structures continue in form of an unmown slope along a small street, which is mainly orientated to north, which do not provide favorable conditions for *L. viridis*. Thus, it is to assume, that the densely populated core area ends at the eastern edge of object 19 and the further slope is only used sporadic by migrating or escaping animals. But SCHEDL (unpublished) found in all recent years also scattered Green Lizards outside the core area which implies a still existing connection with surrounding areas. On the western edge (objects 7 and 24), the core population is interrupted through to intensively used vineyards which separate the population over distances from about 70 -100m from surrounding areas, which are inhabited, proven due to some sparse records of animals (KRENN & SCHEDL, 2017, unpublished). But it is to assume, that the species as a relatively mobile one, is able to overcome such distances in infrequent cases, which leads to genetic exchange.

The sex ratio of 1:0,74 (m:f) shows an imbalance towards males in this population. As mentioned above is to be noted here, that males show more active behavior than females do, which tend to a more secretive life style and therefore more difficult to survey. This is also seen in the average sighting number of males and females, where males in average were recorded 4,9 times and females 2,9 times (see chapter 5.1). Nevertheless, the sex ratio is acceptable, considering other empiric studies, which all show this kind of possible errors. Sex ratios in literature vary within a margin from (m:f) 1:1,1 (mean in three different years) (SCHEDL, 2001), 1:0,81 (REHÁK, 2015) and in a very small examined subpopulation of only 8 – 18 adults in different years 1:0,5 (mean in different years) (KLEPSCH, 1999). BÖKER (1990b) found in 4 very small examined *L. bilineata* population parts in the Mittelrhein-area in Germany (only three to eight adults per section) also sex ratios towards males, but may the sample size be too small to include those results here. However, in 3 small populations of ELBING (2000) were found mean sex ratios of (m:f) 1: 1,3-2,6 which shows a surplus of females. SCHEDL and

ELBING examined populations in natural habitats, the studies of KLEPSCH in vineyards and REHÁK in the Prague zoo took place in anthropogenic influenced areas, as well as this study on Nußberg. May sex ratio correlates with external factors like stress or biocide influence in the populations. One study regarding *Podarcis muralis* (MINGO et al., 2017) in Rhineland, Germany examined non, slight and heavily biocide exposed populations in different land use types (e.g. vineyards and forest) and found out, that the sex ratio in natural habitats showed more balance in comparison to poison influenced populations which showed a surplus of male animals. To determine the correlation of biocide influence and sex ratio in Lacertid species, further studies would be required.

The age distribution in all sightings of *L. viridis* shows a value of about 1,5 :1 adult to subadult animals on Nußberg, which represents a share of 40% subadults (see chapter 5.2). KLEPSCH (1999) reports of a proportion of subadult of 0-42% in a similar habitat in the vineyards of Kahlenberg in Vienna. SCHEDL (1999) found in his survey area on Leopoldsberg in Vienna subadult-shares from about 50 % up to 150% of adult abundance. Data of a mid-term study in Brandenburg are difficult to compare with regional populations of *L. viridis*, because there the animals reach maturity not with two but with only three years (ELBING, 2000). Nevertheless, a proportion of 4% to 35% of animals, which were born the previous year (which is the definition of subadult in this study) are shown by ELBING´s data in the years 1994-1998.
In sum, it is shown, that ratios in age structure is varying a lot depending on the considered year and therefore maybe climatic influences and other environmental impacts. For example, rainy summers can lead to smaller hatching rates and influence the age structure of the following year, due to the fact, that sunshine duration plays a key role in incubation time and females can establish a sufficient fat deposit for the eggs of the following year through enough food availability. Cold winters, in turn, seem to show no significant influence (cf. NETTMANN & RYKENA, 1984). Age structure is seen as an indicator for vitality and survival rate, whereby high amounts of subadults demonstrate a sign of a vital population (cf. ELBING, 2016).

