Česká Zemědělská Univerzita v Praze
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Použití geoinformačních metod k analýze vlivu land use na rozšíření druhu Sympecma paedisca.

Diplomová práce

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Použití geoinformačních metod k analýze vlivu land use na rozšíření druhu Sympecma paedisca

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Objectives of thesis

Šídlatka kroužkovaná (Sympecma paedisca) je ohrožený druh vážky vyskytující se v celé střední Evropě útržkovitě na širokém spektrum biotopů. Předchozí pokusy o stanovení příčin ohrožení tohoto druhu vedly pouze ke zjištění, že na základě porovnání lokálních podmínek nedovedeme vysvětlit výskyt / absenci tohoto druhu v prostředí. Cílem této práce je z dostupných dat pomocí geoinformačních programů predikovat rozšíření tohoto druhu na území ČR a s pomocí nástrojů hodnocení typů krajiny analyzovat vliv jednotlivých faktorů na výskyt tohoto druhu.

Methodology

Na základě dostupných dat bude s syužitím programu ArcGIS a jeho nástrojů vytvořen model predikující výskyt tohoto druhu na území ČR Následně bude predikční schopnost modelu verifikována v terénu.

Harmonogram řešení

březen až duben 2018: predikce a ověření výskytu druhu

květen až září 2018: Hodnocení dat, jejich vhodnost a dostatečnost.

říjen až prosinec 2018: analýza dat, závěry,

prosinec 2018 až duben 2019: vlastní zpracování diplomové práce.

The proposed extent of the thesis

40 stran + přílohy

Keywords

Odonata, biodiverzita, land use GIS, Least-cost path, Circuit theory, Zoogeografie

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Recommended information sources

Borisov, S. N. Adaptations of dragonflies (Odonata) under desert conditions. Entomological Review [online]. 2006, 86(5), 534-543

Dolný A., Bárta D., Waldhauser M., Holuša O., Hanel L., et al. (2007). Vážky České republiky: Ekologie, ochrana a rozšíření. Český svaz ochránců přírody Vlašim, 672 s.

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Prohlášení:

Prohlašuji, že jsem závěrečnou práci zpracoval samostatně a že jsem uvedl všechny použité informační zdroje a literaturu. Tato práce ani její podstatná část nebyla předložena k získání jiného nebo stejného akademického titulu.

V Praze:

Podpis

Poděkování

Rád bych poděkoval mému školiteli za ochotu a pomoc během tvorby práce, mé rodině a přátelům za morální podporu.

Abstrakt

Populace šídlatky kroužkované (*Sympecma paedisca*) se nachází pouze na západě České republiky, a to v Karlovarském kraji a části Ústeckého kraje. Je oddělena od ostatních evropských populací Krušnými horami. Cílem této práce je zjistit, zdali je její schopnost disperze v České republice ovlivněna klimatem, nadmořskou výškou a využitím krajiny (landcover). K testování byly použity metody SDM, aplikace ArcGIS, R studio a prostorová data z několika zdrojů. Ze statistických analýz vyplývá, že prezenci signifikantně ovlivňuje jen jehličnatý les. Pomocí dalších metod byla vytvořena predikční mapa prostorového rozložení populace, která se do jisté míry shoduje s pseudo-absenčními daty. To naznačuje, že zemědělská plocha opravdu hraje roli bariery. Tato mapa ukazuje rozložení populace v Karlovarském kraji a tvoří vhodný nástroj pro budoucí odběr, předpovídá možné šíření a určuje místa konfliktu, která by se dále mohla prostudovat.

Klíčová slova: ArcGIS, SDM, Least Cost path, Odonata, GLM, *Sympecma paedisca*

Abstract

Population of winter damselfly (*Sympecma paedisca*) only appears at the west part of the Czech Republic in Karlovarský administrative region and partially Ústecký region. Ore mountains block its connection to other European populations. The goal of this thesis is to find out, if the population disperse ability in Czech Republic is affected by land use, altitude or climate. For testing this hypothesis, SDM, application ArcGIS, R studio and spatial presence data from several sources were used. Statistical analysis shows only Coniferous forest as a significant explanatory value for presence of the species. However, map predicting the population area was also created using ArcGIS methods. Comparing this map with pseudo-absence data, showcases its accuracy and it implies the barrier like effect of the agricultural land cover. This map can be used to find more important sampling sites, figure out possible disperse corridors and it showcases areas for further examination.

Keywords: ArcGIS, SDM, Least cost path, Odonata, GLM, *Sympecma paedisca*

Summary

1. Introduction

Specific distribution of species population is shaped by many factors, be it historical changes, climate, altitude, biome preferences, barriers or limitation by necessary resources in form of food, shelter, water and many others. While trying to distinguish the most prominent factor it is necessary to not underestimate the effect of others, nor the fact that some of the factors have cumulative effect with each other or even more complicated relationships.

Since we are talking about parameters on different scales, with different effects for different organisms and coming from several fields of study it is practical to focus only on several of those aspects and use case by case evaluation of the best possible hypothesis for given distribution.

In the case of this study our working hypothesis, based on the observation of the data, is that this specific population of *Sympecma paedisca* is limited by two kinds of barriers. The high elevation in the north-west section of its population boarder and the significant change in land use and with that change of habitats at the southern section of the boarder. This hypothesis comes from observation of broad distribution of the species on the whole country and Europe, the specific ecological need of water and its ability to disperse because of its flight.

To figure out these questions several ArcGIS methods were used, together with statistical methods in R program using both presence and pseudo-absence datasets. These methods were used to show both prediction of the shape of the population which could be tested in field study and they also show if there is indeed any correlation with the land use of the area.

As said above specific ecological characteristics are necessary for correct analysis as they obviously shape the species distribution and possibilities to migrate. Which is why the first chapter will be dedicated to brief description of *Sympecma paedisca* zoology, dispersal ability and other characteristics.

Next part of the thesis will be given to brief review of several methods of species distribution models to showcase the amount of possible methods and approaches to these problems.

2. Goals of the study

The goal of the study is to determinate if different land cover, specifically agriculture, climate and altitude significantly limits the distribution of isolated population of S. *paedisca*, using the ArcGIS tools and method together with statistical models in R.

Secondary goal is to create a map of the population area, with significant predictability using ArcGIS tools. Using ecological understanding of the species preferences, landcover data from statistical methods and presence data.

3. Species dispersal

Species dispersal is one of the biggest fields of macroecological studies, as this dynamic field covers both evolutionary and ecological phenomena like genetic drift, migration, speciation, endemism and much more. Generally, dispersal is meant to represent the ability of the species to spatially move. Or specifically to move from natal site towards a breeding site. To find the speed, distance, direction and their change depending on aspects of weather, predation and other factors is the goal of dispersal studies. Knowing those parameters allows us to make predictive spatial models which are highly valued for conservation biology (Trakhtenbrot, Nathan, Perry, & Richardson, 2005), protection from invasion species (Alford, Brown, Schwarzkopf, Phillips, & Shine, 2009), zoogeography (Jokiel, 1984) and evolutionary biology (Van Dyck & Baguette, 2005).

It is also important to note, that while some species disperse on a smaller scale then others, this issue is viewed mostly as macro ecological and with that not every dispersal event is noted as important. Rare one-time events, where an accident, for example wind, helps few individual to disperse over a much longer distance only to not be able to survive there, is not particularly easy to model and find out. Even though this could be very much appreciated in invasion studies.

From island biogeography and evolutionary biology, we know that even few individuals can create a new population after dispersal, mostly in isolated “islands” which are often vulnerable to invasion, because of their properties. For modeling speciation events and genetic changes in and between population it is handy to understand the species spatial movement (Jablonski & Roy, 2003; Losos & Glor, 2003). However, dispersal studies do not concern themselves with only new population but also with migration. Modeling the migration patterns, where the population move in a direction towards a specific goal is important for example for finding best land connectivity in conservation biology (Joshi, Vaidyanathan, Mondol, Edgaonkar, & Ramakrishnan, 2013). Even the movement of the individual in his home range, a space in which the individual lives, is part of the dispersal studies.

Dispersal ability is a dynamic parameter, not only it is affected by outside parameters such as the surrounding condition of the environment, but also by the individual and can be viewed as another possibly selected characteristic for natural selection. Often the dispersal ability differs in time for the species, especially if the species goes through a metamorphosis. This is most obvious in autotrophic species, which are generally stationary and disperse only after reproduction (Nathan et al., 2008).

