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Analysis of biodiversity spatial patterns across multiple taxa, in Sweden

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Master degree thesis, 30 credits in Physical Geography and Ecosystem Analysis.

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ABSTRACT

While many studies have shown the importance to understand biodiversity patterns, it is still rare to find comparisons of different taxa. The aim of this thesis is to identify the biodiversity distribution of different terrestrial taxa in Swedish municipalities, and analyze the protected areas localization to compare it with our results. This analysis suggests a new environmental planning for townships which have high biodiversity and low protection measures, in order to improve their biodiversity conservation. The Global Biodiversity Information, an online source, is used to obtain data on species presence. This paper focuses on analysis of Fungi, Animals and Plantae, with the help of two software: the R software (R development team 2008) to calculate biodiversity indices, and ArcGIS to analyze biodiversity distribution by municipalities.

Firstly, the species presence data used is analyzed and criticized in order to evaluate its quality and improve collecting methods. Biodiversity patterns within municipalities are measured using biodiversity indices (species richness and Shannon index). The usefulness of these indices is discussed along with the results. The last purpose of this study is to evaluate the match between and the location of protected areas. A measure of overlap of areas of high biodiversity and national parks or natural reserves is realized within ArcGIS, and a proposition of protected areas planning for some townships is suggested to improve biodiversity protection.

Keywords: Geography, Physical Geography, Biodiversity, Geographic Information System, Species Richness, Shannon Index, protected areas, Sweden.

RESUME:

L’objectif de cet article est dans un premier temps d’analyser la répartition de la biodiversité de différents groupes taxonomiques terrestres, à l’échelle des municipalités suédoises. Et dans un deuxième temps d’analyser la localisation des aires protégées afin de comparer leur distribution spatiale avec nos résultats de biodiversité. Ce papier suggère un nouveau plan d’aménagement environnemental pour les communes ayant une importante biodiversité, mais comprenant peu de mesures de protection tels que les parcs nationaux ou les réserves naturelles, afin d’améliorer la conservation de leur biodiversité.
The Global Biodiversity Information est une base de données en ligne, que nous avons utilisée pour collecter les données. Dans cette étude nous nous sommes focalisés sur l’analyse de trois règnes, les champignons, les animaux et les plantes. Pour obtenir des résultats, deux logiciels ont été utilisés : Le logiciel R (R development team 2008) pour calculer les indices de biodiversité, et ArcGIS pour analyser la répartition de la biodiversité des communes suédoises.
Tout d’abord, les données ont été analysées et critiquées afin d’évaluer la qualité des données prélevées sur The Global Biodiversity Information, et améliorer la méthode de collecte. En effet, une évaluation des données inutilisables et des possibles biais qui peuvent fausser les résultats a été élaborée. Ensuite, l’analyse se focalise sur la répartition de la biodiversité des communes suédoises grâce aux indices de biodiversité. La richesse spécifique et l’indice de Shannon, calculés grâce au logiciel R, ont été sélectionnés pour calculer la biodiversité suédoise. Il est fréquent que l’indice de richesse soit combiné avec un indice d’entropie comme l’indice de Shannon, un des plus connu et utilisé par la communauté scientifique pour montrer l’hétérogénéité de la biodiversité d’une aire d’étude. Cette combinaison permet une analyse globale de la distribution de la biodiversité, mais aussi d’évaluer leur efficacité afin d’améliorer la recherche des indices de mesure de la biodiversité. La dernière partie de cet article évalue les résultats obtenus sur la biodiversité et compare sa répartition avec l’actuel distribution des aires protégées suédoises. Une comparaison est alors faite afin de proposer l’aménagement d’aires protégées dans certaines communes pour conserver leur biodiversité.

Mots clés : Géographie, Géographie Physique, Biodiversité, System d’Information Géographique, Indice de richesse, Indice de Shannon, aires protégées, Suède.

Acknowledgment

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Contents

1. INTRODUCTION

Biodiversity loss, mainly a consequence of human activities on Earth's natural system, is accelerating (Millennium Ecosystem Assessment, 2005). Study of biodiversity patterns is necessary in order to understand and improve protection planning of areas that have lost biodiversity or threaten to do so (Eglington, 2012). The Convention on Biological Diversity had set a target to reduce loss of biodiversity at global, regional and local level by 2010 (CBD, 1992). Different indicators have been developed to monitor biodiversity, and other indicators are likely to be improving in future research (BIP, 2010).

Indicators are useful for conservation planning. In fact, measuring biodiversity with biodiversity indicators can help identifying areas with a high biodiversity, and help analyzing its evolution (Eglington, 2012). They are used to evaluate biodiversity loss and are mainly based on evaluation of species richness of different taxa (Vassiliki, 2004). However, different indices exist such as calculation of species turnover, or focus on "keystone" species. These tools are essential for conservationists and manager of protected areas to make decisions (Vassiliki, 2004).

Different levels of diversity exist to measure it, from genes to ecosystems. Three levels of organization can be used to calculate biodiversity, called alpha, beta and gamma diversity. The first scale is genes which determine diversity of species at a local scale in a particular area or habitat. The second scale represents diversity of species within communities. And gamma diversity, which is used to calculate biodiversity in this study, refers to diversity of a landscape, in a region including the history of the land (Halffter, 2013).

To conserve biodiversity, it is important to maintain native species in their habitats, where they have the best chance of survive in the long-term (Rodrigues, 2007). Protected areas are recognized as an effective method in conservation strategies. However, it is an expensive way of preserving biodiversity (Rodrigues, 2007). Conservation planning is limited in available resources (land and money), that is why the planning decisions of theses protected areas must be strategic. Different methods and indicators can be employed to evaluate biodiversity and improve conservation planning (Rodrigues, 2007).

1.1 Aim

This paper focuses on the analysis of biodiversity distribution of different terrestrial taxa in Sweden. Terrestrial species of the three kingdoms (Fungi, Animals, and Plants) were explored. The aim of this study is to analyze biodiversity patterns on the municipalities scale in order to localize areas which may need protected areas plans or new environmental planning to improve biodiversity protection. A voluntary approach of data was used, which imposed limits that we will discuss.

1.2 Objectives

In this study, three main points will be analyzed:

- Firstly, the data used is analyzed and criticized. In this study, data comes from an international database, the Global Biodiversity Information Facility (GBIF, 1996).GBIF permits a free access online to data based on biodiversity. Data is collected by volunteers and is used for scientific research, conservation and sustainable development. Because data is collected on a volunteer basis, it lacks consistency in description and does not allow identifying true absences. However for the purposes of this study it was a valuable resource. Analysis of data quality is realized, with an evaluation of unusable data and possible biases due to volunteers' collection.

- Secondly, an analysis of biodiversity indices, with localization of biodiversity patterns in Sweden, is realized. The programming software R is used to calculate biodiversity indices. Indices are importing on ArcGIS to obtain the repartition of biodiversity by township.

- Thirdly, we analyze of municipality biodiversity to observe if towns with the highest biodiversity indices correspond to municipality with the highest percentage of natural areas in its territory. Proposition of protected areas planning in some township is suggested in order to improve biodiversity protection.

2. BACKGROUND

2.1 Biodiversity definition

The number of species presents in Earth is unknown, and Scientifics estimate species diversity between 10 to 30 million, with approximately 1.4 million species known (Quammen, 1997).
Biodiversity is defined in the Convention on Biological Diversity (CBD) as "*the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species between species and of ecosystems*" (CBD, 1992). Ecosystems are characterized by complex relations and interactions between different species, with a living system open, self-organized, and hierarchical (Lister, 1998). Diversity can be evaluated at different scale, from complete ecosystems (gamma diversity), to the genetic of species (alpha diversity).
Biodiversity undergoes a loss at global level, caused by, land-use changes with habitat loss, degradation and fragmentation, pollutions, over-hunting, invasions of non-native species and climate change (Quammen, 1997). Biodiversity loss engenders a decrease of ecosystem functioning and services (Dana, 2012).
Therefore, it is essential to improve scientific research in this field to preserve biodiversity richness.

2.2 Studies of biodiversity

In addition to its intrinsic value (eg, biodiversity reflects diversity of life on the planet and as such must be preserved), biodiversity has an important role in our society. It supports agriculture, cosmetics, pharmaceuticals, pulp and paper production, horticulture, construction and waste treatment. Moreover, this diversity provides cultural services such as recreation and tourism. Biodiversity is linked to ecological functions, and loss of biodiversity can cause major disruptions in the ecosystem functioning (CBD, 1992).
According to Millenium Assessment, benefits bring by ecosystem services can be divided into four groups: provisioning services, regulating services, cultural services and supporting services (Millennium Ecosystem Assessment, 2005).

Biodiversity is complex and different aspects of it are still debated in many studies, as is its role in ecosystem stability. In fact, some studies suggested that diversity can be a component of ecological mechanisms, and not the driver of this relationship (McCann, 2000). However, according to Fisher, increase species number may have a positive effect by ecosystem functions over time and space (Fisher, 2009). Many analyses observed that biodiversity plays a significant role in providing goods and services (Balvanera et al., 2006). In consequence biodiversity loss may cost a lot to society. Some studies attempt to estimate the economic value of continued loss of biodiversity. Ecosystem services economic valuation techniques has been considered by Belvanera *et al.* in a quantitative assessment: "*Quantifying the evidence for biodiversity effects on ecosystem functioning and services"* provide a grounding meta-analysis of experimental work carried out over last half century, from which emerge that would be extremely costly to reproduce artificially any ecosystem services, assuming that a technological and scientific ability to reproduce those ecosystem services are available (Powledge, 2012). The range varies between 16 and 54 trillion dollars per year, with average estimation of 33 trillion dollars per year[1] (Rapport, 1997).

Ecosystem services interact between them and depend on some components of biodiversity (Pereira, 2006). Species richness and composition are important components of biodiversity, and have a role in supporting and regulating ecosystem services (Pereira, 2006). In this study, species richness and heterogeneity of species distribution are taken in consideration in order to have a global idea of Sweden biodiversity.

2.3 The United Nation's Convention on Biological Diversity (CBD)

One of the most important international commitments to biodiversity protection is the United Nation's Convention on Biological Diversity. The aim of this convention is to conserve biodiversity in the world, and assure an equitable distribution of resources (CBD, 1992).

The CBD was decided in 1992, during the United Nations Conference on Environment and Development in Rio de Janeiro, Brazil. During this conference, "Earth Summit" was signed, with two main agreements: the Convention on Climate change based on the control of targets industrial and other emissions of greenhouse gases, and the Convention on Biological Convention, based on conservation and sustainable use of biodiversity.

Due to the biodiversity treaty, 150 governments, including Sweden, signed to respect the document of Rio conference, and later it was 175 countries joining the agreement.

According to the CBD three main points are important to develop:

- The conservation of biodiversity,
- Sustainable use of the components of biodiversity,
- And sharing the benefits arising from the commercial and other utilization of genetic resources in a fair and equitable way.

With this conference, for the first time conservation of biological diversity appears as "a common concern of humankind". Traditional conservation of ecosystems, species and genetic resource was linked to economy with a sustainable use of biological resource.

[1] Total global gross national product is approximately 18 trillion dollars per year.

The aim of the CBD is to reduce loss of biodiversity at the global, regional and national level (CBD, 1992).

2.4 Biodiversity indicators:

2.4.1 Why biodiversity indicators?

Biodiversity is difficult to quantify because of its complexity. Biodiversity indicators aim at capturing this complexity in a way that allows comparison between different regions. For that reason they can be interesting for many environmental actors such as: national and regional agencies for conservation, agriculture or forestry, who aim to preserve or improve biodiversity, or for international, national or regional non-governmental organizations in biodiversity conservation at different levels and scales analysis, and for the scientific community (Duelli, 2003).

2.4.2 Complexity of biodiversity indicators

In this study biodiversity is approached with two simple indicators, species richness and the Shannon index. Species richness simply is the number of species in a defined area. Species richness is the simplest indicator of species structure and their geographic distribution. But it is essential to associate this index with another, such as Shannon index to have better biodiversity information. The Shannon index informs about the relative distribution of species it calculates, if each one is represented by more or less the same number of individuals. For example, an area with high species richness, but dominates by one or two species, Shannon index will show a lower diversity indicator (Bernes, 1994).
The Shannon index quantifies the "evenness" of a community, which means "*the measure of equality of abundances in a community"* (Alatalo, 1981). In fact, this index identifies the ecological community heterogeneity, which is an important measure of biodiversity for many scientific studies (Duelli, 2003). In many cases, if species richness is high, usually structural diversity will also raised, that is why for some taxa, species richness is correlated with habitat heterogeneity, such as Shannon index (Duelli, 2003).

2.4.3 Biodiversity across taxa

Our study is based focuses on gamma diversity (encompassing many different habitats). According to Tuomisto, biodiversity measurement should be completed by genetic approach. In fact, the "species level" is in some cases too simple and not adequate. New studies suggest integrating phylogenetic relatedness to measure beta diversity (Tuomisto, 2010). By using phylogenetic information, connection between ecological and evolutionary processes can be explored (Tuomisto, 2010). But large-scale information on genetic patterns is still rare, and to find absolute measure of genetic diversity it is more difficult than at species level (Bernes, 1994). For example, equivalent of species richness is really complex to develop because "*genetic variation within a species can rarely be defined unambiguously in terms of a definite number of distinct types*" (Bernes, 1994).

2.5 Study area: Sweden

2.5.1 Climate and physical geography

Sweden ecosystems strongly reflect past climate dynamics (Bernes, 1994). During the last glacial age the country was entirely covered by ice. Only since 15 000 years ago, ice retreated and plants and animal species began to be establish by the Danish Straits. The tundra vegetation was the first on the territory, with large mammals as bison and mammoths. Around 10 000 years ago, temperature increased rapidly, following by birches and pines migration by the South. Then more deciduous trees, such as oak, lime, elm, and ash, established in Sweden. Due to this late wave of vegetation in Sweden, fauna and flora needed time to migrate and adapt to the new climate and this can explain why there is not a lot of endemic species, and why fauna and flora are poorer than some countries of South Europe (Bernes, 1994).

After the ice age, the soil was composed of till and material broken due to the previous movement of the ice. Some material left was minerals, which release calcium, magnesium and similar plant nutrients. That is why the first vegetation was mainly composed of species which need a high level of such nutrients (Bernes, 1994).

Sweden is characterized by plains and low lands and in Northwest, and along Norway there is the Scandinavian mountain range, with an alpine ecosystem. Many lakes, rivers and stream occur throughout the country, which covers an area of approximately 29,400 sq km (Bernes, 1994).

It is covered essentially, at 62 per cent, by forests, mainly pines, fir and larch (CBD, 1992). In southern Sweden, in nemoral zone, it is mainly composed of deciduous trees, with beech as dominant. Up to the North, the boreo-nemoral zone is dominated by conifer forests, composing of *Picea abies* and *Pinus sylvestris*. However, most nemoral tree species, are present in this zone (Diekmann, 1994). Birch grows more to North, but the common species of northerly region is dwarf oak, in Boreal coniferous forests. Boreal forests cover a large part of the country. Plants and animals in these northern forests have adapted to the boreal forest fires. Sweden has about 200 plant species (Bernes, 1994), 84 mammal species (with charismatic large mammals such as bear, lynx, wolverine, elk, moose (Bernes, 1994) and 501 bird species. The two important islands of Sweden, Öland

and Gotland, have specific vegetation due to their limestone soil, which have the specificity of retain for a long time the warmth of the sun (Bernes, 1994).

2.5.2 State biodiversity in Sweden

According to the CBD, Sweden is a country with a poor diversity, with around 55 000 different species. This is due to its relatively short history since last glaciation, and its northern location. Bryophytes and lichens are the taxonomic group with the highest diversity (CBD, 1992).