5.3 Movements

As shown in previous studies, *L. viridis* is a mobile species which is able to cover big distances in its habitat, correlating with the phenological and diurnal needs. In most studies are found differences in moving pattern between males and females, were males tend to cover bigger distances or activity ranges (according to linear or spatial extended survey areas). As shown in chapter 5.3 in this study also were shown significant differences between covered distances of males and females. Females were recorded less often than males, 2,9 times in mean, where males in turn were recorded 4,9 times in mean. To determine a correlation between sighting number and recorded covered distance, a GLM was calculated with this parameter and others (SVL and male/ female densities, see 5.3.5) of all captured males. In that case, neither sighting number showed nearly no influence in the measured covered distance of an animal, nor SVL, which is the same result, that SOUND (2005) found out in his study area in Germany. Therefore, all animals, which were seen more than once, were included in statistical movement calculations. The boxplot showed significant differences: Males covered bigger distances than females in this study. In literature terms like "individual district" (BÖKER, 1990b) or "home range" or "activity range" (SOUND & VEITH, 2001) are found, which describe different movements within habitats. "Home range" or "individual district" describes the area, where the main part of active time of an individual is spent, mostly around one structure which is used for basking or as shelter, "activity range" defines the total used space of a single Green Lizard within the habitat. The last-mentioned term is used here to describe the covered distance of *L. virids* on Nußberg. The mean covered distance of males in the examined subpopulation was found about 60m length. In literature are found mainly spatial movement calculations which used the minimum convex polygon method (e.g. MOLNÁR et al., 2016, SCHEDL, 2001) or radio telemetry (SOUND & VEITH, 2001, SOUND, 2005) to calculate each individuals´ activity range. MOLNÁR (2016) et al. found around 70sqm in one study site and about 200sqm in the second one. SCHEDL (2001) found maxima of about 1100sqm in males and 2200sqm in females in his study area on Leopoldsberg in Vienna. In that study, also the maximal distance between recorded points of each individual was calculated, in three years (1995-1997) were measured average distances covered within a spatial home range of 31,3m in males and 22,3m in females, maxima for males were 65m within the study area and for females 76m (cf. SCHEDL, 2001, own calculation).

In one study area in Vienna were also collected linear data, KLEPSCH (1999) shows mean ranges from 180m in male and 54m in female distances along a vineyard edge on Kahlenberg, where maxima of 459m in males and 68m and in females were measured. For the sister species *L. bilineata* were found individual covered distances from about 122-277m (BÖKER, 1990b). Those values reflect the results of my examination in the Nußberg-area, where average distances were found around 60m in males and around 22m in females, while maxima were 255m for males and 65m for females. Logically, the species uses larger distances, the narrower the inhabited structures are. MIKATOVÁ (2001) reports from a Czech population in Moravia, which uses to migrate between hibernation and summer activity place about 500-800m.

Therefore, *L. viridis* is a mobile species with high space requirement that implies a well-structured, connected network of habitats, which do not have to be expanded very much in spatial dimension, since also narrow linear habitats are used.

Males used the connectivity structures to cover distances between habitat slopes, females were found also within those structures, but mainly remaining on one point without moving a lot. In literature many indications are found, that *L. viridis* is bound to a patchwork of cover and shelter structures (bushes and woody structures) in addition to scattered open areas to use a habitat successfully in its full dimension (e.g. ELBING, 2000 & 2016, MIKÁTOVÁ, 2001, RYKENA et al., 1996). Also individual character specifics could play a role in exploration courage as an ex-situ study for examine locomotor behavior shows, where shy and bold individuals were distinguished within *L. viridis* and *L. agilis* (PACUTA et al., 2018).

<u>Females influence males´ movement patterns</u>

Therefore, what is the motivation to move? Statistical analysis was carried out for the movements of 61 adult males in this study to may find any indications of correlation between population- connected parameters and covered distances. A General Linear Model (GLM) was applied to evaluate possible influences of age, male and female density as well as male and female – "availability" (individuals per activity range) on individual covered movement distances. The GLM revealed significant influence of the two female-related parameters: The less females a male found in his "home base territory" (female density at point of first record), the higher the estimated covered distance by this individual male. Second, the bigger the covered distance by an individual male, the more activity ranges of females he crossed and, therefore, the more potential mating partners he passed by. Thus, according to this model it is to assume, that female distribution controls males´ movements and covered distances in the study area. In object 24 was found a big imbalance in sex ratio with 9 males and only one recorded female. A three-year-old male migrated more than 250m from object 24, where it was recorded in March along connectivity structure object 13 to the lower main slope (object 6). In object 13 it was recorded paired with a female in May, in June it was sighted in object 6 in the lower main slope, where females were recorded on the same day in close proximity. In object 6 in total were found four males and four females, one young adult male (age class 2014-2015: 2-3years old) was recorded with all four of them during the mating season while he covered a distance of nearly 80m within objects 6 and 13. Connectivity structure object 12 was inhabited by two females which were recorded between beginning of April and mid of May. The two males of object 12 were recorded end of March and beginning of June, while one of them

(12MA-7MA) was recorded first in object 7 and migrated uphill in object 12, although in object 7 were found four females and only two males. Both males were assigned to age class 3 years. Consequently, the assumption that young adult males rather tend to cover bigger distances than older ones has to be rejected in this population, which is also displayed as result of the GLM analysis.