There are several characteristics of the individual that affect animal species distribution the most. Size and the ability to cross many different habitats, could be argued to be the most prominent ones. Based on ecological studies and observation it is known that size of animals will affect maximal size of its home range which offers enough food to sustain them (as well as other resources), this of course applies with various degree. For example large mammal carnivores have much larger home range territory compare to none migratory herbivore, simply because their resource is more elusive (Harestad, Bunnel, & Bunnell, 1979; McNab, 2002). Migratory species have of course much larger spatial distribution, when taken in the account their migration, but they often simple shift their home range while migrating around the direction of their travel making it often even narrower as they spend less time at one particular place.

The ability to cross different types of habitats is a bit harder to generalized, since it depends on many other characters of the species (for example if they have specific diet, many possible enemies, lower defensive capabilities for small changes in environment etc.). Dispersal ability to cross waterbodies or other landscape features generally view as barriers needs to be address here as well, since its heavily influences the disperse ability of the species. Flight is such an important feature for species distribution that it gives opportunity for over ocean migration (Stoddard, Williams, & Marsden, 1983).

3.1 Odonata

The order Odonata is know from Permian time period although morphological similar orders are known from Carbonian era. Their prominent trait of flight was already well developed, and it is not much of a stretch to attribute their relative success to it. Their flight is active and the way their wing morphology develops gives them great mobility. Combined with complex sight in form of compound eyes and grasping legs which are advantageous for catching pray, gives them body of a successful predator linage. They undergo incomplete metamorphosis with several stages each with specific ecological and behavior differences.

The nymphs morphology differs giving their life in water, they differ most prominently by not having wings and having modified mouthparts with the labium being adapted into a clade specific prehensile organ for grasping prey. To undergo metamorphosis the nymph needs to exit the water and find suitable surfaces, often nearby vegetation.

Order Odonata has very complicated reproduction system, not found in any other insects, which results in the male holding the female in a tandem specific trait found only in this order.

Due to their nymph stage living in water the adults also appear near it. Most commonly near fresh water ponds, peat bogs, marshes, lakes and smaller streams, but their ecological strategies don't tied them to it completely as their dispersal capabilities allow them to also live in nearby habitats such as bush lands and forests. (Daly, Doyen, & Purcell, 1998)

3.2 Damselflies

Damselflies (order Zygoptera) appears in late Permian period and their specific traits distinguished them from more robust dragonfly species. Damselfly fold their wings over their abdomen in contrast to dragonflies which rest their wings out to the site or downward. Nymphs of damselfly breathe through external gills on the abdomen, while dragonfly nymphs respire through a pyramid organ in their rectum.

Their life style doesn't differ as much, damselfly nymphs live in water as predators and their adult form uses flight to catch insect pray. There doesn't appear to be any large competitive difference between dragonflies and damselflies even though they occupy similar niches both spatially and ecological, both sub-orders are capable of competing with each other. However this is only in their flying stages, in their larval stages the predation and competition is much greater (Harabiš, Dolný, & Šipoš, 2012a).

3.3 *Sympecma paedisca*

Animalia » Arthropoda » Insecta » Odonata » Lestidae » *Sympecma*

Fig.1: *Sympecma paedisca*

From:http://www.vazky-sokolovska.cz/sidlatky/sidlatka-krouzkovana-sympecma-paedisca/#gallery_12984904-2

Sympecma paedisca (Fig 1.), also known as Siberian winter damselfly, has range as the name suggest in Siberian, but also over European continent, rest of Asia and even Japan. (https://www.iucnredlist.org/species/165459/19166641)

This order most distinguishing feature is their uncommon strategy overcoming winter as imago life stage, which resembles their adult forms morphologically, but it is not capable of reproduction. Using overwintering in combination with their camouflage they spend the cold months of the year waiting on vegetation for the first rise in temperature to use the opportunity to be the first active competition in their respective niche. This of course comes with the price of being very vulnerable to possible predators with good ability to see through their disguise, unintentional disturbance, or even accidental death by big herbivore species, on contrast evading competition in their larval state in ponds possible frozen due to the cold or to avoid winter competition with other larva (Harabiš, Dolný, & Šipoš, 2012b; Manger & Dingemanse, 2009).

For our work there are several characteristics with specific importance to us. The fact of it having two different life styles, one strictly tied to water without the ability to survive on land and without flight, second as flying predator, with complicated usage of various habitats near water such as shrubs and grasslands as foraging areas and water surfaces especially at mating. This time-based usage of different habitat shapes its ecological niche and with it the ability to disperse especially through not as wet landscapes. That said, species have been reported in many habitats like lakes, marshes, gravel pits, fenlands and peat bogs.

One specific characteristic of this species is its overwintering strategy that differs greatly to other Odonata and it’s not exactly common in insect in general. Normally Odonata overcome winter as their larval states in the water, yet this species uses its cryptic coloration capability and survives overwintering period. It finds a suitable vegetation to cling unto and shuts its metabolic processes (Manger & Dingemanse, 2007, 2009).

In Czech Republic, the species is known to have a population at the west border with Germany, most prominently in the Karlovarský administrative region. The species shares its niche with another species of the same genus *Sympecma fusca* and many other Odonata species. The population appears to be isolated from the rest of the European and other populations (Buczyński, Brożonowicz, & Czerniawska-Kusza, 2013).

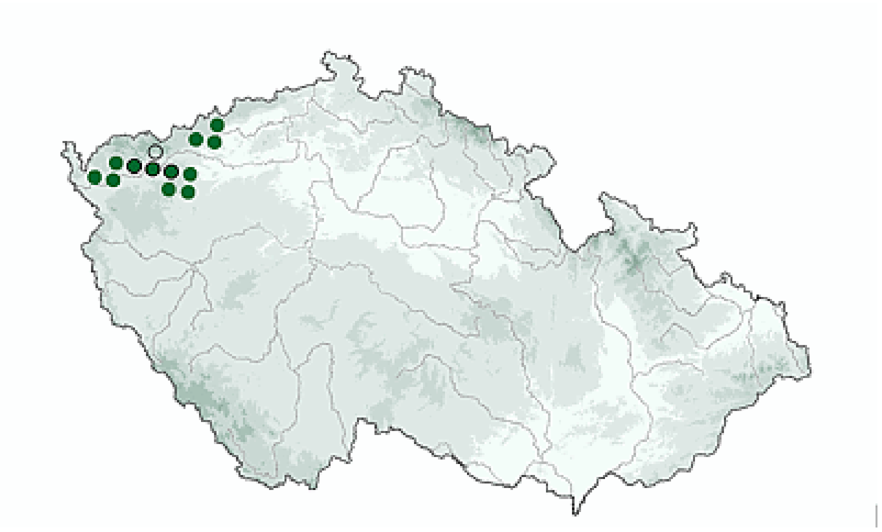
4. Location of the study

Data used in this thesis were gathered from this location, the only known area in which *Sympecma paedisca* was observed in Czech Republic.

For better understanding of the area (Fig. 2.), here we present the description of the location in more detail.

Fig.2 Population area of S. *paedisca*

Ilustrative image of the known sites of Sympecma paedisca in Czech Republic.



http://www.vazky.net/cs/700-sidlatka-krouzkovana---sympecma-paedisca

The biggest part of the studying area in Czech Republic falls in administrative region (Karlovarský) which is located in the north-west part of the country. It boarders with Germany on its west and north, with another Czech region (Plzeňský) at the south, and region (Ústecký) at the east. Here is also located small portion of the study area.

The area of the whole administrative region is 3,315 km^2 which is smaller area compared to other regions in the country, but this region is still rich on different kinds of geology, hydrology, geomorphology, land use and therefore interesting from biological perspective as well. The different between the two regions in which samples were taken isn't as prominent giving the scale and the fact that the overlap is just at the edge.

The population of *Sympecma paedisca* doesn't appear in the whole region, but it covers most of its north and center. Although the population continues partially to Ústecký region, the difference in the characteristics are too small to be relevant.

4.1 Geomorphologic details

As was pointed in the introduction, this region's northern side has higher elevation due to the mountain range of the Ore mountains (Krušné hory). This mountain range from the Hercynian orogeny of the late Paleozoic era, with tallest peak 1 244 m above sea level (Klínovec), is definitely big enough to possibly influence the disperse of *Sympecma paedisca***.** The average altitude is 603 m. After Hercynian orogeny there has been more geomorphological shaping of this area, be it by sea in Mesozoic era, or by ice age event just few thousand years ago.