A lot of Sweden ecosystems are managed by humans, mostly for agriculture and forestry (Bernes, 1994). Agricultural landscapes in southern Sweden support species that cannot be found in the rest of the country, but agricultural intensification is threatening those (Bernes, 1994). During the past 50 years, old farming traditions have been abandoned and replaced by intensive agriculture, with consequences on agricultural landscape diversity. In fact, with this change of agriculture, farming practices have been intensified, fragmentation has increased, and pesticides were more used, which affected species and habitats (Rundlöf, 2008).

Forestry has also impacts on species diversity. Since the 19th century, changes in use of forests have affected biological diversity of forest (Bernes, 1994). However, Sweden counts a lot of forests, and forestry has been increasing. But biodiversity has decreased because of abandonment of forest grazing, due to the density increasing of forests. Lichens, fungi and invertebrates were especially affected to this change of landscape, and some of same had disappeared from the managed forests. For example, in a boreo-nemoral virgin forest species richness is estimated at 8000 species, whereas in a spruce plantation in the same region, only 2000 species will be present. Therefore, some species have been reduced because of planning forests (Bernes, 1994). Moreover the declining of old forests causing also by intense forestry management affects fauna and flora of Sweden. Osprey, goshawk, eagles, and other birds are sensible to this change because they need coarse-stemmed trees to construct their nests. Also, a lot of species such as beetles, butterflies and moths are dependant of old deciduous forests, defined as their habitat. Many threatened species depend on this typical forest, especially in southern and central Sweden where the old deciduous trees are considered as the most important single survival factor for UICN red-list species (Bernes, 1994).

Sweden is affected by air pollution containing sulphur, because this pollutant acidified precipitation, soil and inland waters. This phenomenon has important consequence on soil because with acidification mineral nutrients loss is observed. Indeed, acidification had lead to an impoverishment of the lichen flora especially, but also to some bryophyte and vascular floras. Southern Sweden is particularly affected. However, nitrogen content of emissions has a fertilizer effect on vegetation (Bernes, 1994).

Hydroelectric activity has impacted biodiversity in rivers.

Buildings and infrastructure have modified the landscape and create fragmentation of habitats for species. Species population are isolated and reduced with important effects on biodiversity.

Sweden has around 3500 species on the IUCN red-list of Threatened Species, equivalent at 7 per cent of all species of Sweden (Bernes, 1994). To help conserve these species, ongoing introduction of new species should be controlled and limited, such as in agricultural or horticulture use.

2.5.3 A country engaged in biodiversity protection

Sweden is committed to conservation and protection of biodiversity. According to CBD, Sweden in 1991 adopted different strategy to protect biodiversity. Forestry, Agriculture, fisheries and aquaculture, reindeer herding and the building and physical planning sector, with the CBD was engaged to promote the conservation and sustainable use of biodiversity. Different categories were improved such as: protection of areas with a high biodiversity, especially in natural forests, improving the status of species on the UICN red list, development of regional and international cooperation, development of knowledge with inventories for example, development of methods in long term sustainable use of biodiversity in agriculture, forestry, fisheries.
Moreover, in Goteborg, in 2001, took place, within the framework of the CBD, a European council showing the commitment of Sweden in its biodiversity protection. The objective of this council was examined current trends, exploration of plausible future scenarios and improving efforts at policy and institutional levels to improve conservation and develop new strategies. This includes measures at biodiversity conservation inside and outside protected areas, and limited loss of biodiversity in all economic sectors (Pereira, 2006).

As seen previously, intensive agriculture affects biodiversity of agricultural landscape. European Union acts to reduce negative effect of this agriculture by adopting new agricultural policies (Rundlöf, 2008). In fact, it proposes installation of organic farming organized around rotation of varied crop, with forbidding of pesticides and fertilizers used. Sweden decided to develop this organic farming in order to improve agricultural landscape diversity. However, distribution is not equal on the territory. Most of organic farming are installed in mixed agricultural landscapes, and not in area with the more intensively agriculture (Rundlöf, 2008). Organic farming has a positive effect on heterogeneity, and seems like an important practice to enhance biodiversity.

At national level, the Swedish Environmental Protection Agency aims also to preserve Swedish ecosystems biodiversity and its services. Different measures exist focused on protection of threatened species, limitation of overexploitation of ecosystems, maintaining ecosystem services, limitation of landscape fragmentation (Swedish Environmental Protection Agency, 2013).

3. DATA

This study uses presence data from an online source, The Global Biodiversity Information Facility (GBIF). To ensure consistency in data quality I used only data from GBIF even when other data was available.

3.1 Taxonomic Data

GBIF was established in 2001 by governments of different countries, and is supported by several organizations. Its role is to facilitate the access to biodiversity data over time and space. This initiative focused on voluntary data collection for scientific research, conservation and sustainable development.
The data from GBIF used here comes from the Swedish initiative ArtPortalen, which is a web-based tool for the collection of Swedish species. More than 35 million species have been recorded in the database since the early 2000s. Like GBIF, it is a free access to the data, which is available and accessible to all (yet some sensitive species are not registered). Volunteers (professional and non professional volunteers), from any part of the country, report their observations to inform naturalists and scientists at conservation service. This database is used especially for projects to protect environment, endangered species monitoring, national environmental monitoring, protected areas monitoring, or for “kommun” and other national authorities. Artportalen was developed in cooperation with SLU and ArtDatabanken at the Swedish University of Agricultural Sciences and Norwegian Species Information. Both the Swedish Environmental Protection Agency and the Norwegian Ministry of the Environment contributed to the financing of ArtPortalen. However, the current format of ArtPortalen does not allow downloading of large data files, and most of its data was only accessible through the GBIF website.

Downloading data from GBIF also presented some problems, especially when the size of data for a group was too important. This was the case with the bird data, which remained impossible to download.

As this study focuses on terrestrial ecosystems, we excluded classes composed only of aquatic species. This led to the following classes being analyzed: for Arthropoda phylum, Arachnids class, Entognata class, Insecta class, Chilopoda class and Diplopoda class were analyzed. For Chordata phylum, Amphibians class, Mammals class and Reptiles class were selected.

For Fungi only subkingdom was chosen with Ascomycetes and Basidiomycetes phyla. Chytridiomycetes division, Glomeromycetes class and Zygomycetes class were available on GBIF, but were not selected for our study, because they are cryptic fungi and are difficult to observe.

In the fungi kingdom we obtained three groups:
Ascomycetes class,
Basidiomycetes class,

Amongst animals, seven groups were selected:
Amphibians class,
Arachnids class,
Aves class,
Hexapods subphylum, with Enthognata class and Insecta class in,
Mammals class,
Myriapods subphylum, with Chilopoda class and Diplopoda class in.
Reptiles class.

Amongst plants, there are four groups:
Bryophytes, with Anthocerotophyta class, Bryophytes class and Marchantiophyta class,
Ferns, with Equisetophyta class and Pteridophyta class in,
Lycopods,
Spermatophytes, containing Ginkgophyta class, Gnetophyta class, Magnoliophyta class and Pinophyta class.

This selection offers a variety of taxa to evaluate biodiversity.

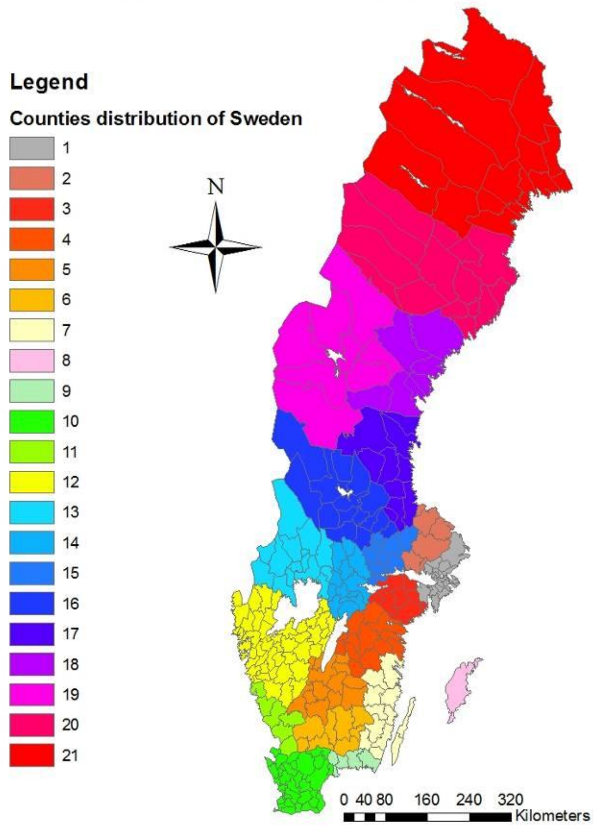
3.2 Geographic data

To localize information, three different maps were used. First, a map with the limits of Swedish municipalities as polygons was downloaded on the website www.arcgis.com (Sverige Kommungränser, 2012). The shapefiles were exported as tabular data (csv). The projection of the map was RT90 2.5gV.
Secondly, the two other maps showing areas where there are national parks or nature reserves were downloaded. They were found on the website www.gis.lst.se, a Swedish website of national pooled stock from county administrative boards. All files of this website are in RT90 2.5gV (Länsstyrelsernas GIS-tjänster. 2013).

3.2.1 Township ("kommun") scale analysis

Township scale was used as it is a fundamental unit of management and policy implementation in Sweden. This analysis level can be useful to improve on conservation and planning strategy for «kommun». Biodiversity indices were analyzed on a municipality scale in order to observe which township should elaborate an efficient conservation planning to protect its biodiversity. In some cases, high biodiversity municipalities are localized in the same area, to simplify distribution, counties names are used to situate these areas (Figure 1). The results of this study can be used for national park or protected areas to see if a link exists between municipalities with high level of biodiversity and municipalities with high percentage of protected area.

<u>Figure 1:</u> Counties distribution of Sweden.

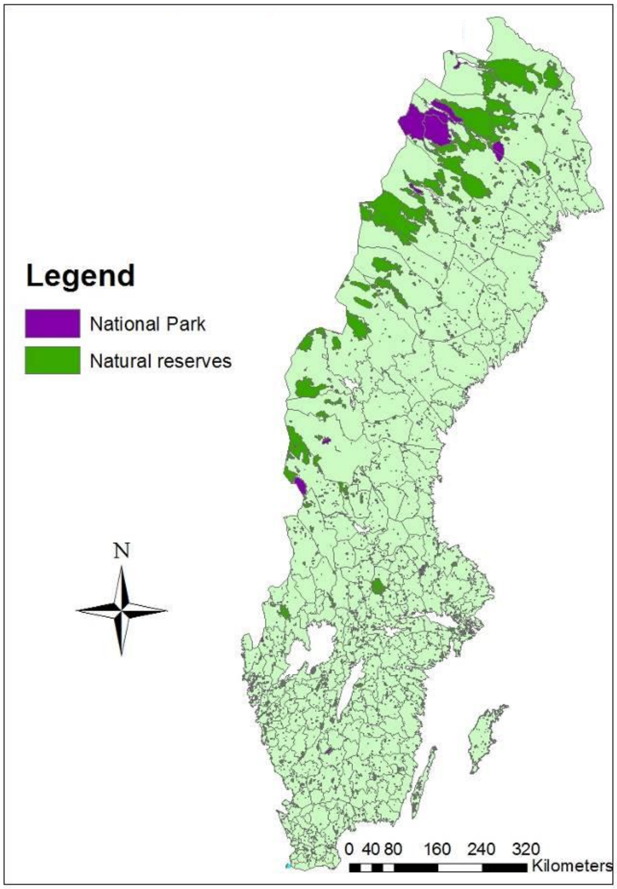


Code	Counties name
1	Stockholm
2	Uppsala
3	Södermanland
4	Östergötland
5	Jönköping
6	Kronoberg
7	Kalmar
8	Gotland
9	Blekinge
10	Skåne
11	Halland
12	Västra Götaland
13	Värmland
14	Örebro
15	Västmanland
16	Dalarna
17	Gävleborg
18	Västernorrland
19	Jämtland
20	Västerbotten
21	Norrbotten

3.2.2 Natural areas

For each township we also calculated the proportional area covered by a national park or a nature reserve (Figure 2). We wanted to know if areas of high biodiversity coincided with areas of high protection, using the township as reference scale.

Figure 2: Distribution of protected areas in Sweden.



<u>4. METHODS</u>

4.1 Materials

Two software were used the R software (R development team 2008) to calculate biodiversity indices, and ArcGIS to analyze spatially the biodiversity by community.

4.1.1 R Software

The R software uses a language and an environment for statistical computing and graphics (R Development Core Team. 2008). R provides a large choice of statistics, including ecology analysis. The software was firstly written by Robert Gentleman and Ross Ihaka, but the current R is a result of collaborative effort with contributions over the world.

R is useful for data manipulation, calculation and graphical display, with a data handling and storage facility, different operators for calculations on arrays, especially for matrices, a collection of intermediate tools for data analysis, graphical facilities for data analysis, and a programming language well developed. Many statistical techniques are installed in R, which can be extended via packages. Eight packages exist with R distribution, and many more are available with the CRAN family of Internet websites (R Development Core Team. 2008).

The packages “vegan” and “diversity” were used to analyze community patterns and calculate biodiversity indices (Oksanen, 2013).

4.1.2 ArcGIS

ArcGIS is the name given to a set of GIS applications, and it is a suite of products from ESRI (Environment Research Institute, Inc.). ArcGis Desktop is used especially for GIS desktop, and contains three applications:

- ArcCatalog, for management, documentation and navigation databases (spatial or not).
- ArcMap to display, create map, edit, query and analyze geographic data.
- ArcToolbox for conversion operations (projection, format) and geoprocessing.

With these tools, all GIS tasks can be effectuated, including mapping, geographic analysis, data management, visualization and geoprocessing (Ormsby, 2010).

4.2 Preparing Data

4.2.1 Triage Data

I downloaded the data for each taxa from the GBIF website. Along with each observation different variables were recorded: collected date, scientific name, country, latitude and longitude. However, the collected date was missing for most of the species, that is why a temporal analysis was not realized. I used collected data over years and years, assuming that general biodiversity patterns have not changed significantly during that period.

4.2.2 Unusable Data

In almost all taxa files, some information was missing or unusable. In fact, for some species, geographic coordinates were not collected, causing the species to be unusable for analysis. Some species were also marked as unidentified. This data cannot be use because the person who found these species was not sure of the scientific name. Some species were registered by their class, order, family or gender, so they could not be used as biodiversity indices, because our analysis focused on species level.

4.2.3 Preparing data for ArcGIS analysis

In order to analyze taxa representation in townships, it was essential to localize the data. I intersected the township map and the biodiversity data in ArcGis 10. This way each township was attributed a number of species points. The resulting data was then exported as csv files to be analyzed.

4.3 Biodiversity indices Analysis

The different csv files were imported to R.
But the data had some problems, such as name of order, family or gender in species name. With R software all entries with wrong species names were removed.
I used an already written function to convert the table for a given group data to a matrix with sites in rows and species in columns, to facilitate the analysis of biodiversity. This function was applied to every taxonomic group. I used the vegan package (Oksanen, 2013) that provides tools to analyze the biodiversity of the different group data.

I used the total number of observation points in a given township to analyze the distribution sampling effort (the number of species observations reported by volunteers).

To estimate the relative abundance of different species, I used the ratio of the number of observations for a given species on the total number of observations. This was the only way to get an idea of the abundance pattern of species when sampling effort (= volunteers) varied greatly. However, it must be noted that a species with many observation points might be reported more often because i) it is more abundant ii) it is easier to observe (detection bias), or iii) more volunteers were interested in reporting this species (expert bias). The total number of observation points per taxa was divided by the area of the township, in order to have the number of points observed per km^2.