Other studies in different populations report of territorial males which crowd females around them, or males, which try to mate an "unguarded" female as well as populations, where the sex ratio shows a high surplus of females, where males switch between females over big distances (>100m) to stay with them and mate (ELBING, 1999 & 2016). REHÁK (2015) describes territorial males that try to mate also females paired with other males. Due to a low female density in my study area, males would not have any benefit to be territorial and occupy an area, if there are no females. In case of the shown male 24MB-13MA-6ME, which started in object 24, he was found with a female about 200m away from his origin in May and in June at the southern slope in object 6. On that day, females were recorded in object 6 as well.

From ELBING (1999) described mating system in areas with high female density and low male abundance (see above), only one section of the Nußberg area could be compared: Object 6, where male 6MA-13ME on May 11th was found with two females in half an hour, in total he was recorded with four different females, which is the maximum recorded female amount of one male. In the mating season, a balanced sex ratio was recorded in object 6 (4 m/ 4 f).

Contrary to the assumption that age and snout-vent-length correlate with covered distances, this was rejected in the used model. MOLNÁR et al. (2016) found the same result in their study, where they searched for correlations between space-use, throat brightness and SVL (correlating with age) in two Hungarian *L. viridis* populations.

5.4 Use of connectivity structures

As mentioned above, in connectivity structures were found primarily males, which used those corridors partly as habitat in sections with denser vegetation and also covered big distances between habitat slopes and potential habitat to stay. The example of three males shown in chapter 5.3.4 represent the movements within two habitat corridors which connect the upper and lower main slopes in a distance of about 170-200m show, that the animals accept both grassy as well as woody or other denser vegetation structures to migrate. All three males were found with females within the connectivity structures in mating season, object 12 consists partly of private garden sections with hedges, where the females were found. No movements of

females could be recorded in these parts, they moved in a very small range from less than 1m. For example, female 13WA was found only at one point, while she was recorded four times between 2nd and 19th of May at a grassy structure along a fence in object 13.
Object 10 seemed to be also a well-accepted structure for migrating, while it consists of a ten meters wide strip of fallow land, which provides very heterogeneous basking, hiding and covering structures. Actually, it should be classified as habitat extension of the slopes, not only connectivity structure. Sadly, it was totally cleared in winter 2017, so in 2018 were no animals sighted in this object anymore.

GLANDT (2018) also recommends hedges and edge habitats as migrating corridors, as well as established biotope islands, which are important landscape features in reptile habitats. He underlines the usefulness of corridors, in particular for migrating individuals like floaters within one population. BEIER and NOSS (1998) researched for studies, which examined the utility of connectivity structures for different species. Among others, one study investigated the efficiency of biological corridors in salamanders by placing them in artificial corridors of 40m length and measuring the number of complete corridor transits. Other studies only counted animals and recorded their presence in corridors (BEIER & NOSS, 1998). Furthermore, they mention the notable fact, that corridors almost certainly support movements of many species, not only the target ones. But in literature it is suggested to both establish and assess connectivity structures species-specific (BEIER & NOSS, 1998, TAYLOR et al., 2006), which was successfully carried out in this study based on connectivity structures, which were established for *L. viridis*.

5.5 Habitat use

As reported by different authors, *L. viridis* is reliant on heterogeneous habitat structures to fulfill all life functions, such as basking, hiding, feeding, hibernating and reproduction. Daily used structures (basking, shelter, feeding) must be provided in patchwork-like arrangement in the daily activity range to ensure safe everyday life. Underlined is also the preference for edge-habitats like waysides, agriculture- or forest edges, railway embankments etc. Open areas without any cover structures are being avoided by Green Lizards generally (ELBING, 2016, KORSÓS, 1984, NETMANN & RYKENA, 1984). Regarding to MIKÁTOVÁ (2015), *L. viridis* prefers to stay 50cm around shelter structures, while basking, which is the most frequently done activity.