Ice age changes brought for example new type of habitat of peatbog. The rapid climate changes in the Ice age of course enlarge the areas with permanent ice and snow cover which is now known to be one of the more prominent reasons for the distribution of isolated populations of many taxa. Therefore, it is possible that this population of *Sympecma paedisca* happened to be trapped with this ice cover few thousand years ago. If that is the case, new question arrives as for why now it doesn't disperse to the rest of the country since the ice cover is gone.

4.2 Climatic details

Region is situated at the 50°13′42″N 12°58′00″E in central Europe and with that the annual weather changes accordingly. Average air temperature in this region is 7°C. While it rains on average 70 mm monthly per year.

4.3 Land cover

This region has great amount of forest and agricultural cover, but significant is also unusually large areas of dumps sites from various coal mines. As is common to the country there is also great number of artificial ponds and smaller streams.

Routes, towns and other industrial cover is also permanent here, but in CORINE dataset used in the models it is not as distinguished as other types of cover. (https://land.copernicus.eu/pan-european/corine-land-cover)

5.SDM

Species distribution models (SDM) use broad variety of statistical technics. There have been several dozens of studies in distribution of Odonata alone using many of those methods. Summary of those studies is well presented in a review of (Collins & Mcintyre, 2015).

Here is a table of most common SDM from (Collins & Mcintyre, 2015):

BIOMOD
Generalized linear models
General additive models
MaxEnt
Generalized boosted models
Artificial neural networks
Multivariate adaptive regression splines
Classified tree analysis
Flexible discriminant analysis
Boosted regression trees
Surface range envelopes
Mixture discriminant analysis

From SDM can be extrapolated not only the potential model of the population distribution depending on what other variables were used, but it is also possible to find probable corridors of migration of many species based on the variable. These are important for study of migratory preferences and with that important for conservative study of land connectivity (Ferreras, 2001; Koen, Bowman, Sadowski, & Walpole, 2014; Pelletier et al., 2014).

These models can also point out which areas appear as barriers for the given species and those places can be used in further studies and are also widely use in higher scales to compare species preferences, or to find hotspots (Domisch et al., 2013; Schmalz et al., 2015; Titeux et al., 2010).

Species distribution methods use mostly statistical methods depending on the kind of datasets being used. The most necessary value for SDM is the species presence data. Although problems with how accurate this value is giving the nature of human error are well known and still discuss in paper review. These errors can be diminished by using correctly the best know method for the specific species at the specific and correct time and space, possible controlling the same sample locality to give as much accurate number as possible. These problems mostly concern not the presence itself but the numbers of counted individuals, but it is possible especially for cryptic, small species to be so well hidden that even presence data can be false negative (Phillips, Anderson, & Schapire, 2006).

On the contrary, the value of absence is of course impossible to prove and while presence can be justified by one or two sightings, absence cannot as the species could be always hiding. That said there are instances were absence can be justified, for example small areas which can be thoroughly examine can be considerate with much more certainty but generally speaking locality where the species was not observed should be used as pseudo-absence and thus with less predictable ability (Barbet-Massin, Jiguet, Albert, & Thuiller, 2012).

5.1 GIS

ArcGIS is a geographic information system that can use spatial data to create shapefile layers which can be used in spatial modeling and to create maps. In GIS it is possible to use GPS coordination to create point shapefile, from which distribution models can be made. Using spatial data to visualize the studying area is in itself very helpful and hypothesis can be created from these overviews

Using other available datasets of landcover, climate, annual temperature or other specific spatial datasets can be used to change the disperse direction using Least cost path method, which instead using simple Euclidean distance measurement uses values given to specific parts of any shapefile as additional cost while traveling through them. This visualizes the spatial distribution based on the values chosen. Values are chosen by theoretical prediction from specific hypothesis, and known species preferences, which makes this approach as a predictable model of the distribution map (Driezen, Adriaensen, Rondinini, Doncaster, & Matthysen, 2007; Etherington, 2017; Hall & Beissinger, 2014).

It is possible to extrapolated possible distribution model using other such similar methods like random walk distance, which uses semi-random decision of movement in a cell like grid between several points (Doyle & Snell, 2006).

Circuit method uses the value given to the different categories of the shapefile as not a cost of movement but as a resistance of the category and each cell boarders are used as resistors calculating the overall resistance. This method advantage is the fact it works like electrical grid, where the species is interchangeable from electrical current (H. McRae Dickson, Keitt, & Viral, 2008; McRae, 2006; McRae & Beier, 2007; Pelletier et al., 2014; Spear, Balkenhol, Fortin, McRae, & Scribners, 2010).

All these methods need at least small sample of known presence data to create models surrounding them, but it is possible to create prediction models solely based on hypothesis on special barriers using the Least cost path method to just simply visualized the area showcasing the most costly pathways for the species and then check this model by sampling the areas which are on the boarders of these barriers and/or behind them

Of course for all this it is necessary to figure out exactly what kind of numerical value should those for example landcovers have, how much are they in comparison acting like barriers to the specific species (Watts, Nevin, Ramsey, Stevenson-Holt, & Bellamy, 2014).

Even from GIS programs the end results are often a table which is then used in statistical methods, mostly to find if the species population is affected by the landcover, clime or whatever variation explanation is given.

5. 2 Statistics in SDM

Statistics used in SDM varies in complexity, robustness and other aspect as there is great number of different approaches. Even in R statistical program is possible to use method which use raster or vector-based data for SDM, overlapping in use with GIS, but even basic statistical approaches can be used for SDM.

5.2.1 Regression models

Widely use methods in ecology especially for SDM. Are regression models. At least for now the consensus is that these methods have robust explanatory power, if used correctly on specific data distributions. Their basic description is as follows. This method takes a response variable (e.g. presence– absence, abundance) and set of specific environmental predictors (e.g. climate, land use, altitude). These predictors are related to the response variable and their influence on the data variability is compared to find the most influential predictor.

The basic linear model could be used in SDM, but it depends on the variable distribution, as it must be normally distributed (i.e. Gaussian) and on its variance which not change as a function of the mean (homo-scedasticity). Because of this necessary characteristic its more useful to use Generalized Linear Models (GLM) as this regression model has more flexibility with what distribution the data can have (Guisan, Thuiller, & Zimmermann, 2017).

Other Regressive models used as SDM like GAM and MARS are even more flexible in their use but use more complicated algorithms in the basic GLMs giving slightly different results.

Since these methods are often used together for comparison several R packages were made to compose them, like BIOMOD (https://CRAN.R-project.org/package=biomod2).

6. Methodology

General dispersion of the species is known throughout Europe from several broad population examining studies. There is yet to be found a link of real connectivity between any of those population with the Czech population in west part of the country. Question this thesis is answering is simply at hand. What is the exact boarder of the Czech population of the species? What are its natural and/or human made barriers?

Since we are dealing with an insect species with the ability of active flight its necessary to take in account the possible range of travel of an average individual. Though for more precise data deeper study of the dragonfly flight are needed the home range was extrapolated from this ability (Dolný, Harabiš, & Mižičová, 2014).

The working hypothesis was that the population was blocked by a barrier of landcover, specifically agriculture land and mountains. Just by simple visual comparison of its habitat with the surrounding area we could see the obvious change of terrain and/or elevation. Also because the lack of water in agricultural land (Goertzen & Suhling, 2019). We also put up front the possibility of weather limitation and also the dragonfly need of water and other possibly limiting habitats.

For this study data were gathered from several sources and make a dataset of 135 areas (ponds) with known presence or pseudo-absence of *Sympecma paedisca*. Significant amount was gathered by students, from my supervisor, but some data were taken and also checked from. This dataset was needed to be arranged in Word Excel for usage in ArcGIS, specifically it was necessary to correctly enter GPS coordinates so it could be possible to use ArcGIS function to create points directly from this table.

While presence data are possible to safely assume as accurate, absence data are hard to empirically treat with the same certainty and thus absence is going to be called pseudo-absence and are treated with less of a certainty. Both were in one shapefile points layer but distinguished by color for better visualization.

To gather at least some absence data, the same sources have been used, but absence was extrapolated from the presence data of other Odonata species where *Sympecma paedisca* was not found at that time. In ArcGIS new layout with several freely available shapefiles was created. Using just two administrative regions (Karlovarský & Ústecký). because none sample was outside these regions. as the mask to cut the large Landcover CORINE data from 2012 for much smoother processing.

6.1 GIS landcover

To be more accurate several methods have been used in ArcGIS (ESRI 2011. ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute.) to compare with each other as well as to weaken the bias in the whole process. Methods finding correlation between the landcover use, distribution of the species and altitude were also used.