4.3.1 Species richness

Species richness refers to the number of biological types of species that can be found in a particular area (Jonathan, 2009). We measured it at the township scale, in order to compare easily biodiversity between different areas, and to suggest biodiversity conservation actions for some township. The index was divided by the area of the township, otherwise species richness is biased, because in major case species richness will be higher in a big township than a little one (more space so more species can be observed). It is more interesting to analyze the index when the area is the same to see which township contain really an important biodiversity.

4.3.2 Corrected species richness

For each taxonomic group, species richness index was corrected in order to remove the influence of the number of observed points. Maps of corrected species richness were created to understand the difference between observation points, which is the number of points identified, and species richness, which is the number of different species represented in community. It can reveal us which municipality seems to be rich in species because of its number of observation points, and conversely which ones appear rich in species but for which GBIF does not have much information about the area. To create this map, the number of different species were divided by the number of observation points, and multiplied by 100 in order to obtain percentages.

4.3.3 Shannon index

The Shannon index, from Claude Shannon who is considered as the creator of this index, is used for ecology analysis, as a measure of biodiversity (Janssen, 2007).
The Shannon index is defined as:

$$H' = -\sum_{i=1}^{S} p_i \log_2 p_i$$

According to Janssen (2007), *H'* represents the absolute amount of information captured, *S* is the number of possible categories, and *pi= ni/N*, the proportion of observations in the i category (i = 1,...,C), where *ni* is the observed number of scores (responses) in category *i* and *N* is the total sample size. A logarithm is used in order to have results as bits per individuals. The higher the index H´ is, the more information exists in the data. When S describes species, higher H' means higher biodiversity in the area. If the distribution among categories is homogeneous, then the optimal amount of information will be present in the area and, H´ will be high, which equals $\log_2 C$. With an equal distribution between different species in the area, Shannon index will be significant as a measure of biodiversity. Also with increase of categories number, H´ increase also, but if in the same time the different categories have a homogeneous distribution, therefore H´ will be at his maximum value.

4.4 Spatial Analysis of biodiversity indices

Biodiversity indices calculated in R were exported to ArcMap in order to create maps of biodiversity indices. To do so I used the "joint" tool in ArcGis 10, between the current map of «kommun» of Sweden and the csv files exported from R.
Observation points, species richness, species richness corrected and Shannon indices were selected to analyze biodiversity per community.

ArcMap was also used to analyze the distribution of national park and natural reserves of Sweden. The aim was to see if the protected areas are localized in township with the higher biodiversity.
An intersect between the map of «kommun» of Sweden and the map with national park was done, in order to obtain the area of national park per community. The result is processed bytownship, therefore it was essential to link the two maps. The same process has been done for the map of natural reserves, an intersect between this map and the map of «kommun». The total sum of these areas was made in order to obtain a value in kilometers of protected areas per municipalities. These values were translated in percentage for a best understanding of numbers.
The total sum of species richness index was performed, to create a general map of biodiversity per township, with all data collection. With this manipulation, we can have a general idea of species richness distribution per municipality.

4.5 Summary

Figure 3: Summary diagram of the methodological process

GBIF → downloading Data

↓

Data selection→ (Animals, Fungi and Plants, municipality scale)

↓

Preparing Data → Remove Data without coordinates or with question marks

↓

Data distribution with ArcGIS → Intersect data with list municipalities to create data per towns

↓

Analyze csv Data create with ArcMap on R software per municipality

↓

Installation of vegan package to create biodiversity indices per municipality

↓

Biodiversity indices distribution on ArcGIS

↓

Intersect tows with national park or natural reserve, to analyze correlation between protected areas and municipality with high biodiversity

5. RESULTS

In this part, I first show the results of data quality analysis, emphasizing the uncertainties encountered, to understand how the data was used and how many per cent of the total of points collected by GBIF was utilized for spatial analysis. The second part focuses on spatial analysis of biodiversity. Distribution of the different taxa per observation points, species richness, corrected species richness and Shannon index are analyzed in order to identify biodiversity hotspot. In the last part, protected areas and high biodiversity areas are compared to understand spatial localization of protection planning with our result.

5.1 Data Analysis

Data analysis is presented in the form of tables. The first column is the name of the group of species, named taxon. The second column is the total of points used without any sort. The third column is the percentage of points that did not have geographic coordinates. These points cannot be used because it cannot be represented spatially, and we do not know at which township it is attached. The fourth column is the percentage of species that contains question marks. These points are unusable because volunteers that collect these species were not sure of the species. To have less bias these points were deleted. The firth column is the total of useful points, accumulated points without geographic coordinates plus points with question marks in the name of species.

5.1.1 Fungi taxonomic group

Table 1: Analysis of data records for fungi

Taxon	Total of points	% without geographic coordinates	% with ?	% unusable	% points for analysis
Ascomycota	352983	15,5	0,16	15,7	77,9
Basidiomycota	887819	4,3	0,38	4,6	91,9
TOTAL	1240802	7,5	0,32	7,8	87,9

Table 1 shows the characteristics of the Fungi group, which accounts 1 240 802 points in total. 7.5% of the fungi data lacked geographic coordinates and 0.32% had question marks in the name of species. Then, 7.8% of the observed points were unusable. When data was located on the "kommun" map, some points were lost due to point's localization that did not correspond to the edges of the map. For example, species identified in sea, lakes, rivers cannot be present on the map because only terrestrial area was considered. Also, if some species coordinate points were not totally equal to the map coordinates,

some borders species can be excluded of the map. In total, 87.9% of fungi data was used for the spatial analysis.
Ascomycetes have 352 983 registered points. In these points, 15.5 % were without geographic coordinates, and 0.16% of points had question marks. Geographic coordinates missing explain mainly the percentage of unusable data, which amounts to 15.7%. In total, 77.9% of the data was used for analysis.
8 87 819 points from basidiomycetes were registered with GBIF. Only 4.3% of the data did not have geographic coordinates, and 0.38% had question marks, therefore 4.6% of points were deleted our analysis. In total, 91.9% of points from this group were utilized for the biodiversity analysis.

5.1.2 Animals taxonomic group

Table 2: Analysis of data records for animals

Taxon	Total of points	% without geographic coordinates	% with ?	% unusable	% points use for analysis
Amphibians	22950	2.1	1.7	3.7	85.3
Arachnids	49597	20.1	1	21.1	71.9
Aves	46019	0	0	0	97.2
Hexapods	254933	0	0.3	0.3	93.5
Mammals	44241	51.5	1.3	52.9	42.0
Myriapods	3006	0.07	1.3	1.4	91.9
Reptiles	4506	2.6	0.5	3.1	87.7
Total	425252	7.8	0.5	8.4	85.5

In table 2, registered points of Animals are represented. In total 425 252 points were reported. 7.8% of these points did not have geographic coordinates and 0.5% contained interrogation point in species name. Consequently, 8.4% of the data was unusable. 85.5% of points were used for spatial analysis.
For Amphibians, 22 950 species were observed by volunteers. 2.1% did not have geographic coordinates, and 1.7% had question marks in species name. 3.7% of the total of points was excluded of analysis. On biodiversity maps, 85.3% of Amphibians data was utilized for analysis.
Arachnids have registered 49 597 points. In these points 20.1% did not have geographic coordinates and 1% had question marks in species name. Therefore, for Arachnids spatial analysis 85.3% of data was used.
For Hexapods, 254 933 points were registered. In these points, 0% did not have geographic coordinates, and 0.3% had question marks. It is only 0.3% of points that were not useful. In total, 93.5% of points were used for spatial analysis.

For Mammals, 44 241 points were downloaded. More than half of the data, 51.5%, did not have geographic coordinates, and 1.3% contained question marks. Consequently, it is 52.9% of points that were unusable. And only 42% were used for indices maps.

3 006 points were registered for Myriapods from GBIF. 0.07% was without geographic coordinates and 1.3% had question marks in species name. In total, 1.4% of observed points were unusable for analysis. 91.9% of this data was localized for following maps in the second and third part of results.

For Reptiles, 4 506 points were downloaded. In these points 2.6% did not have geographic coordinates and 0.5% contained question marks. Therefore, 3.1% of data was not fit to be utilized. And it is 87.7% of points were utilized for biodiversity maps.

5.1.3 Plants taxonomic group

Table 3: Analysis of data records for plants

Taxon	Total of points	% without geographic coordinates	% with ?	% unusable	% points use for analysis
Bryophytes	164262	1.6	0,.5	1.7	96.7
Ferns	48981	3.1	0.01	3.1	90.8
Lycopods	25890	6.8	0.06	6.8	89.7
Spermatophytes	334612	3.1	0.06	3.2	89.4
Total	573745	2.8	0.08	2.9	91.6

In total, 573 745 plant records were downloaded (Table 3). In these group data, 2.9% of points were excluded of the analysis because they were unusable. 91.6% of points from this data were used for biodiversity maps.

Bryophytes have 164 262 registered points. 1.6% points did not have geographic coordinates and 0.15% had question marks in species name. Therefore, it is mainly geographic coordinates missing that can explain 1.7% of data unusable. 96.7% of points were usable for spatial analysis.

For Ferns, 48 981 points were used. From this group, 3.1% of data was unusable. In total, 90.8% of points were used biodiversity maps.

For Lycopods, 25 890 species were collected by volunteers. 6.8% did not have geographic coordinates and 0.06% had question marks. Therefore, it is 6.8% of points unusable. In total, it is 89.7% of points that were used for spatial analysis.

Spermatophytes, 334 612 points were downloaded. From this group, 3.1% did not have geographic coordinates and 0.06% had question marks in species name. Consequently, it is 3.2% of data that cannot be utilized. 91.6% of points were used for maps analysis.

5.1.4 Observation points distribution per kingdom

In this section we analyze the number of records per township to undertand how volunteer effort vary spatially. Before analyzing biodiversity it is important to know which areas favor naturalists, and these observations may help to explain the patterns found for species richness. This analysis is made at kingdom scale, to see if differences exist between fungi, animals and plants in their observation distribution.

In Figure 4, four areas contain mainly observation points of Fungi kingdom: in Gotland, around Stockholm county, in North part of Västra Götaland county, in Rättvik and Leksand. Between 10 and 486 species are collected in these areas. This map shows which municipalities are mainly chosen by naturalist to observe fungi.

In figure 5, naturalists which collected Animals kingdom are localized in the South of Sweden (Skåne, Kalmar, Blekinge, Halland) but also in Gotland, around Stockholm town (Stockholm county, Uppsala county, Södermanland county, and Östergötland county), and in Dalarna county. These four areas are a lot observed by volunteers, between 1 and 66 species collected per km^2.

In Figure 6, it is also four areas favor by naturalist for Plants collection. The two islands, Gotland and Öland, and Dalarna county, with Rättvik and Leksand municipalities, contain a lot of observation points, between 10 and 71 species per km^2 collected. Two other counties appear with a lot of observation points: Västra Götaland county and Södermanland county.

To conclude, Fungi, Animals and Plants have some similar observations points distribution that volunteers favor, even if in details differences appear. In general, the two islands, Gotland and Öland, around Stockholm town, and in Dalarna county, a lot of species are collected, which mean that it is likely the main areas where naturalists go to observed species.

Figure 4: Distribution of Fungi observation points sum per km^2 in Swedish municipalities.

Figure 5: Distribution of Animals observation points sum per km^2 in Swedish municipalities.

Figure 6: Distribution of Plants observation points sum per km^2 in Swedish municipalities.

Figure 4:

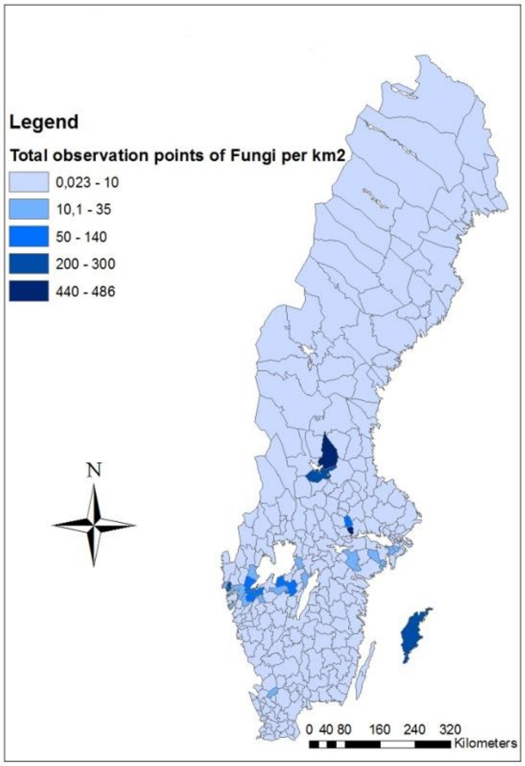


Figure 5:

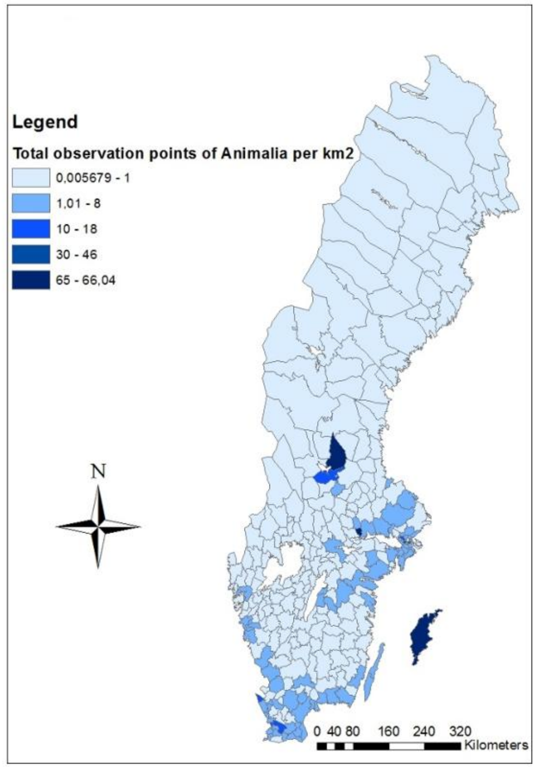
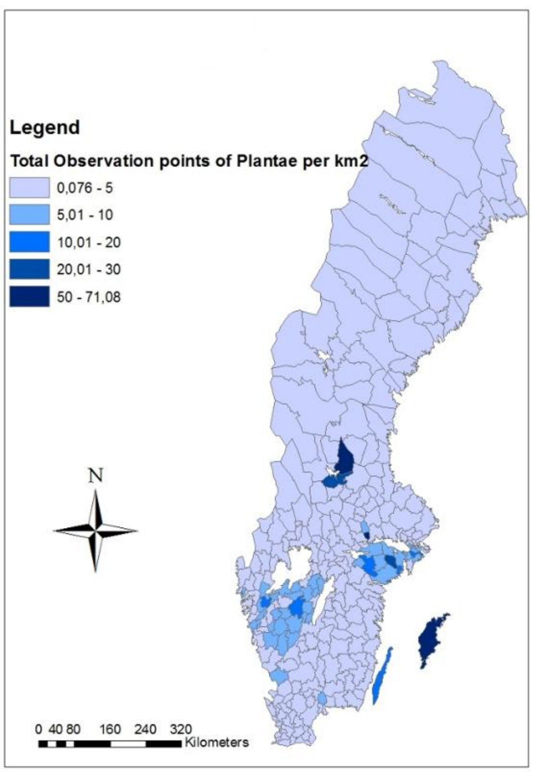


Figure 6:



5.2 Spatial analysis of Biodiversity

5.2.1 Fungi

- **Ascomycetes**

This set of four maps analyzes the biodiversity of ascomycetes, per municipality. The first map shows distribution of observation points, and four “kommun” have more than 100 species identified per km^2 (to 100 to 176.6 species). The main observed townships are Rättvik, Leksand, Hallstahammar and Gotland. The second map illustrated the species richness of ascomycetes. Three municipalities are distinguished by their biodiversity, between 13 and more than 33 species different per km^2 for the highest. Ascomycetes seems to be a lot observed in all Sweden, except for the West coast of Skåne which does not have a lot of observation points compare to the number of species.
Figure 9 reveals that corrected richness distribution does not correspond to species richness index distribution. In fact, high values illustrate the real species richness, without influence of observation points. Skåne, Västra Götaland, Örebro, Dalarna, Gävleborg, the South of Jämtland and Norrbotten seem to be the counties with the highest biodiversity. Figure 9 defines the real species richness, removing bias of volunteers’ observations method.
The fourth map analyzes heterogeneity distribution of species with Shannon index. This index is really high, between 1.5 and 5.05 for all municipalities of Sweden. This is due to the important number of species and its equal distribution per area.