Regarding the chosen habitat, *L. viridis* shows clear preference for certain expositions to south with high solar insulation. Mainly, populations of this species in Middle Europe are found in thermo-favorable slopes in south-eastern to south-western orientation. SOUND (2005) shows a solar insulation map of the Rhine valley in Germany and the distribution of *L. bilineata* within the study area (figure 49). It demonstrates nearly the same pattern than the insulation map of Nußberg in Vienna (chapter 4.2.4): In areas with high insulation (red) are found Green Lizards, in ones with low irradiation (blue) were recorded almost no individuals (figure 50). This shows the dependence on warm and southern orientated habitats and structures of *L. viridis*.

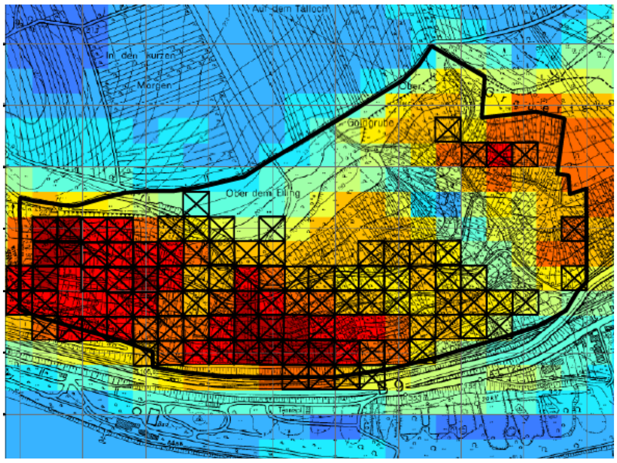

Figure 49: Distribution and solar insulation L.bilineata in the Rhine valley – grids (SOUND, 2005)

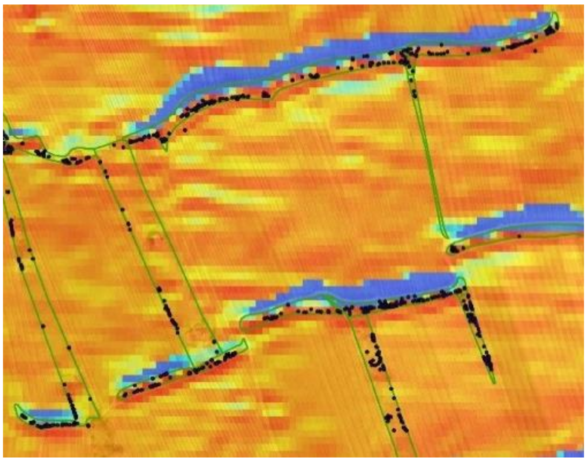

Figure 50: Distribution and solar insulation at Nußberg [Map Detail] – data points (KRENN, 2018)

As mentioned above, the examined subpopulation showed non-equal distribution within the study area. The clusters occurred around heterogeneous habitat structures that provide food, basking- and resting places in form of herbaceous structures, stone or wood piles, bushes or woody structures as well as options to seek out shelter in direct vicinity. Object 1 and the mentioned border of objects 15/16 (chapter 4.5.1) show very heterogeneous small scaled structures and here is found a high abundance in both, individuals as well as sighting numbers. About one third of adults were recorded in herbaceous vegetation, which is found in nearly all sections of objects. The animals often were recorded at the edge of higher vegetation, which provided fast cover possibilities. Walls, stone and wood piles are also very commonly used structures, they make up another third of the records - as mentioned, they are preferred basking places for this species (see also ELBING, 2000a, 2016). A further commonly used structure are slopes which are overgrown with herbaceous vegetation, but may show also scattered other patches with dry cutting remains or single stones, bare soil etc. Remaining used structures as hedges, *Clematis vitalba* thicket, break off-edges, cutting remains or even concrete structures show, that the species accepts also other structures for activities like basking, but they prefer others like mentioned above. But it is to be emphasized, that of course the distribution of used structures correlates with the structures´ availability within the populated area. In literature are also found information about used structures like bulky waste, sand embankments (ELBING, 2000a), trees as basking structure (SCHEDL, 2001) or heath areas (SOUND, 2005).