6.1.1 Method 1 - Grid

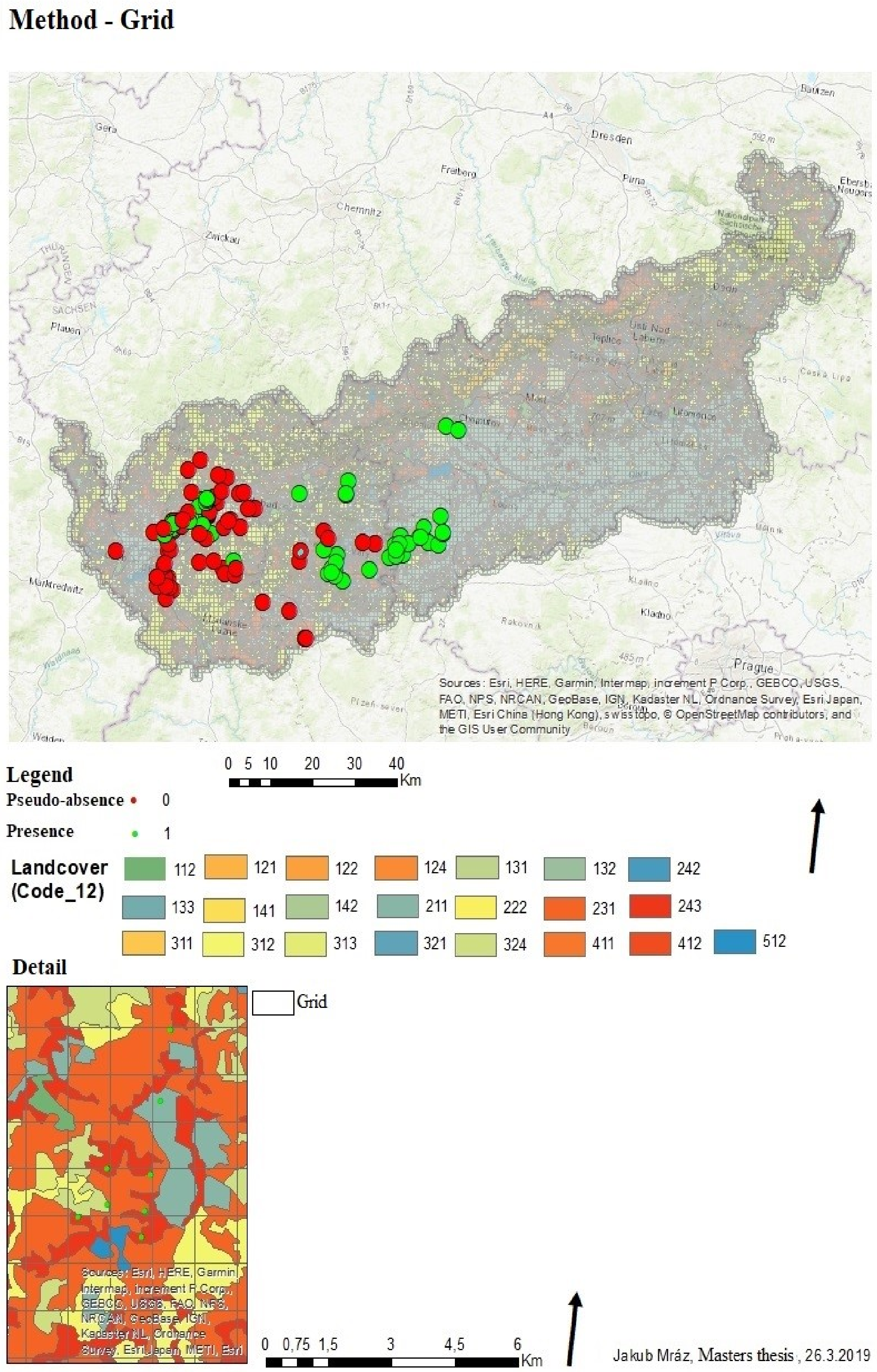
First method used, was creating a vector-based grid with each cell having 1000m x 1000m size, giving it 100ha of area based on the damselfly disperse ability. This was done by Fishnet tool in

ArcGIS. The grid was made bigger then the region, so every piece of land cover was inside a cell. Then it was necessary to correct possible mistakes in the table, by checking the point location directly on the layout. These data were visualized as a point using the X/Y conversion. These species data were now inside of the grid and in land cover shapefile, but for statistical methods it was needed to gather from ArcGIS a table with all the land cover inside of the grid cell and points that belong to each grid cell. For all the shapefiles basic Union method was used, creating the needed table. The result was a table that showed all the sample points, the 100ha cell in which they appear and the areas for different land cover in the cell (Fig.3).

It’s necessary to point out that the grid was not made with the points as its center, making some samples fallen inside the same grid. The grid was made to compare percentage of different landcover in same sized cells.

Fig.3. Method 1 – Grid

Map showcasing the first used method – Grid in which two whole regions were covered in grid with 100ha sized cells. Each cells contains landcovers which were then extrapolated and attachted to the samples of S. paedisca inside the cell. Detail of the grid cell and landcover is also shown.

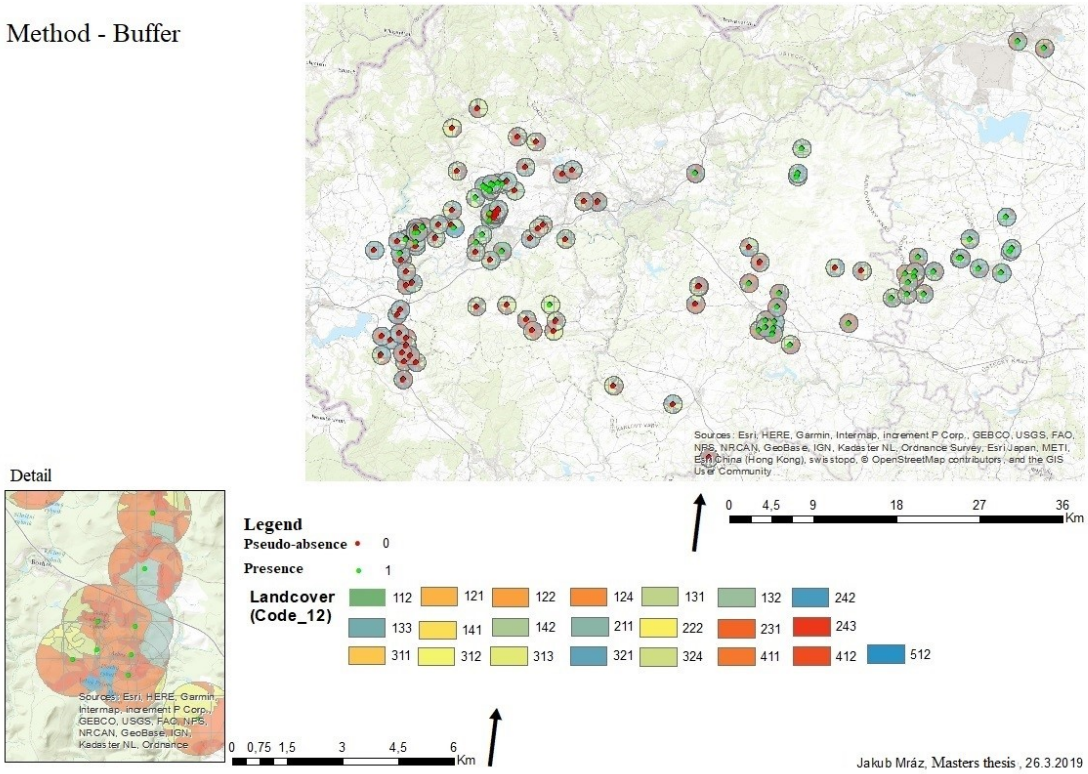


6.1.2 Method 2 - Buffer

Second method is very similar to the first, but instead using the grid and 100Ha big cells, it was made by using the sample location as center of the damselfly possible home-range and so made 1km big buffer around each location, then it was just necessary to join together yet again the buffer home range, landcover and points to create a table with same layout as the first one. While this method treats the sample location as a home range it is unclear if indeed it is a center of the damselfly home range and since pseudo-absence data were treated with the same method, they also happen to be covered by 1km buffer for even comparison (Fig.4).

Fig.4. Method 2- Buffer

Map showcasing the second used method – Buffer. In which every sample site was used as a center for 1km buffer. Buffers were then put together with landcover for further statistical use. Detail shows a detail of the buffer and landcover.