Figure 7: Distribution of Ascomycota Observation points per km^2 in Sweden.
Figure 8: Distribution of Ascomycota Species Richness per km^2 in Sweden.
Figure 9: Distribution of Species Richness per Observation points of Ascomycota in % per municipalities of Sweden.
Figure 10: Distribution of Ascomycota Shannon index per “kommun”

Figure 7:

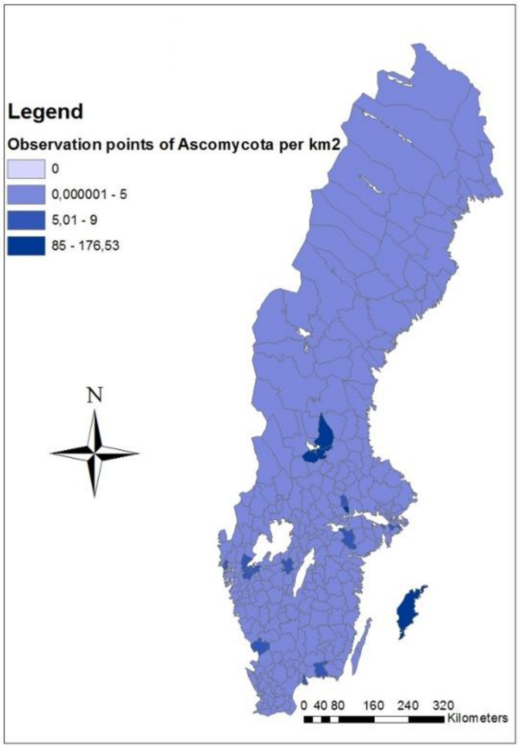


Figure 8:

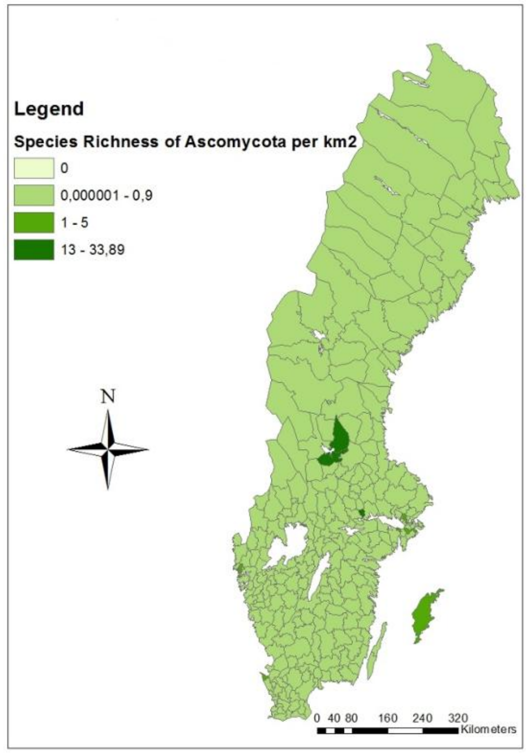


Figure 9:

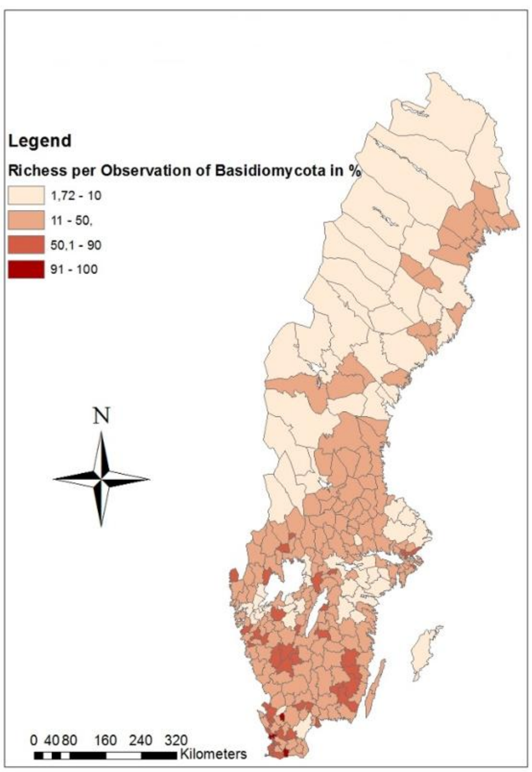
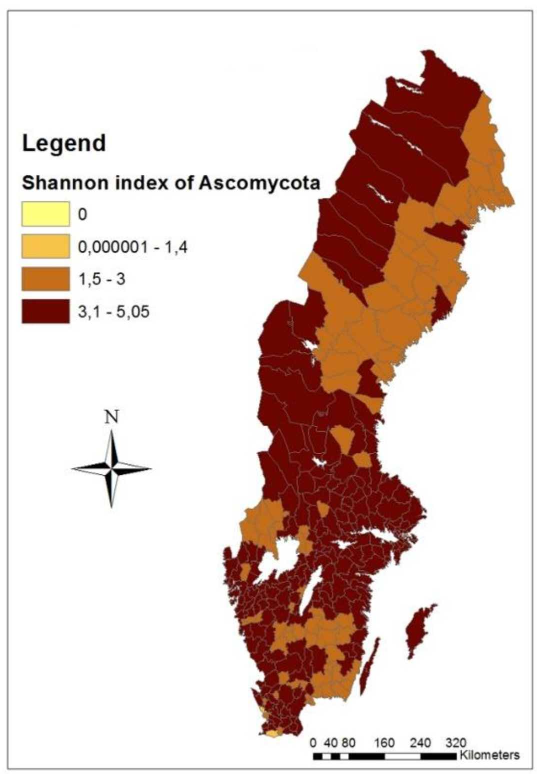


Figure 10:



- **Basidiomycetes**

The fourth maps analyze biodiversity of Basidiomycetes. This group contains many observations, and is distributed in all Sweden. Some municipalities have between 51 and 150 observed points, and Rättvik, Leksand, Hallstahammar, and Lysekil account between 151 and 384.16 observed points. Some counties are distinguished by their species richness index such as Skåne, Västra Götaland, Gotland, Stockholm and Dalarna. Hallstahammar has particularly high species richness, with 73.96 different species per km^2.
The figure 13 shows where there is high percentage of corrected richness. The real Basidiomycetes richness is mainly situated in the South part of Sweden, especially in Skåne, Kalmar and Västra Götaland. Conversely, the North part of Sweden, Gotland, Uppsala and Södermanland count a lot of observation points without having high biodiversity.

Such as Ascomycetes, Shannon index is important; almost all towns have an index between 4 and more than 6 (except for some areas in the northern). The South part of Sweden accounts the highest Shannon indices (between 5 and 6, 35).

Figure 11: Distribution of Basidiomycota Observation points per km^2 in Sweden.
Figure 12: Distribution of Basidiomycota Species Richness per km^2 in Sweden.
Figure 13: Distribution of Species Richness per Observation points of Basidiomycota in % per municipalities of Sweden.
Figure 14: Distribution of Basidiomycota Shannon index per “kommun”.

Figure 11:

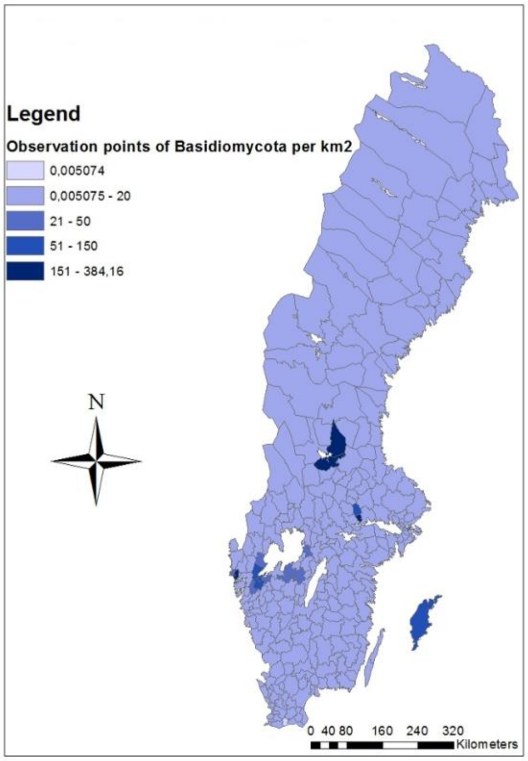


Figure 12:

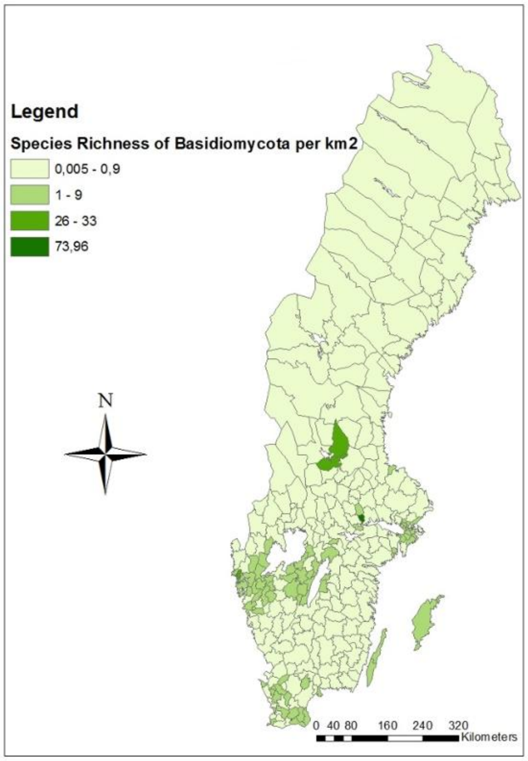


Figure 13:

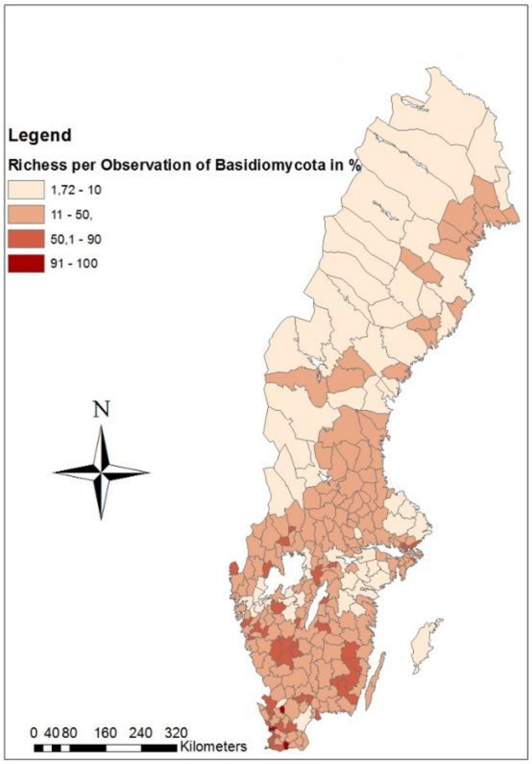
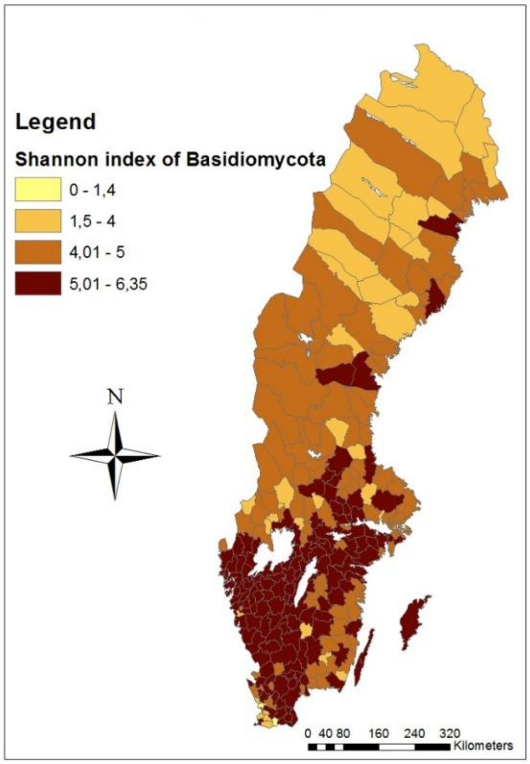


Figure 14:



5.2.2 Animals

- **Amphibians**

These fourth maps analyze Amphibians biodiversity repartition. Figure 15 and Figure 16 have similar distribution of species, except for the South, in Skåne and Mörbylånga municipalities, where there are highest numbers of observation points located, with around 4 species observed per km^2. Species richness values are low, with a maximum at only 0.5 species per km^2 for Hallstahammar.

In figure 17, real species richness is the most important in Dalarna, northern Skåne, southern Kronoberg, and in some municipalities of Västra Götaland and Norrbotten counties. However, Uppsala, Kalmar and Gotland register a lot of observation points but do not have high biodiversity.

Even if Shannon index is not really high, with a maximum at 1.96, two areas confirm their high biodiversity: the South of Skåne and Kronoberg.

Figure 15: Distribution of Amphibia Observation points per km^2 in Sweden.

Figure 16: Distribution of Amphibia Species Richness per km^2 in Sweden.

Figure 17: Distribution of Species Richness per Observation points of Amphibia in % per municipalities of Sweden.