The collected data about used substrates show matching results, most recorded animals were found on vegetation, whereas one quarter was found on green and one quarter of animals on dry vegetation. The separation of herbaceous vegetation points out the different thermal qualities of these two options, where dry vegetation provides quickly heating up basking terrain and green vegetation may be used on hot days to spend time on. The substrates wood and stone represents the mentioned wood, stone and wall structures, which are commonly used for basking and other activities like pair binding etc. Also KLEPSCH (1999) found a high amount of more than 22% of all recorded animals on woody substrate.
About 10% of the animals were found on bare soil, which seem to be a well-accepted substrate. In a comparable habitat were also found animals on soil to similar parts (11%) by KLEPSCH (1999). SCHEDL (2001) and ELBING (2000a) found animals on sand, but none of them indicates soil as used substrate. Open soil or sand plays another role in *L. viridis´* life, which is to provide nesting sites at sunny and soft grounded areas, it is an essential habitat feature for stabile populations (cf. e.g. ELBING, 2016, MIKÁTOVÁ, 2001, SCHEDL & KLEPSCH, 2001). The results in figure 49 (chapter 4.5.2) represent the importance of vegetation, as well as stone and wood as substrate in Green Lizards´ habitats. Half of the recorded animals were found either on green or dry vegetation or a mix of those, another third was found on woody or stony structures.

It is to assume, that *L. viridis* is dependent on different structures in its habitat, but the species is flexible in using different materials as long as they fulfill its demands of their daily needed activities like basking, feeding and hiding. Thus, habitat management measures should aim to provide a heterogeneous structured habitat mosaic as well as to establish a habitat connectivity system, which leads to migration between population parts.

6 Literature

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7 Appendix

APPENDIX I: Study area and object numbers

APPENDIX II: Detailed numbers of photographic recorded animals (photographed head sides)

Animals	Photo left	Photo right	Photos both sides	Total	Assigned
♂♂	83	74	178	**335**	332
♀♀	40	31	66	**167**	132
Subadults	55	39	69	**163**	/
Total				**665**	**464**

APPENDIX III : Covered distances by males and females

Individual ♂ (n=61)	Distance [m]	Individual ♀ (n=29)	Distance [m]
1MA	27,7	1WA_F8	6,7
1MB	22	1WC_F24	24,8
1MC	48	1WD	28,1
1MD	16,7	1WE_F43	30,2
1ME_F2	14,2	1WF-45WB_F25	64,5
1MF_F18	41,6	1WG	1,3
1MG_F36	35,4	1WH-45WC	19,9
1MI	53,2	8WA	42,3
45MA-1MJ_F44	90,6	13WA	1,2
45MB-1MK_F51	86,7	6WB	27,2
19MA_F45	29,7	4WA_F13	40
19MC	20,7	7WC	24,7
8MB-4MA-5MB_F58	171,7	7WB	21,5
2MA_F1	29,9	4WB	17,3
2MB	10,3	12WA_F31	33,5
4MC	12,1	24WA	0,3
4MB_F68	18,3	15WD	3,1
4MD-8MA_F7	103	15WA	29,1
4MH	55	15WB	11,1
4MJ	11	15WE	22,6
10MA	94,3	15WF	13,3
5MA-4MF_F53	65,8	16WB-15WJ	10,6
10MB	53,6	19WA_F46	28,4
4MG-10MC	64,3	9WA_F57	13,1
10MD-4ME-5MC_8MC_F59	224,4	9WB	15,4
6MA-13ME_F41	79,2	9WC	0,6
7MB-6MC-12MC	101,2	45WA	55,9
6MB	78,4	13WA	1,6
12MA-7MA_F3	159,4	9WE	49
12MB-24MI_F30	128,4		
13MC_F37	8,2		
13MD-14MC_F38	152,7		
24MA-13MB-14MB_F4	89,3		
24MB-13MA-6ME_F6	255,1		
24MC-14MA_F32	100,1		
24MG-14MD	32,8		
24MD	48,9		
24MH	53,1		
15MB_F15	31,9		
15MC_F19	3,4		
15MA-16MA_F5	42,1		
15ME-16MC_F52	120		

15MD-16MB_F20	16,7		
15MF	16,3		
15MH	70,9		
15MI	4,4		
15MJ	1,3		
15MK	43,8		
15ML	44,5		
15MN	45,7		
15MO-16MF	176,8		
15MP	6,3		
15MQ-16ME	15,2		
16MG	55		
9MA	70,9		
9MB	30,9		
9MC	13,7		
9MD	8,3		
9MF	41		
6MD	13		
24MF	48,9		

APPENDIX IV : General Linear Model - Input

(Males distances, age class, males and females/ 50m radius & activity range)