6.1.3 Method 3 – Least cost path

Third method differs, since it was ArcGIS only method, with no need for further statistical correlation method. In this method was first used ArcGIS Polygon to raster tool to create a new raster shapefile of the landcover used in both previous methods and give every different landcover type value of cost to travel across. These values were extrapolated from the known ecological preferences of the damselfly, but since it is not simple to accurately represent the difference for the species to disperse in any giving land cover, several comparative measures were used.

This can already have some useful value in a study of species disperse ability and population location shape. Only just categorizing the raster values in to raster which visualizes the cost to traverse the land cover could be also very helpful for predictions. This visualization is nothing more than reclassification, in this case land cover layer, so it is not in any form a model. More of a tool for better understanding of the hypothesis, which in itself doesn't take from its usefulness in any way.

Using the Path distance as the Least cost path method, in which instead of using Euclidean distance, the value of distance depends also on the value given to it, as the cost to traverse the specific raster category. These values are meant to represent barrier for the species and are derived from known ecological behavior, but in this tool, it is possible to also include points which can indicate where the source of the distance measurement is. Those points act like the starting points for the method and thus the Euclidean distance is still very important.

Values chosen for this thesis were as follows for each landcover: Abundance of land covers from previous methods also played a role in deciding the values. Here is a table of the cost used in the method.

Landcover Code_20	Cost
512,243,511 (Water, diverse shrub vegetation)	1
321,324 (Shrubs)	2
411,412,112 (Wetlands)	3
311,312,313,324 (Forest)	4
131,132 (Dump sites)	5
142,141 (Artificial vegetation areas)	6
222,242 (Agriculture with vegetation)	7
221,231 (Agriculture less diverse)	8
113,111,122,121,124,133,211 (Urban areas)	10

While the general idea of which of those are more suited for distribution of *S. paedisca* could be agreed upon easily based on its ecological preferences, it the degree in which this is represented could be discussed. Here it was used seemingly basic additive point system where each higher category gains additional point to be travestied. This linear change could be replaced by more exponential distribution of values, but that would need more specific explanation on every step of the change and could lead to not as well supported hypothesis. Also giving the scale and size of each sell in raster, the cumulative values grow large enough to show the distribution well.

Reasons for these categorizes are based on ecological preferences. *S. paedisca* is tied to water bodies and hunts in shrubs and bushes, giving those land covers less points. Spoil heap sites were given also smaller point value as they often are not in climax stage, so the vegetation their more resembles shrublands. Forests which often lack the shrubs *S. paedisca* searches for are evaluated higher, but not as high as dry agricultural landcovers and urban areas.

Pseudo-absence was not used in this method, as the method doesn’t work with point-based barriers and created some other barriers from the absence could be too theoretical without any actual justification. Though if more samples with pseudo-absence were present in denser location perhaps some slightly higher value could be given to those areas, using the pseudo-absence as kind of additive bonus of the space acting as barrier, but it was rather decided to not use this in this thesis.

Using the new landcover data, now named as Cost layer, together with the landcover and the sample data several maps were created to visualize the given distribution. Using this method, the values of the maps are additive cost of the travel from the sample points to that particular raster cell. Therefore, this method showcases a prediction of the population boarder shapes using extrapolated from the cost to traverse those areas.

6.2 GIS climate

Though at the beginning of the thesis as stated in the introduction, climate was supposed to be also used as a possible factor for shaping the population of *S. paedisca*, but after further examination of the data it was clear that this was not that valid approach.

Data for climate correlation were not used due to them being in too much different scale. Population of *S. paedisca* in Czech Republic covers only a small area relatively for climate data. Bioclim, commonly used data sets of world climate for SDM happens to operate on global, or perhaps continental scale which for our relatively small population is too broad and it's highly unlikely that this scale could affect the data. Other possible climate data either deal with specific value, like average month temperature, or the monthly rainfall are also too broad for such a study. The difference in the surrounding areas are simply too small to use this data as explanation of this particular population. Though microclimate might play a role in the species disperse ability no comprehensive and valid data for the whole area could be found. Also, the microclimate is highly affected by the landcover, making those two variables intertwine enough to use landcover in of itself.

6.3 Statistics

Tables created in these methods were translated to R statistical program (R Core team, 2013) in which both tables were used to find if variation between presence and absence data in the data is significantly influenced by landcover or altitude.

Method used was GLM, but since the amount of possible factors tested was too great the model wasn't the basic GLM model found in R but Generalized linear mixed model (GLMM), where these were the possible explanatory values for the presence data: Discontinuous urban fabric (112); Industrial or commercial units (121); Road and rail networks and associated land (122); Mineral extraction sites (131); Dump sites (132); Sport and leisure facilities (142); Non-irrigated arable land (211); Fruit trees and berry plantations (222); Pastures (231); Complex cultivation patterns (242); Land principally occupied by agriculture, with significant areas of natural vegetation (243); Broad-leaved forest (311); Coniferous forest (312); Mixed forest (313); Natural grasslands (321); Transitional woodland-shrub (324); Peat bogs (412); Water bodies (512) and altitude.

Here is the model code:

```
model.avg(object = get.models(MA, subset = TRUE))

glmer(formula = Presence ~ &lt;512 unique rhs&gt;, data = pred, family = binomial)
```

	Estimate	Std.Error	Adjusted SE	z value	Pr(>|z|)
312 – Coniferous forest	-1.952e-02	6.911e-03	6.976e-03	2.798	0.00514

Was only significant result from the Buffer method. The Grid method did not bring any significant results.

7. Results

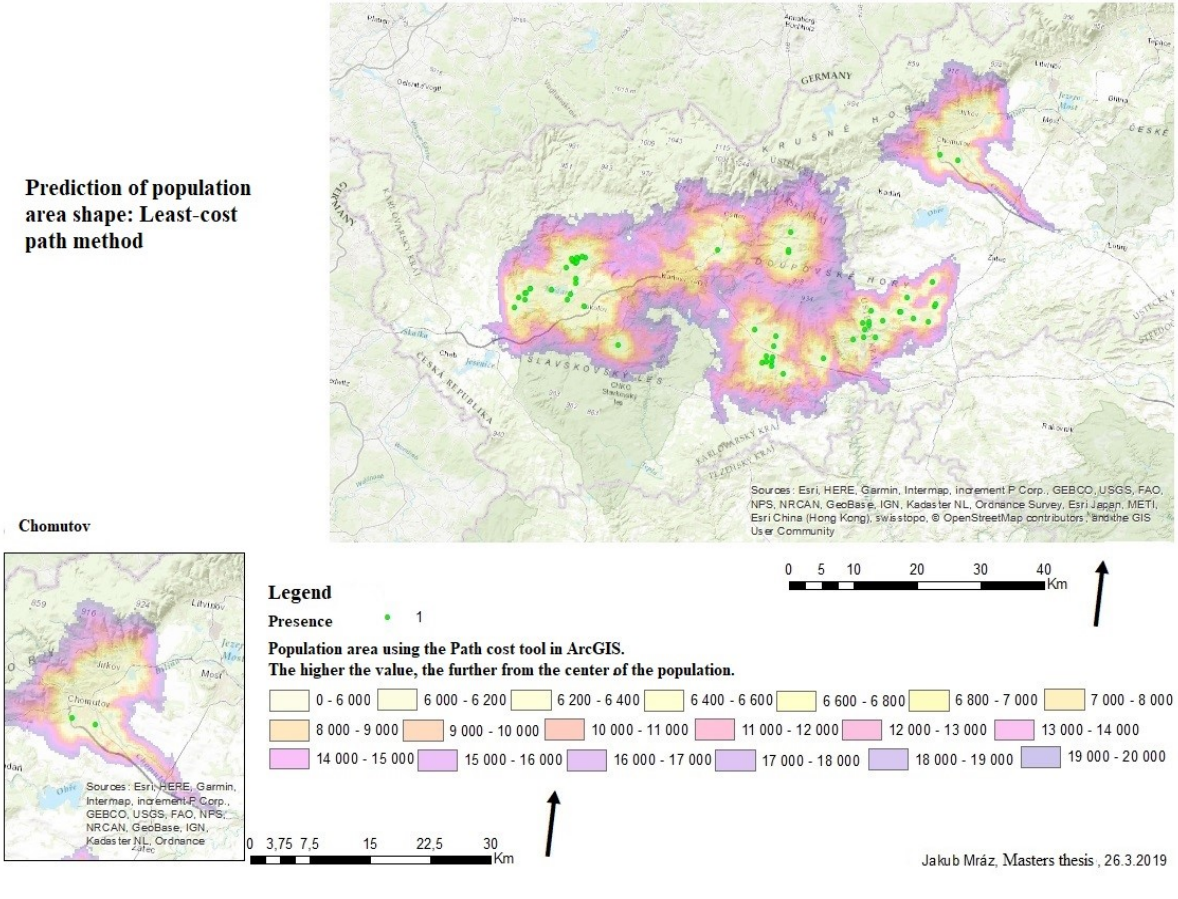
The hypothesis of this thesis was that altitude, climate or land cover shapes the population area. Climate data was not used for several reasons mentioned in Chapter 6.2, while altitude was used even though the difference of each sample was not exactly great and so the focus was on landcover. In statistics altitude was used as another possible variable, together with the sampled landcover data.