Figure 18: Distribution of Amphibia Shannon index per “kommun”

Figure 15:

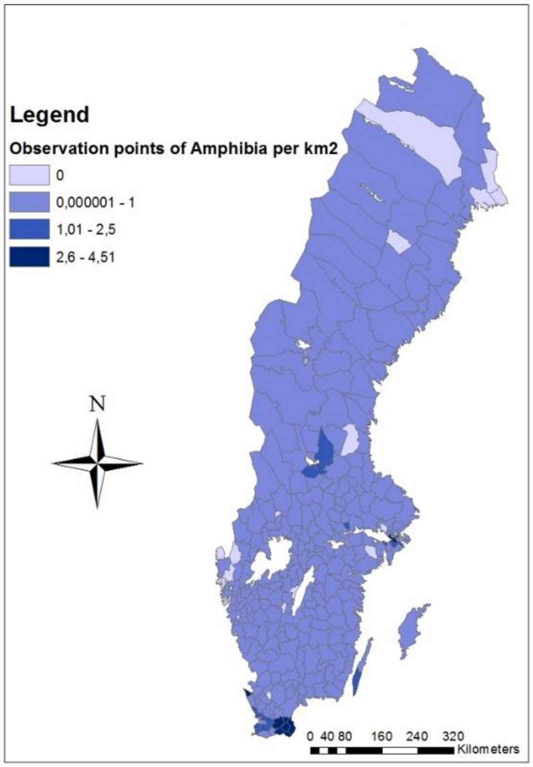


Figure 16:

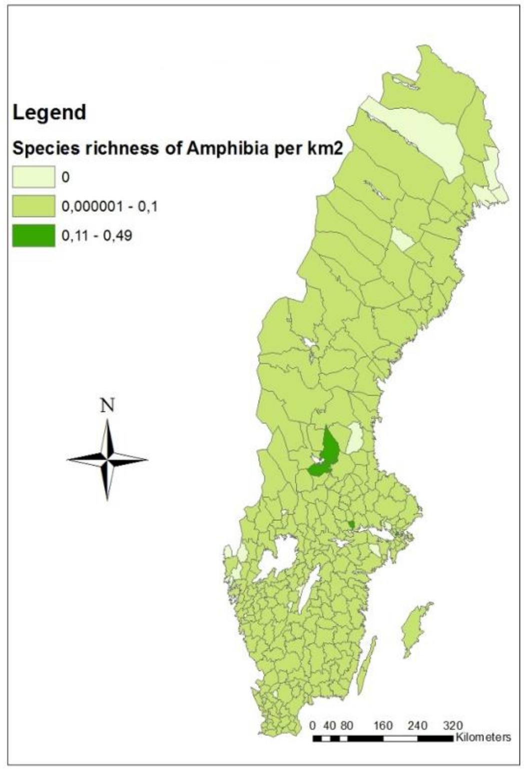


Figure 17:

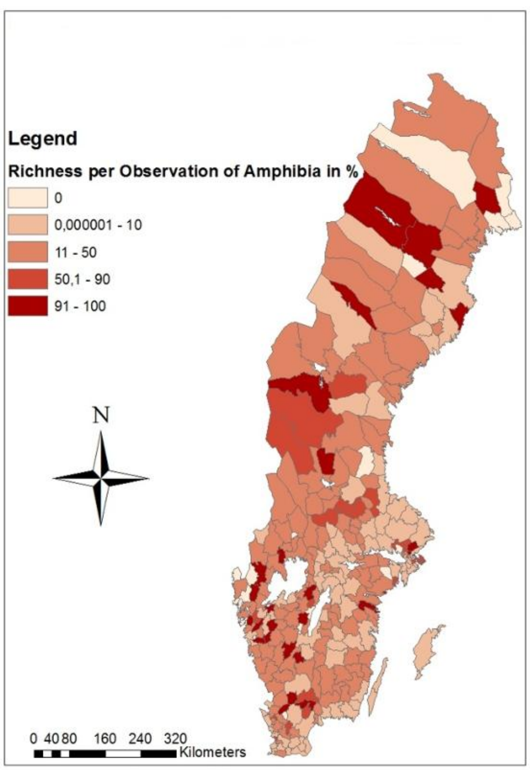
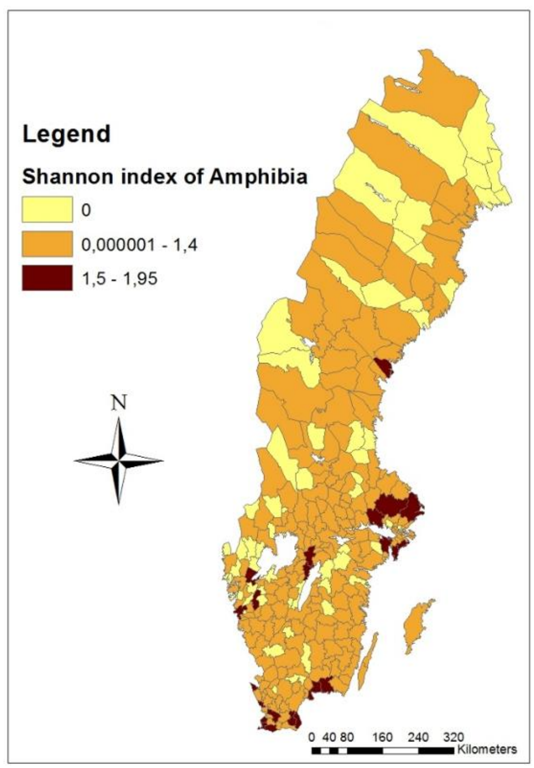


Figure 18:



- Mammals

In this example, only 42% of Mammals data was used to create these maps, that is why biodiversity spatial analysis cannot be relevant. However, we can observe that three municipalities are characterized by their species richness index, Rättvik, Leksand and Hallstahammar, with a maximum of 1.6 species per km^2.
Figure 21 illustrates three main areas with high biodiversity thanks to corrected species richness: in the southwest with Västra Götaland and Värmland counties, in the center East in Gävleborg county, and in the northern in Norrbotten county. Yet, Västra Götaland does not have high Shannon index, meaning that its species are not equally distributed in the area.

Figure 19: Distribution of Mammalia Observation points per km^2 in Sweden.
Figure 20: Distribution of Mammalia Species Richness per km^2 in Sweden.
Figure 21: Distribution of Species Richness per Observation points of Mammalia in % per municipalities of Sweden.
Figure 22: Distribution of Mammalia Shannon index per “kommun”.

Figure 19:

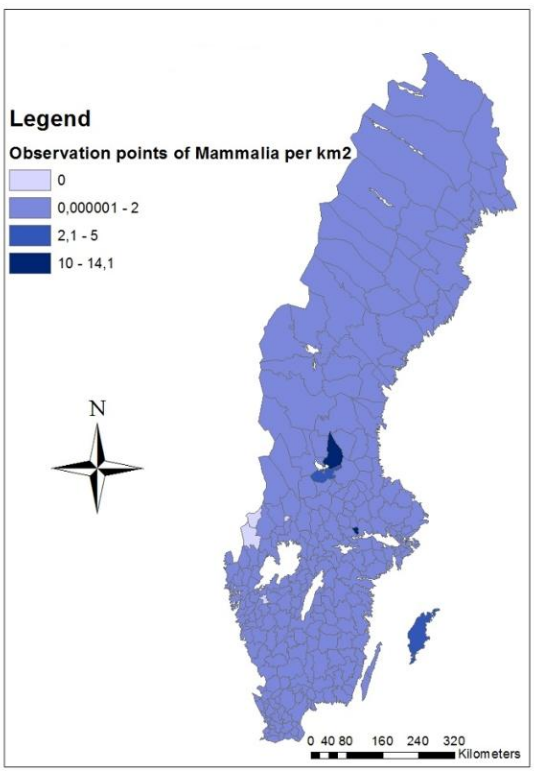


Figure 20:

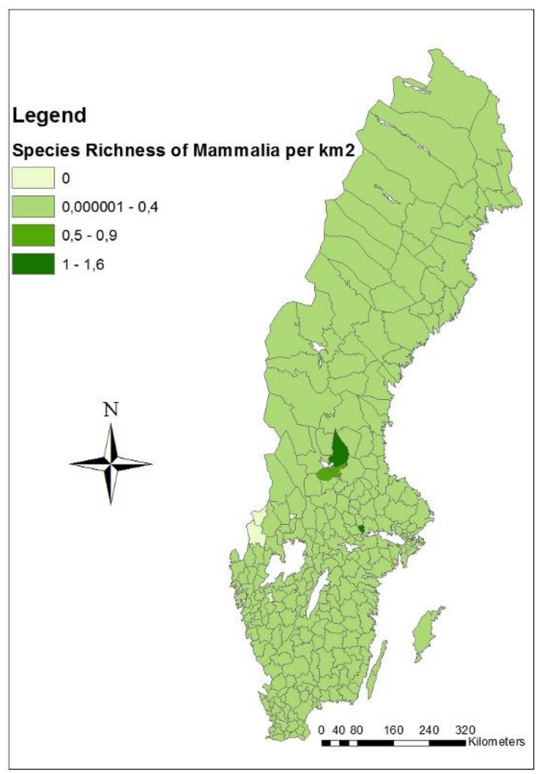


Figure 21:

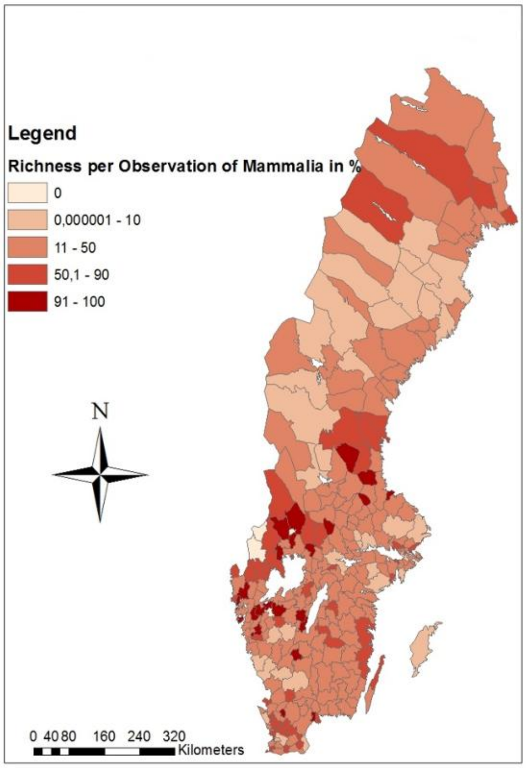
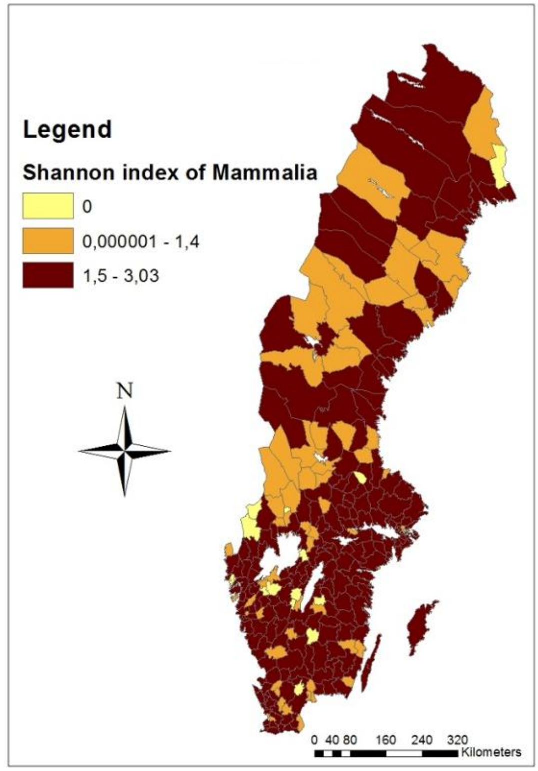


Figure 22:



- Reptiles

The three Chordata Phylum, Amphibians, Mammals and Reptiles, show a quite similar biodiversity distribution, with the same counties and almost the same municipalities with high species richness index.
Figure 25 illustrates the real species richness distribution, which is concentrated in Norrbotten, Dalarna, Västra Götaland, northern of Skåne and southern Kronoberg.
Gotland and the mountain range of Sweden have a lot of observation points compared to their corrected species richness.
Shannon index is quite low, with a maximum of 1.67. In fact, heterogeneity distribution begins to be proportional when the index is higher than 1.5.

Figure 23: Distribution of Reptilia Observation points per km^2 in Sweden.
Figure 24: Distribution of Reptilia Species Richness per km^2 in Sweden.
Figure 25: Distribution of Species Richness per Observation points of Reptilia in % per municipalities of Sweden.
Figure 26: Distribution of Reptilia Shannon index per “kommun”

Figure 23:

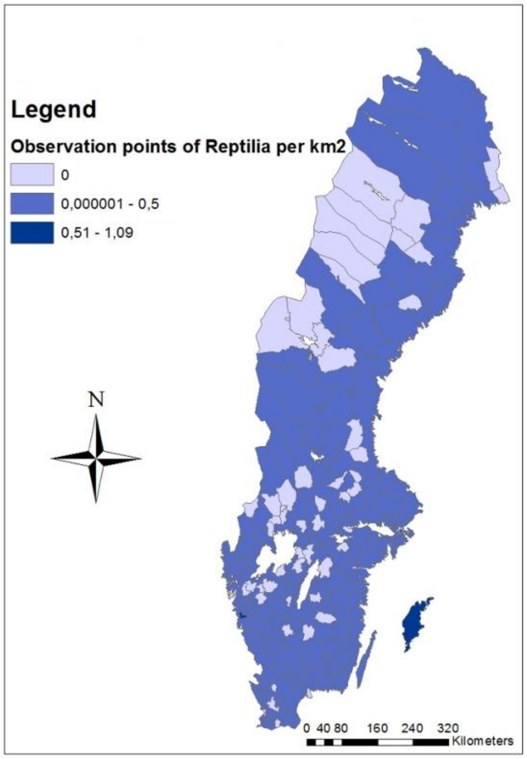


Figure 24:

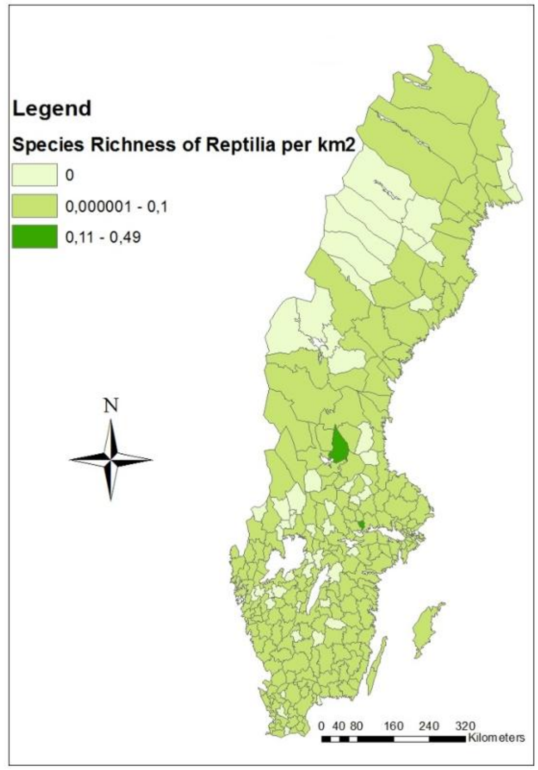


Figure 25:

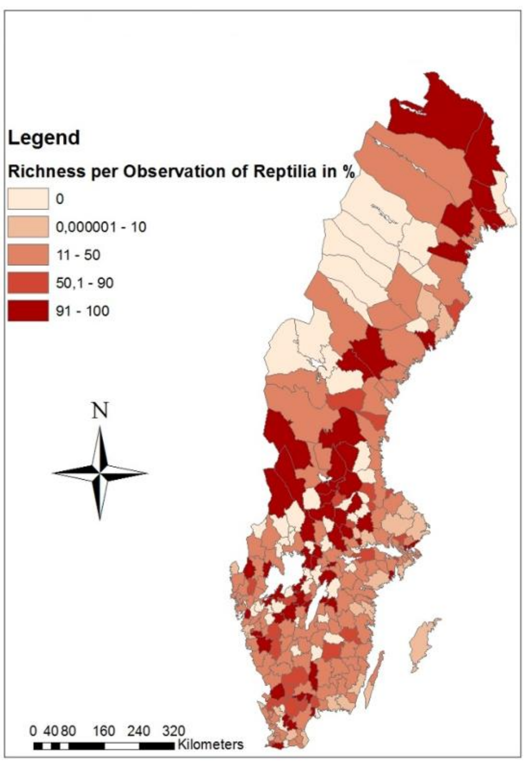
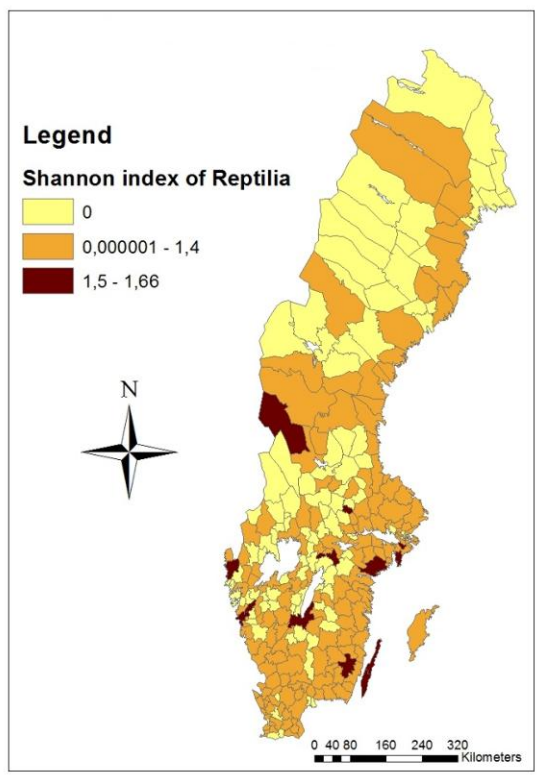


Figure 26:



- Arachnids

Arachnids are distributed over almost the whole of Sweden, with several species observed per km^2. The maximum is more than 20 species observed for Gotland and Rättvik. Observation points, species richness index, and corrected species richness have a quite similar distribution, with high biodiversity in all Sweden However for Gotland, Uppsala and Östergötland, corrected species richness is low whereas a lot of volunteers collected Arachnids data in these areas.
Shannon index show high value of heterogeneity, with more than half of the country with a Shannon index between 1.5 and 5.48.