Individual	Age class	Distance [m]	f/50m*	f/AR	m/50m*	m/AR
1MA	2015	27,7	3	2	4	3
1MB	2015	22	8	4	8	4
1MC	2014-2015	48	10	6	10	7
1MD	2014-2015	16,7	10	4	10	2
1ME_F2	2014	14,2	10	3	10	6
1MF_F18	2014	41,6	10	5	10	7
1MG_F36	2015	35,4	10	4	10	8
1MI	2014-2015	53,2	10	4	10	6
45MA-1MJ_F44	2014	90,6	2	5	1	5
45MB-1MK_F51	2014	86,7	2	5	1	5
19MA_F45	2014	29,7	2	2	2	2
19MC	2015	20,7	2	2	2	2
8MB-4MA-5MB_F58	2014-2015	171,7	6	6	10	10
2MA_F1	2014	29,9	2	1	3	3
2MB	2015	10,3	2	0	3	2
4MC	2015	12,1	4	1	11	6
4MB_F68	2014	18,3	6	2	10	7
4MD-8MA_F7	2014	103	6	6	10	10
4MH	2014-2015	55	6	4	11	5
4MJ	2015	11	4	1	11	3
10MA	2014	94,3	2	3	2	3
5MA-4MF_F53	2014	65,8	4	2	10	7
10MB	2014	53,6	5	2	8	3
4MG-10MC	2014	64,3	5	3	11	9
10MD-4ME-5MC_8MC_F59	2015	224,4	6	7	10	12
6MA-13ME_F41	2015	79,2	4	4	4	4
7MB-6MC-12MC	2014	101,2	4	3	2	3
6MB	2014-2015	78,4	4	4	4	4
12MA-7MA_F3	2014	159,4	4	5	3	4
12MB-24MI_F30	2014	128,4	2	2	2	4
13MC_F37	2015	8,2	3	0	4	2
13MD-14MC_F38	2014-2015	152,7	3	3	6	4

24MA-13MB-14MB_F4	2014	89,3	2	2	7	6
24MB-13MA-6ME_F6	2014	255,1	2	5	7	7
24MC-14MA_F32	2014-2015	100,1	3	3	6	7
24MG-14MD	2014	32,8	2	1	7	5
24MD	2015	48,9	0	0	1	0
24MH	2014-2015	53,1	2	1	7	5
15MB_F15	2014	31,9	6	3	8	5
15MC_F19	2014	3,4	5	2	5	5
15MA-16MA_F5	2014	42,1	5	2	5	5
15ME-16MC_F52	2014	120	1	3	1	7
15MD-16MB_F20	2014	16,7	5	2	5	5
15MF	2014-2015	16,3	3	0	5	2
15MH	2014-2015	70,9	3	3	7	7
15MI	2014-2015	4,4	6	0	8	4
15MJ	2015	1,3	8	0	5	1
15MK	2014-2015	43,8	7	3	6	3
15ML	2014	44,5	7	3	6	3
15MN	2014	45,7	7	5	6	5
15MO-16MF	2014-2015	176,8	3	8	6	14
15MP	2014-2015	6,3	7	0	6	4
15MQ-16ME	2014-2015	15,2	5	2	5	5
16MG	2014-2015	55	3	2	4	1
9MA	2014-2015	70,9	3	3	4	4
9MB	2014-2015	30,9	3	2	4	4
9MC	2014-2015	13,7	3	2	4	4
9MD	2015	8,3	3	2	4	4
9MF	2015	41	3	2	4	4
6MD	2014-2015	13	4	0	4	4
24MF	2014-2015	48,9	2	2	7	5

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2016	Biosphere-Reserve Wienerwald (Vienna woods) education partner (training)
2015	Ranger training course at the Nationalpark Neusiedlersee-Seewinkel (Fertö-Hánsag)
2009 -2014	Bachelor´s program "Landscape architecture and Landscape planning", University of Life Sciences (BOKU), Vienna
2001- 2009	Highschool, focus Life Sciences, Vienna

Conferences

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Theses

2017-2018	Master Thesis "Movement patterns and use of habitat connectivity in Eastern Green Lizards (*Lacerta viridis*) in the vineyards of Nußberg, Vienna"

Experience

May -June 2018	Population survey of Barn swallows (*Hirundo rustica*) for Vienna´s Nature Conservation Department (MA22)
Since 2017	Research assistant at the *Institute for integrative Nature Conservation Research*, University of Life Sciences
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Summer 2016	8 weeks of Turtle monitoring project on Zakinthos, Greece
Summer 2014	Nature-education-coach for children in Vienna
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