The results were unexpected as from both methods (6.1.1 & 6.1.2) only one landcover was shown to be significantly influencing the presence of S. *paedisca* and it was not expected agricultural land, but rather Coniferous forest.

Using the ArcGIS method was more fruitful, as the result is a prediction map of the population area (Fig 5.). The prediction is based on the hypothesis of which landcover should affect the population and the sample data.

Fig.5. Method 3 – Least cost path

Map predicting the general shape of the population of *Sympecma paedisca* using Least-cost Path. In which extra cost was given to different land cover based on the ecological needs of the species. Agricultural land was picked as one of the most costly landcover. Details shows a smaller disjointed population in Chomutov area.



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

8. Discussion

Several questions arise during the study, but the most important is the most obvious, why in the statistical model the agricultural landcover wasn't significant for the presence data when visually and from the Least cost path, the correlation is much clearer.

Several reasons are put in front. The first is that none landcover used in this thesis wasn't define from ecological perspective, but from urban development perspective. Land cover data have specific categories with enough distinguish habitats, but those categories might not be viewed accurately in the field. Smaller patches could be blended to the overall category which surrounds them. Furthermore, the definition of landcover categories in Corine might not line up with biological definition of those habitats. From ecological perspective some landcover are very similar to each other while others are too broad. Because of this, these categories might also not detect finer details which could be significant for ecological evaluation or this species. Although the area of the population appears to be large, it is possible that effects on the finer scale have more significant effect on the dispersal ability. For example, smaller time depended habitats are not visualized. Of course, the land cover data are consistent in the study, but these inconsistencies could be the reason why the results are not as clear (Hou, Burkhard, & Müller, 2013; Luoto, Virkkala, & Heikkinen, 2007; Tomaselli et al., 2013).

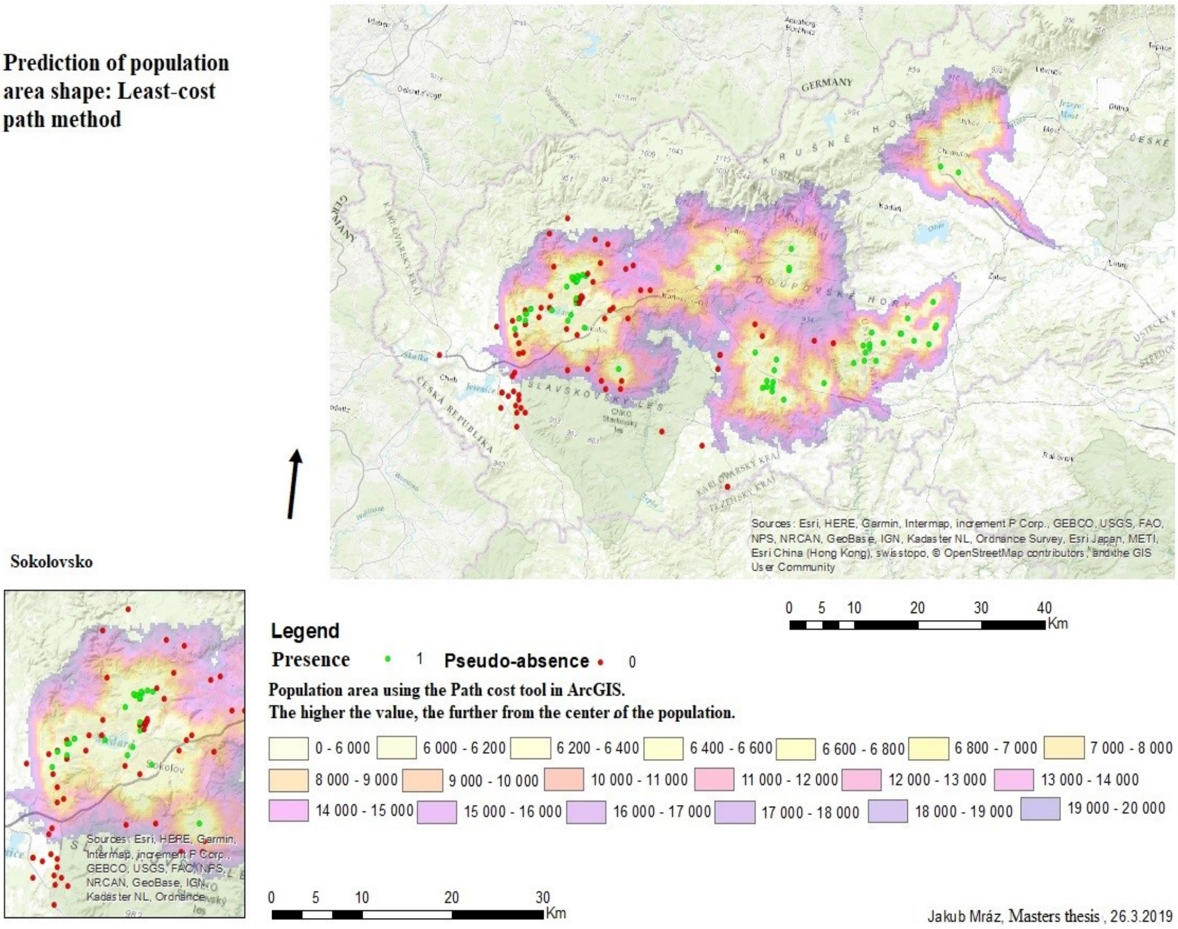
To be more specific, one of the reasons, for this data to not correlate as predicted, is probably the fact that the presence data are mostly taken from a location of spoil heaps. Those have their on specific landcover category, while for our purposes the category is irrelevant only brings more confusion. Not all spoil heaps are in the same condition and often with different covers depending on succession rate. Because some are older than others and have different management (Hodáčová & Prach, 2003) The research of changes in succession of dump sites shows that primary succession comes in forms of vegetation similar to grasslands or shrubs, before trees overgrown the site (Prach, 1987). Which is one of the reasons this category was valued similar to those. However, to see how accurate this comparison depends on the specific condition of the sites.

The reason for why the only land cover showed as significant was the Coniferous forest is probably not because of the habitat itself, but its relationship with the effect of the Ore mountains. While the altitude did not appear to be significant, slope was not tested and correlation between it and the Coniferous forest could be reflected here. Also the suspected agricultural land might not play such a big role as expected due to possible corridors of small natural vegetation patches not recorded in land cover data as suggested here on study of butterflies (Delattre, Pichancourt, Burel, & Kindlmann, 2010).

On the other hand, the GIS method which predicts the population area, could also show another possibility. Comparing the newly made population model with pseudo-absence data points, not used in the method, gives us more insight to the possible problems.

Fig.6. Comparison with pseudo-absence

Here is prediction map compared with pseudo-absence sites to showcase is accuracy and further highlight several areas of interests. Detail shows part of the region with several pseudo-absence points inside the predicted area.



While most pseudo-absence points happen to be further away from the center of the predicted population area, some fit inside. This is probably the reason why the statistical method didn't work as expected. This could be an issue of pseudo-absence being actually just false negative (Barbet-Massin et al., 2012), or the location have different characteristics not focused by this thesis, for example microclimate (Varner & Dearing, 2014). Never the less the prediction model is based on land cover only and it has prediction ability mostly for its boarders, while not taking in the account change in the landcover cost in time for the damselfly, or any other micro ecological characteristics of its disperse ability.

This map could be used as a handful tool for other studies which could focus on several points of interest. The area of the spoils heaps (Sokolovsko), where the pseudo-absence samples fit inside the population area to determinate possible reasons and check if the pseudo-absence is indeed correct. This could generate data for another map with finer scale of just this area.