Figure 27: Distribution of Arachnida Observation points per km^2 in Sweden.
Figure 28: Distribution of Arachnida Species Richness per km^2 in Sweden.
Figure 29: Distribution of Species Richness per Observation points of Arachnida in % per municipalities of Sweden.
Figure 30: Distribution of Arachnida Shannon index per "kommun".

Figure 27:

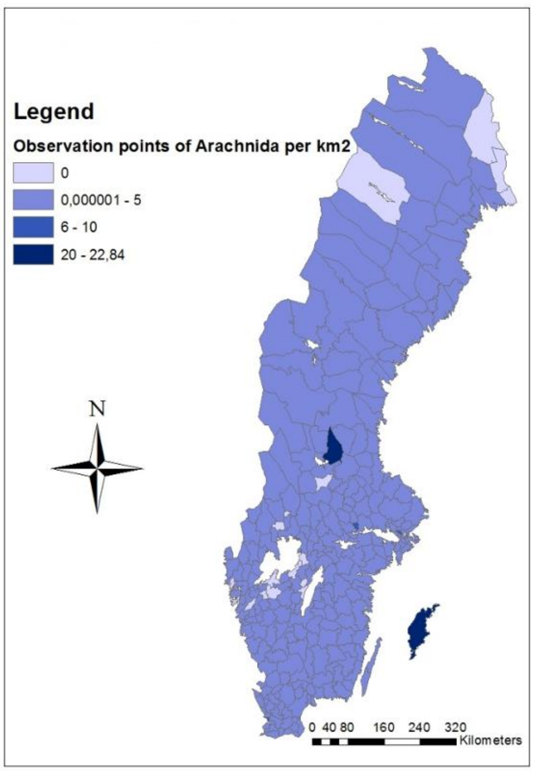


Figure 28:

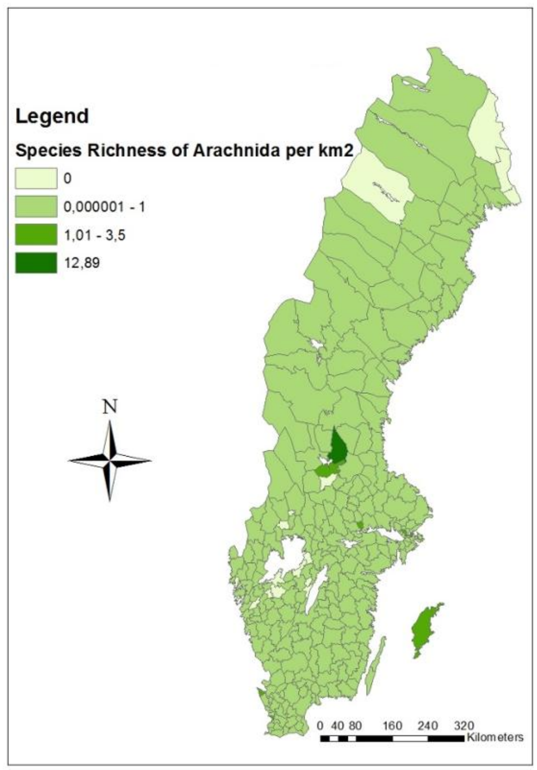


Figure 29:

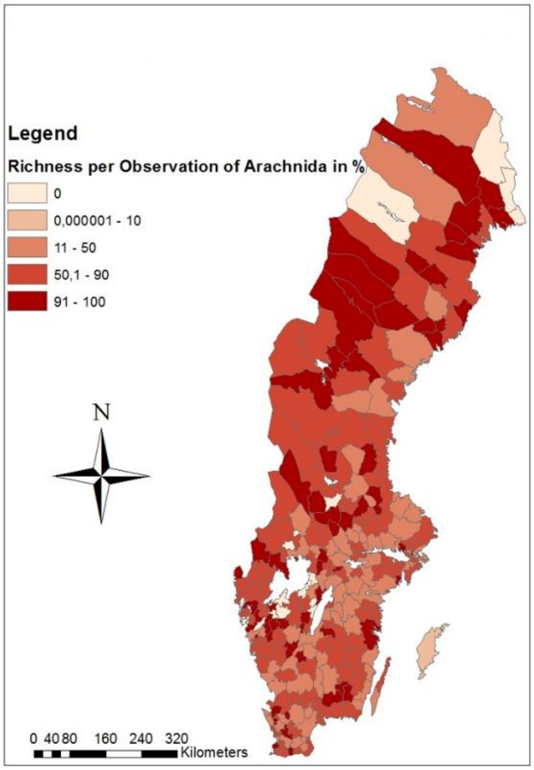
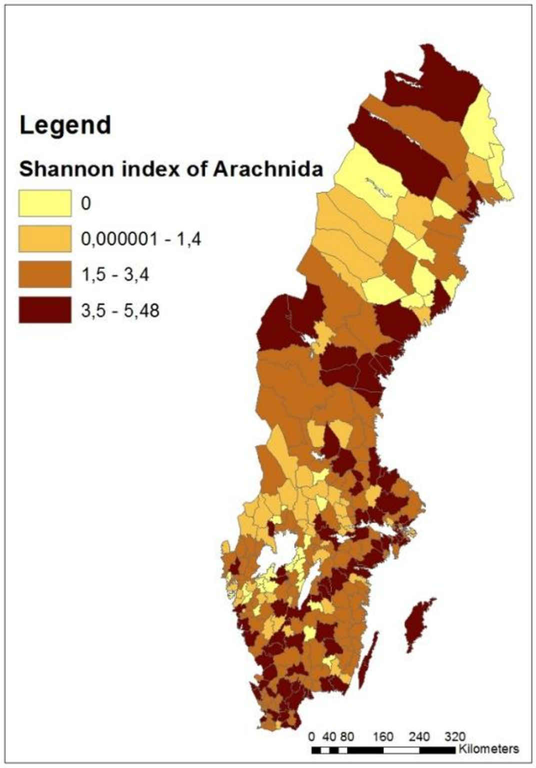


Figure 30:



- Hexapods

Hexapods are present in all Swedish municipalities, and most of them contain between 0.0013 and 1 species per km^2. In Gotland and Rättvik maximum points are observed with 20 to 40.07 species per km^2. In figure 32, species richness index shows a high biodiversity in Rättvik and Hallstahammar.

Figure 33 illustrates municipalities with a lot of observation points compare to their real richness. Corrected species richness is low in the Scandinavian mountain range, in the two islands Öland and Gotland, in Södermanland and Östergötland.

Shannon index is high in all « kommun » which indicate a proportional distribution of species, especially in the southeast.

Figure 31: Distribution of Hexapoda Observation points per km^2 in Sweden.

Figure 32: Distribution of Hexapoda Species Richness per km^2 in Sweden.

Figure 33: Distribution of Species Richness per Observation points of Hexapoda in % per municipalities of Sweden.

Figure 34: Distribution of Hexapoda Shannon index per “kommun”.

Figure 31:

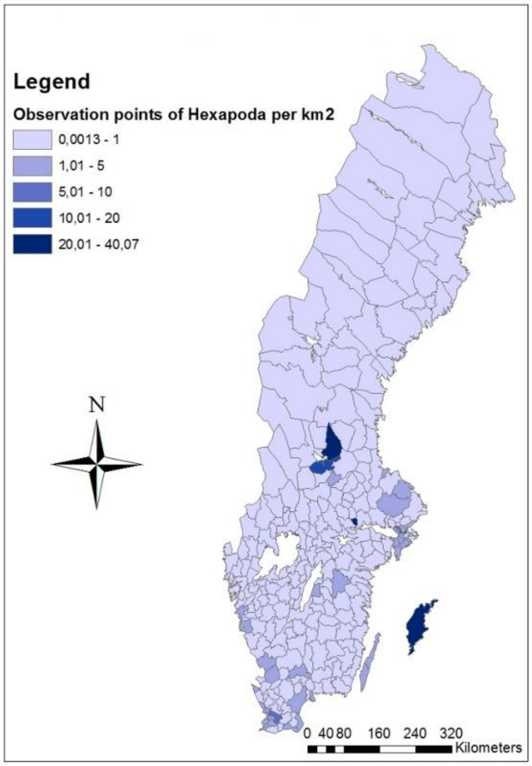


Figure 32:

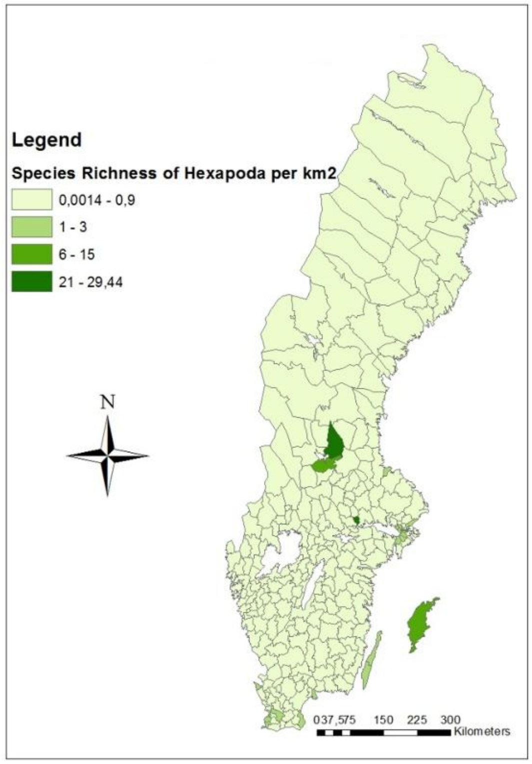


Figure 33:

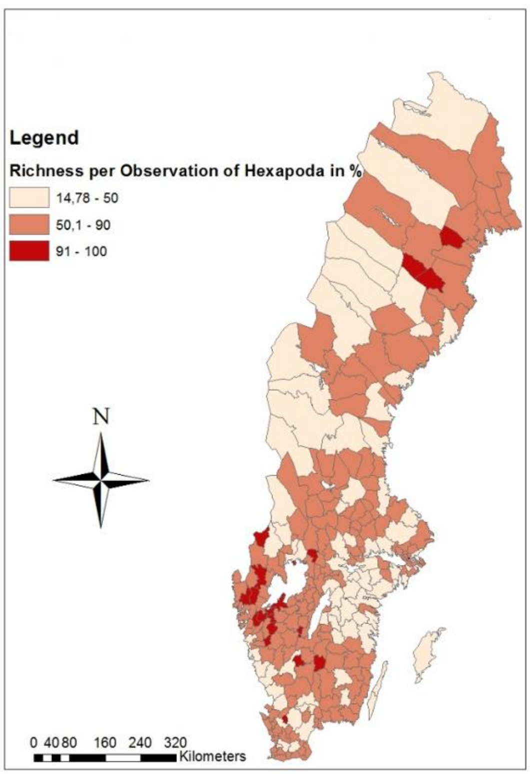
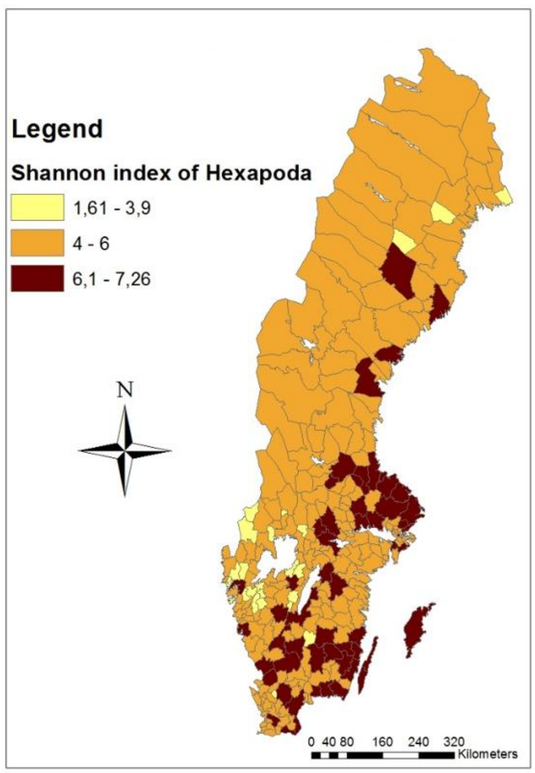


Figure 34:



- Myriapods

For the Myriapods, the number of observation points is quite low; almost half of municipalities do not have observed species. Species richness index illustrates in figure 36, is also low with a maximum of 0.75 species for Hallstahammar. Townships with Myriapods are mainly located in the southern half.
Shannon index is not important, except for some municipality mainly in the South part, which has an index higher than 1.5.

Figure 35: Distribution of Myriapoda Observation points per km^2 in Sweden.
Figure 36: Distribution of Myriapoda Species Richness per km^2 in Sweden.
Figure 37: Distribution of Species Richness per Observation points of Myriapoda in % per municipalities of Sweden.
Figure 38: Distribution of Myriapoda Shannon index per "kommun".