Another point of interests is the area of Chomutov. Although this area was created using only two sites, it's shape interestingly shows possible dispersal to the opposite direction of the rest of the population. To check the prediction ability of the map, checking the space between the Chomutov and the overall population would be ideal. Of course, figuring out if the suggested dispersal in north and south-east from this smaller population happens. There is yet to be any genetic work done to see the genetic distance between these two groups, but that could give us much clearer idea about their relationship.

To find the overall predictability of this map, it would be ideal to focus on both the boarders of the area and places showcased as inside the easy to disperse area which have no nearby presence samples. The map is not completely connected even at the bigger population, which could be artefact of the values used in visualization. It could also be a real barrier, but one that could be better explored with climatic data or to be more accurate use both climatic data and landcover together. That analysis would have to take in the account the different scales for both these parameters as suggested here (Fournier et al., 2017).

This map also shows, although not directly, the effect of the ore mountains. This is pure visualization, as altitude was not used in this method and it could be argued that this is due to the sampling location which happened to be further from the mountains making the distance more relevant in this case then the fact there are mountains in that direction.

There are still many unknowns that could play role for the species dispersal not mentioned or tested here. Just to name few: effects of wind, competition in other habitats, different predation, pond density etc. Biggest problem of those possible parameters is that their effects operate at different scales. It would also be interesting for this kind of study to find areas in Czech Republic similar to Karlovarský region and see if the reason S. *paedisca* is only here because of some historical event. Many species were affected by the climate changes of the ice age cycles of the Quaternary epoch and S. *Paedisca* could be one of those.

9. Conclusions

The goal of this study was to find if landcover, climate or altitude affects the population of *Sympecma paedisca* size using SDM in R or ArcGIS methods. For various reasons the aim slightly shifted, and it was focused on the landcover, especially agriculture and its effect on the boarded of the population.

While the statistical method used showed that only one cover (312-Coniferous forest) as significant in influencing presence/pseudo-absence of the data. This is unexpected and reason for this were discussed above.

On the other hand, method which uses ArcGIS Path distance tool was used to create a prediction of the population area shape with using landcover as the only influential variable.

This prediction can be used in future studies as a tool for better sampling sites preparation, or to map the boarders more in detail in the field. However, the pseudo-absence used in this thesis partially fit the prediction, they don't completely fit especially in one specific area, but pseudo-absence could be caused as false negative error, making this just another possible use for this model. To find if those places are indeed without the presence of *S. paedisca* and what condition are there for further study. It is highly possible that the population is affected by other unknowns, especially those on finer scale not designed to be judged by ArcGIS base spatial models.

It is safe to say that the population of S. Paedisca is shaped in a way to suggest that Ore mountains and agricultural landcover act like barriers. However, this study mostly showcases the prediction map which needs to be more accurately examine in the field. The effect of Ore mountains was judge by significant statistical importance of Coniferous forest, not slope or altitude. The effect of landcover was judged by comparing the population map with pseudo-absence.