Figure 35:

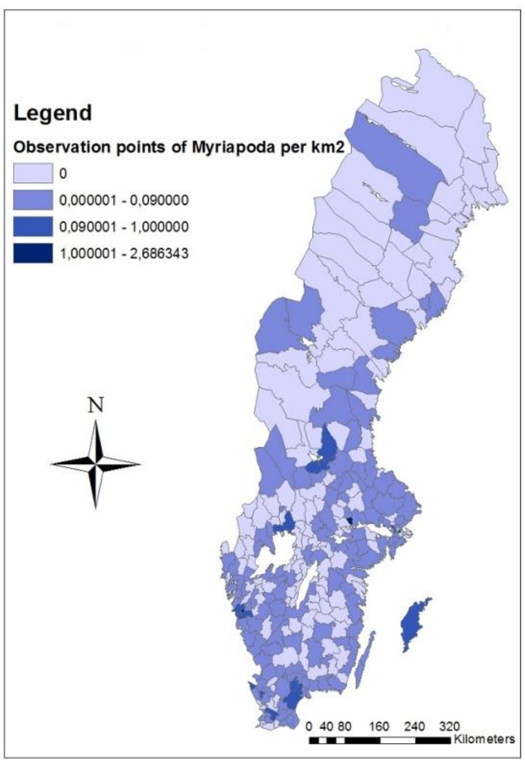


Figure 36:

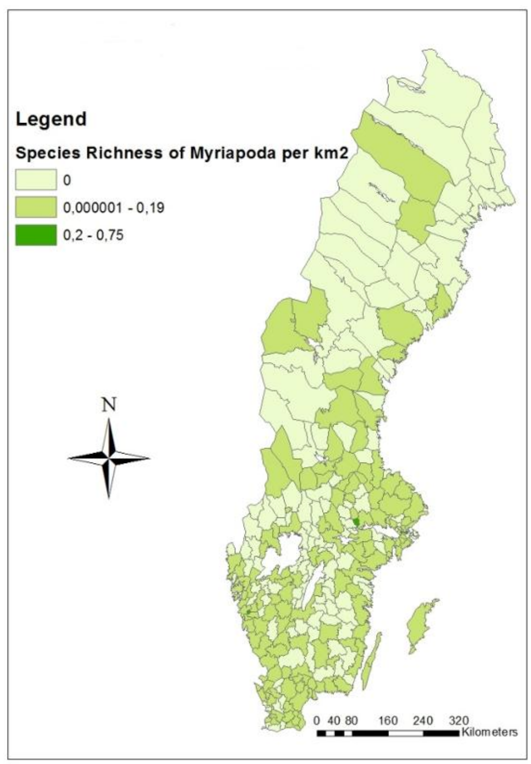


Figure 37:

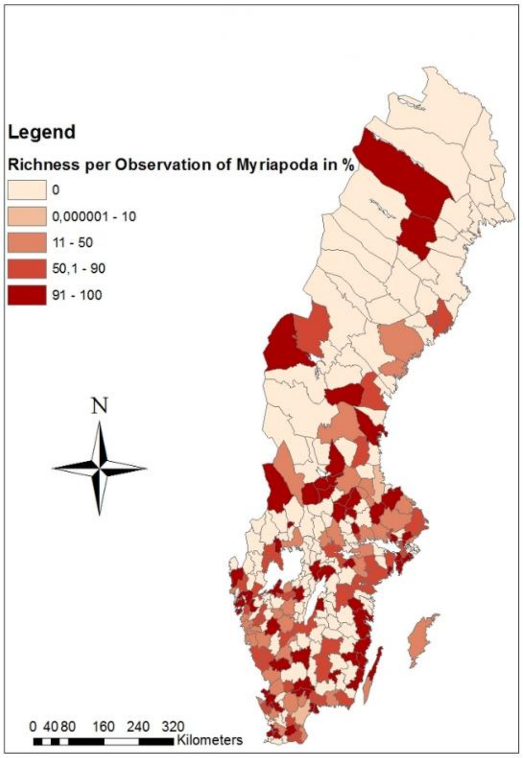
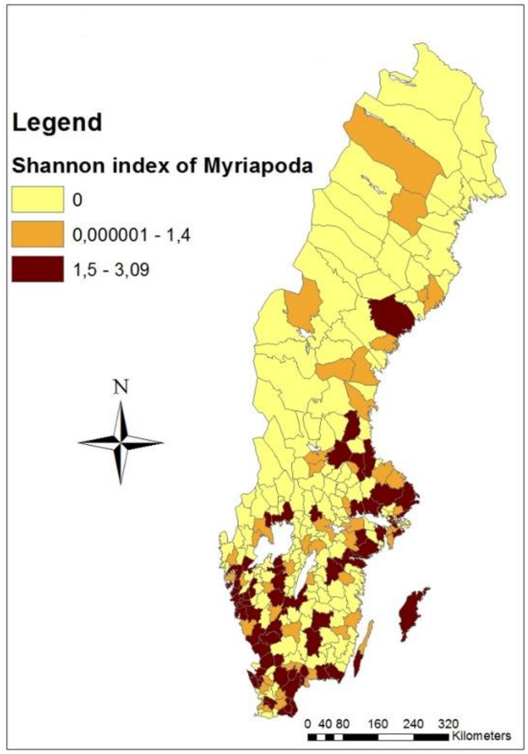


Figure 38:



5.2.3 Plants

- Bryophytes

Bryophytes are present in almost all Swedish municipalities. Two of them were more observed than others: Gotland with 17.64 species per km^2 and Rättvik with 50.21 species per km^2. The figure 40 indicates that species richness index is superior to 1 species per km^2 for some townships such as Leksand, Hallstahammar, Lysekil, Tyresö or Rättvik, (maximum of 9.45 different species per km^2). According to figure 41, some “kommun” as Gotland contains a lot of observation points whereas its corrected species richness is quite low. Therefore, Gotland was a lot observed compare to its biodiversity level. Concentration of biodiversity for Bryophytes is concentrated in the South part of Sweden. In the last figure, Shannon index is analyzed. The index is high in almost all the country (more than 1.5), except for Skåne. Biodiversity is particularly high in the southern half, from Dalarna to Kronoberg.

Figure 39: Distribution of Bryophyta Observation points per km^2 in Sweden.
Figure 40: Distribution of Bryophyta Species Richness per km^2 in Sweden.
Figure 41: Distribution of Species Richness per Observation points of Bryophyta in % per municipalities of Sweden.
Figure 42: Distribution of Bryophyta Shannon index per “kommun”.

Figure 39:

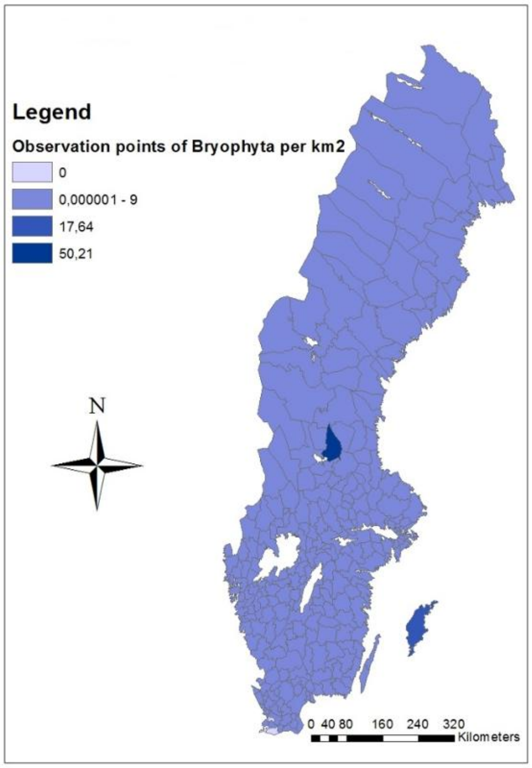


Figure 40:

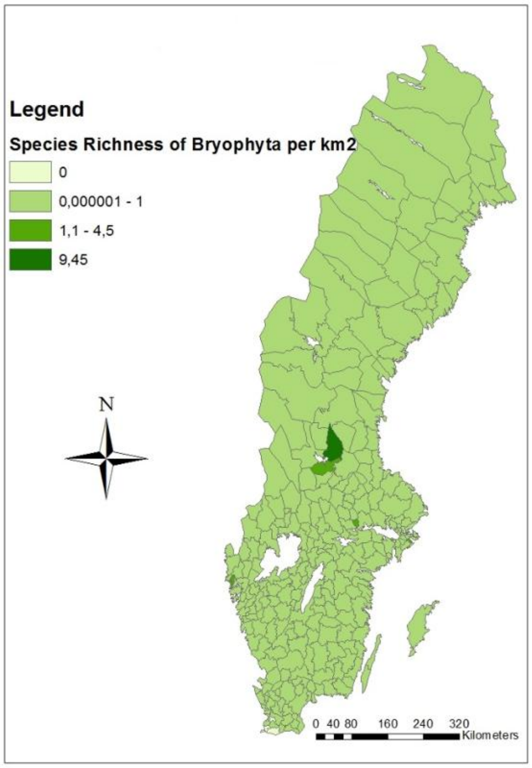


Figure 41:

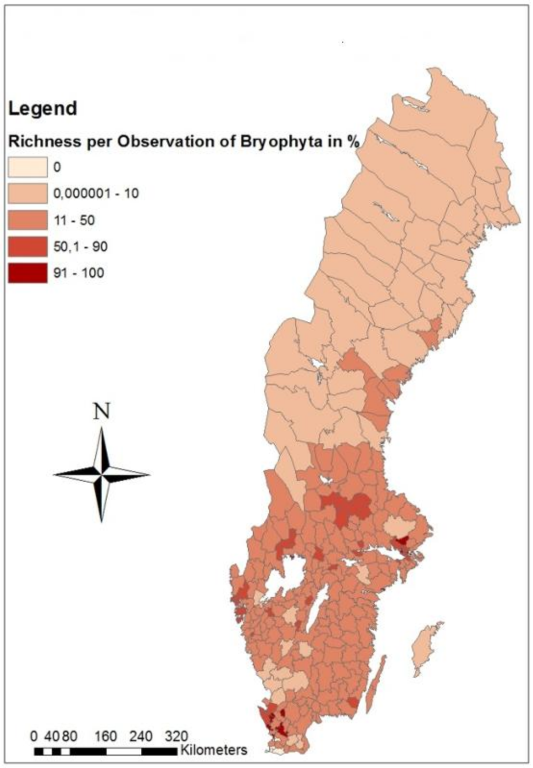
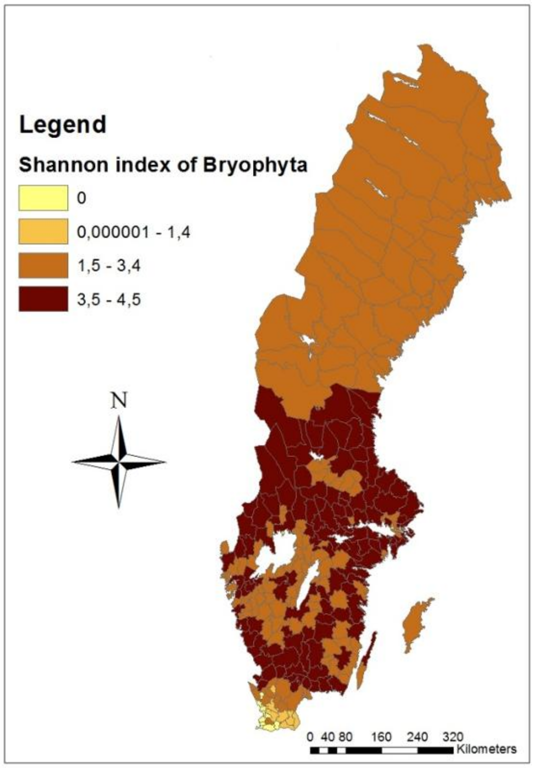


Figure 42:



- Ferns

Ferns are also present in almost all Sweden. Some municipalities are more observed than others, such as Rättvik, Leksand, Hallstahammar, the two counties Västra Götaland and Södermanland, and the two islands Gotland and Öland. However, species richness index shows a slightly different distribution: Rättvik, Leksand Lysekil, Tyresö, Partille, Salem, Oxelösund and Hallstahammar, appear as townships with the highest species richness index. In figure 45, species richness without influence of observation points is measurated. Two main areas indicate high biodiversity: the North part of Västra Götaland to Dalarna, and Kalmar to Skåne. Shannon index shows an equal distribution of species in almost all Sweden, except for some counties such as Skåne, Västra Götaland and Norrbotten.

Figure 43: Distribution of Ferns Observation points per km^2 in Sweden.
Figure 44: Distribution of Ferns Species Richness per km^2 in Sweden.
Figure 45: Distribution of Species Richness per Observation points of Ferns in % per municipalities of Sweden.
Figure 46: Distribution of Ferns Shannon index per "kommun".

Figure 43:

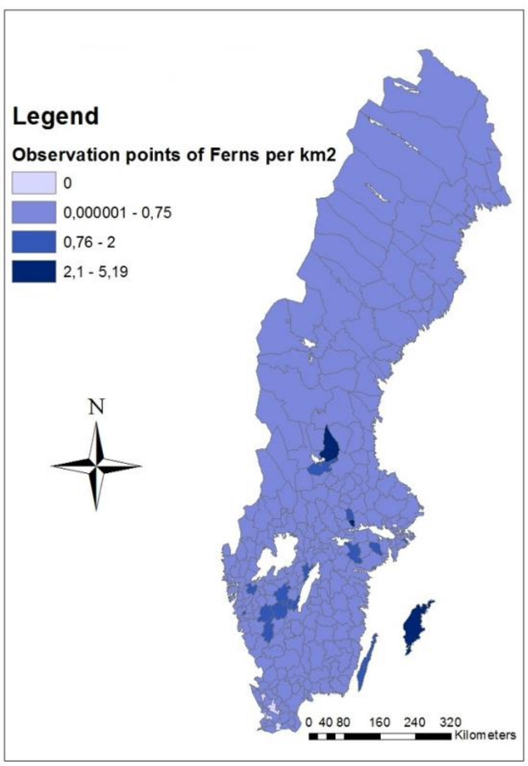


Figure 44:

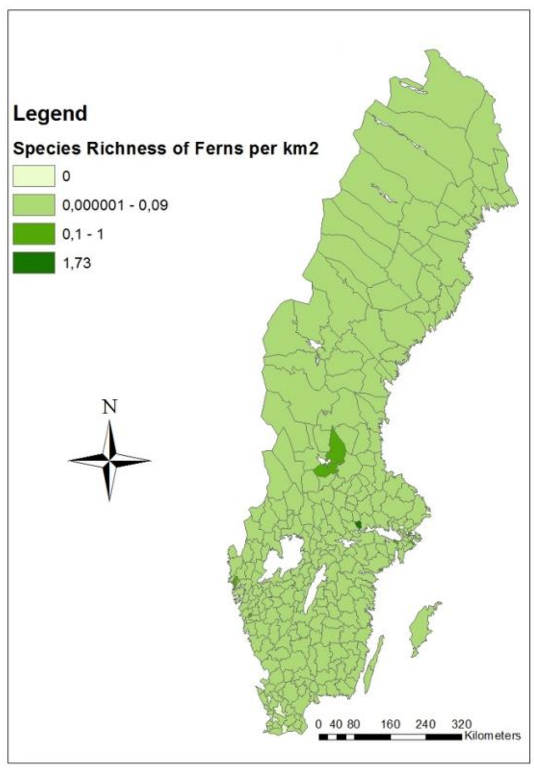


Figure 45:

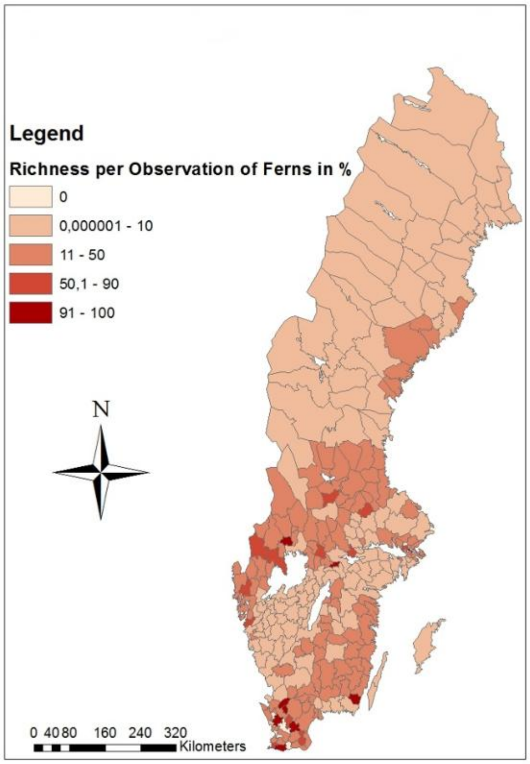
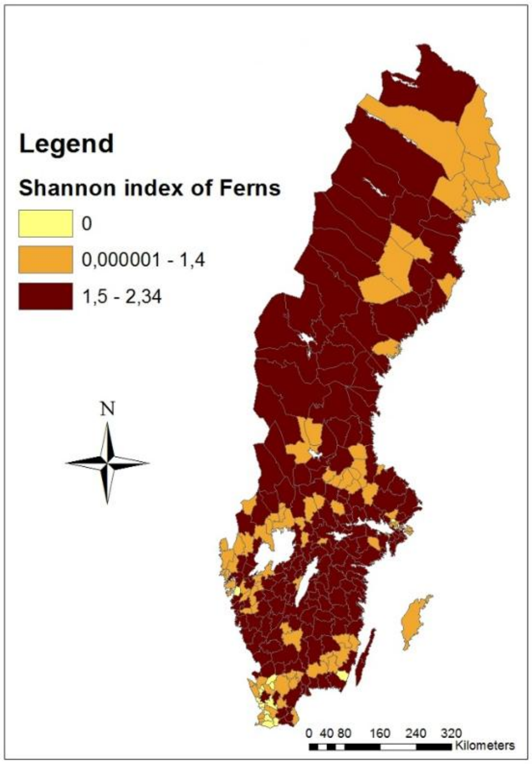


Figure 46:



- Lycopods

Lycopods are represented in practically all townships of Sweden, except for Skåne. Distribution of observation points is similar to ferns, except for the islands Öland and Gotland which have less than one species observed per km^2 in Lycopods. And as for Ferns, values are not high, between 0 and less than 2 species observed per km^2. Species richness is also not important with a maximum of 0.1 species per km^2 for Rättvik.