10. Attachments

Fig.1: *Sympecma paedisca*

Fig.2 Population area of S. *paedisca*

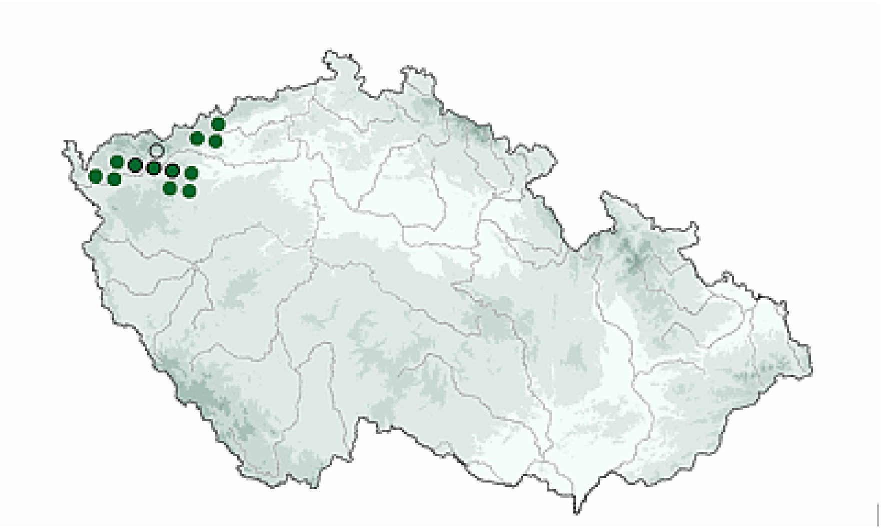


Fig.3. Method 1 – Grid

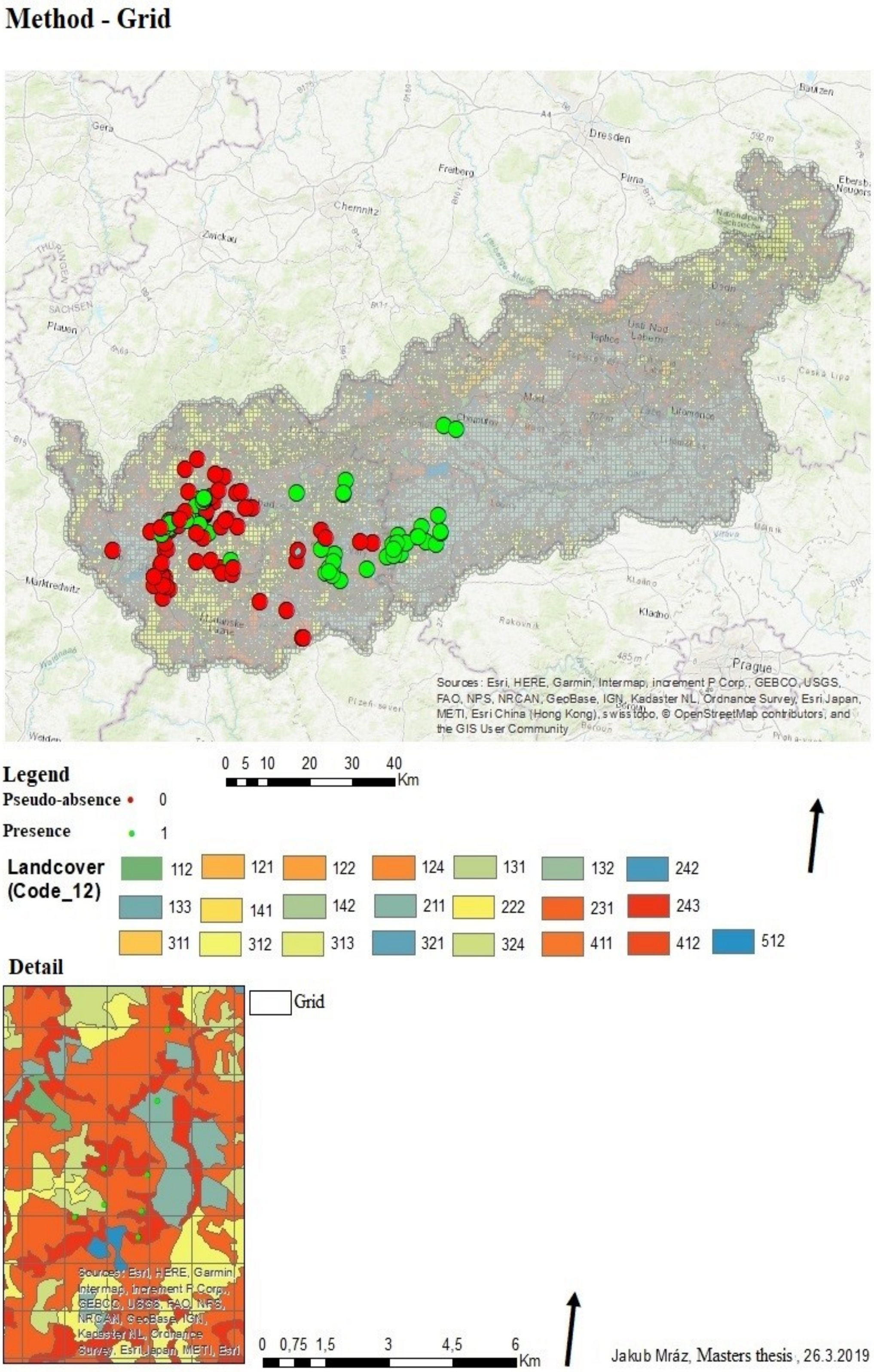


Fig.4. Method 2- Buffer

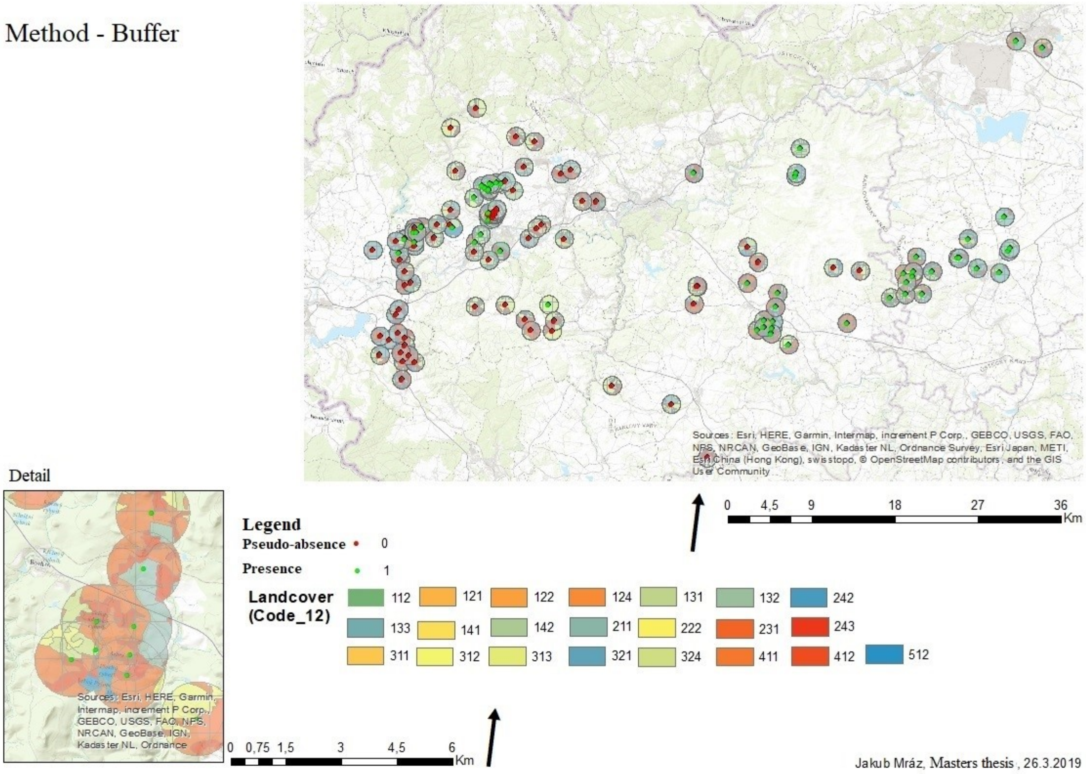


Fig.5. Method 3 – Least cost path

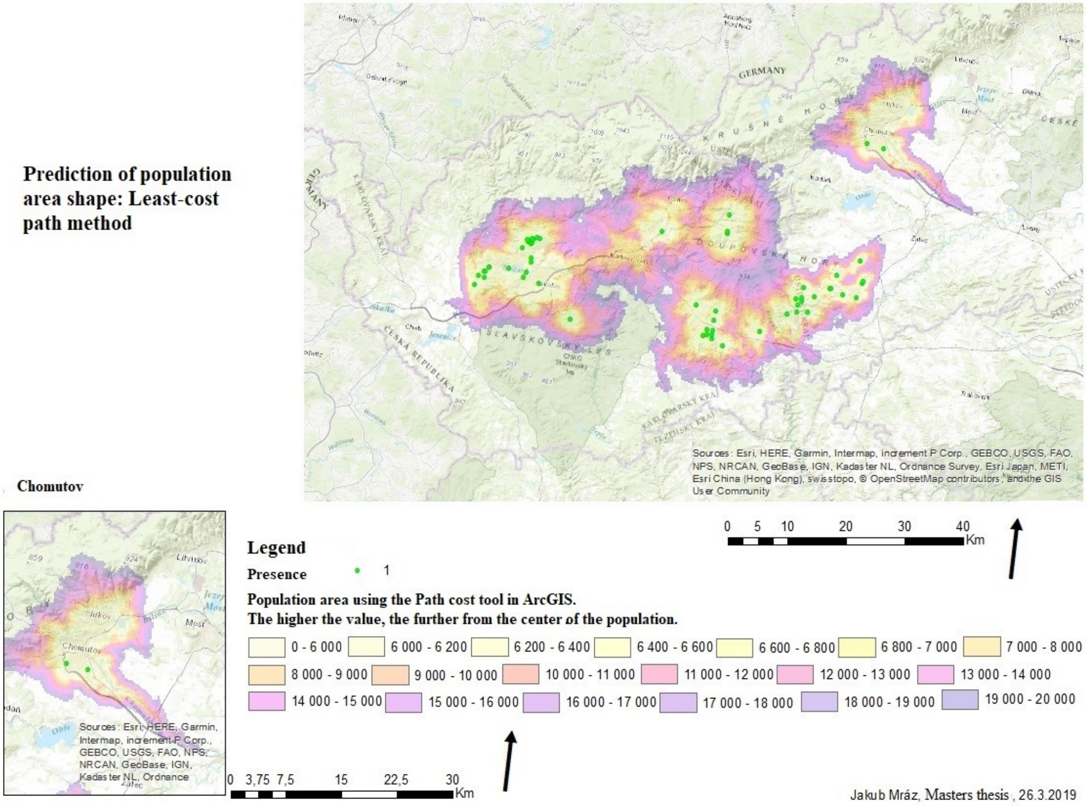
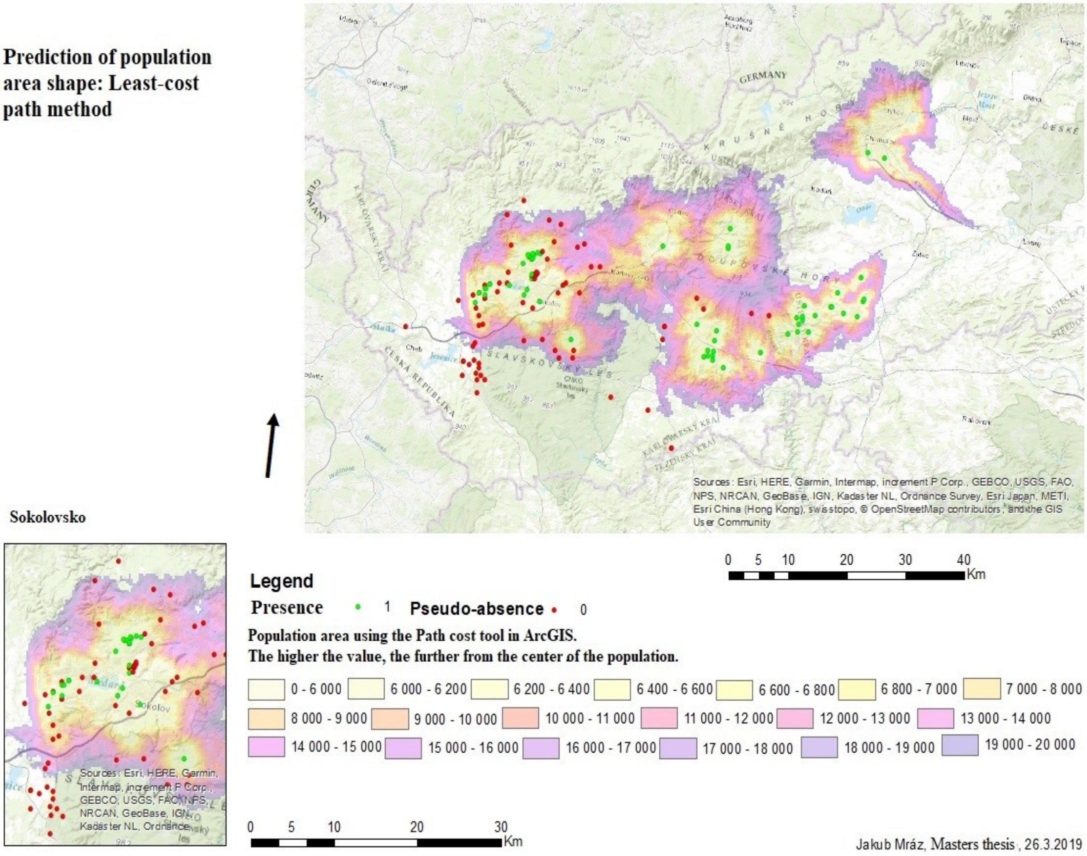


Fig.6. Comparison with pseudo-absence



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