Figure 49 identifies areas which have a lot of observation points compare to their real biodiversity. It is the case of the North and the South-West of Sweden which have low corrected species richness.

Shannon index is high in most of municipalities, with an index between 1.5 and 2.34. Except for the South and the North extremities, species distribution is well distributed.

<u>Figure 47: Distribution of Lycopodiophyta Observation points per km^2 in Sweden.</u>

<u>Figure 48: Distribution of Lycopodiophyta Species Richness per km^2 in Sweden.</u>

<u>Figure 49: Distribution of Species Richness per Observation points of Lycopodiophyta in % per municipalities of Sweden.</u>

<u>Figure 50: Distribution of Lycopodiophyta Shannon index per “kommun”.</u>

Figure 47:

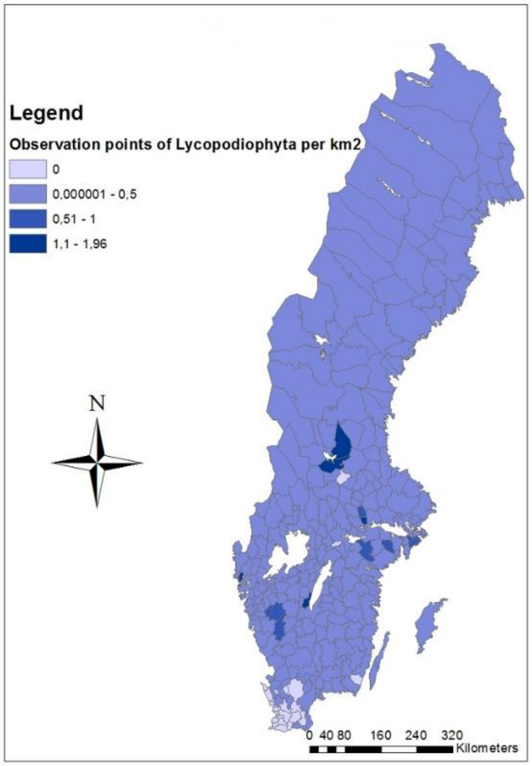


Figure 48:

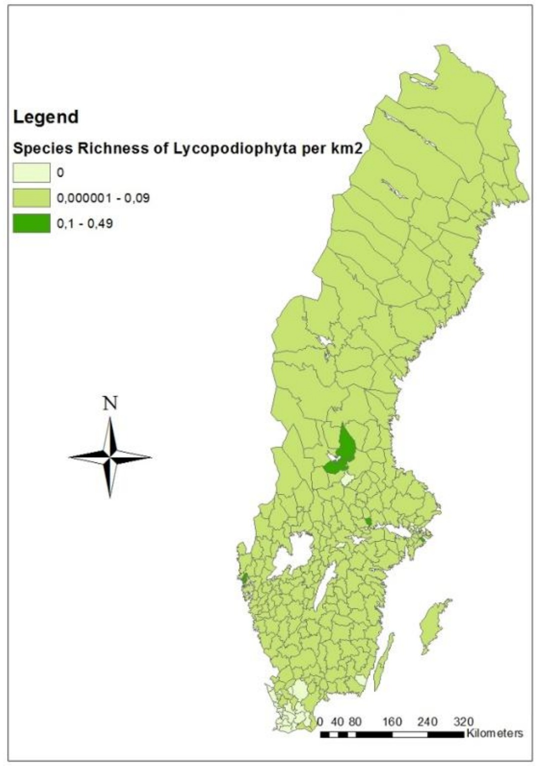


Figure 49:

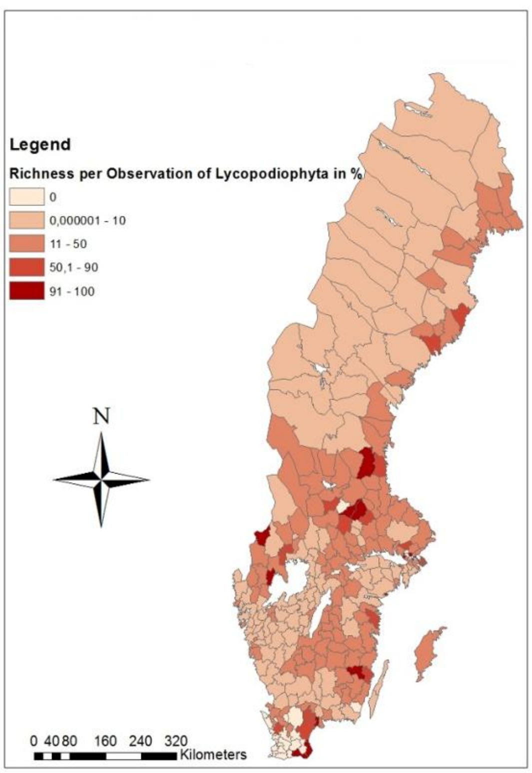
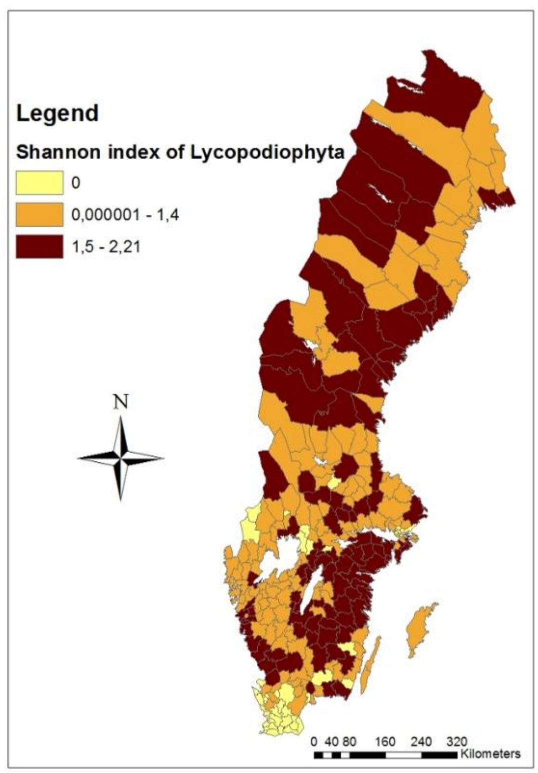


Figure 50:



- Spermatophytes

Spermatophytes are present in all "kommun" of Sweden. The number of observation is high, especially in Gotland and Hallstahammar. The southern Sweden appears clearly with a high species richness index, to Uppsala to Skåne, with an average of 1 to 9 different species per km^2. The maximum is important compare to other municipalities, 24.74 species per km^2 in Hallstahammar.

The figure 53 illustrates corrected species richness. Biodiversity without observation points influence is located in Skåne, Västra Götaland, Dalarna and Gävleborg.

Shannon index is higher than 1.6 in all the country, which means that Spermatophytes biodiversity is equally distributed in Sweden, particularly in the southern.

Figure 51: Distribution of Spermatophyta Observation points per km^2 in Sweden.

Figure 52: Distribution of Spermatophyta Species Richness per km^2 in Sweden.

Figure 53: Distribution of Species Richness per Observation points of Spermatophyta in % per municipalities of Sweden.

Figure 54: Distribution of Spermatophyta Shannon index per "kommun".

Figure 51:

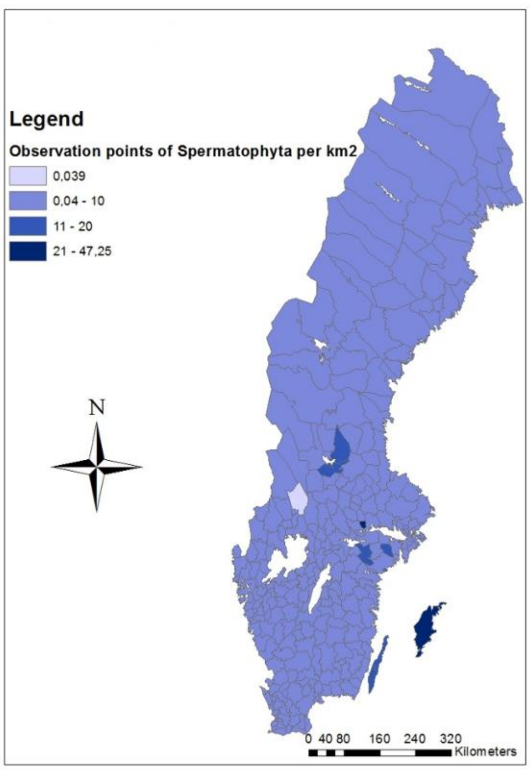


Figure 52:

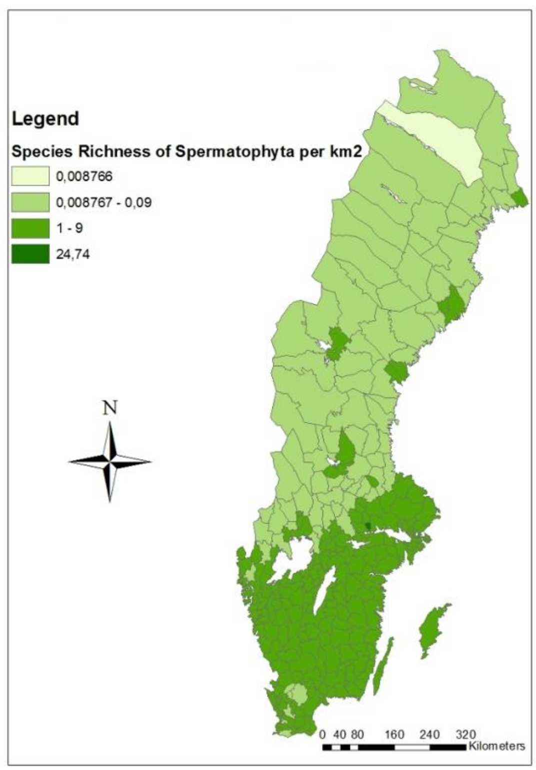


Figure 53:

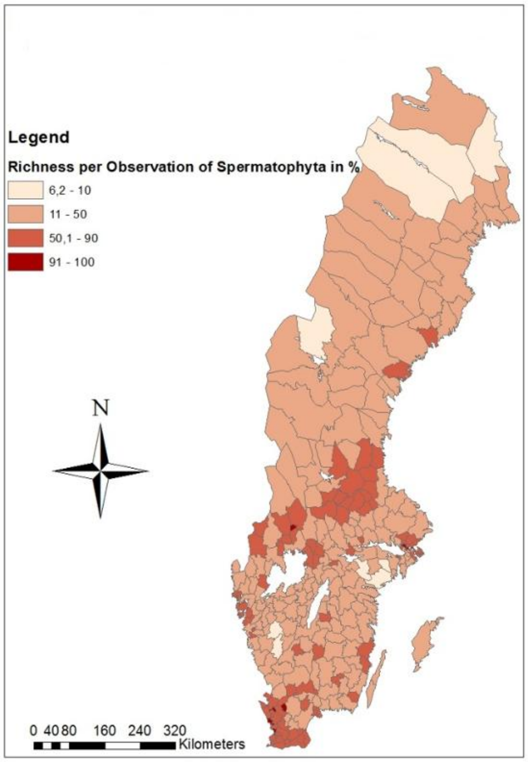
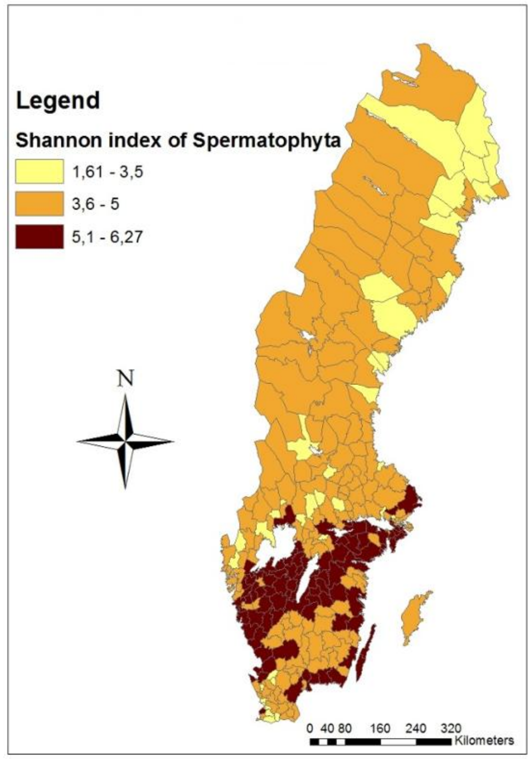


Figure 54:



5.2.4 Analysis of protected areas and biodiversity areas distribution

The three following figures were created to analyze the match between species richness and distribution of protected areas per municipalities.

In figure 55, percentage of protected areas per township was calculated. Jokkmokk, Sorsele, Tyresö, Salem contain the highest percentage of protected areas, with a rate between 45% and 57.67% of the area reserved for protection. Eight municipalities have between 20 and 35% of protected areas such as Sollentuna, Huddinge, Götene, Smedjebacken, Älvdalen, Åre, Krokom, and Kiruna. These townships with a high percentage are mainly located in the North-West, in the Scandinavian mountain range, or in Stockholm suburbs. The southern half of the country has mainly between 0.0055% and 10% of areas dedicated to protection. Therefore, northern Sweden contains more protection planning due to the high percentage of protected areas in these municipalities.

In figure 56, distribution of species richness sum per km^2 is totally different than in the previous figure. In fact, municipalities with a high species richness index are concentrated in the South. In the northern half of Sweden, species richness adds up to 0.044 to 1 species per km^2. In the center of Sweden, two townships appear with an important richness. It is the case of Leksand, with more than 72 species and Rättvik with 125 species different per km^2. The indicator is between 0.044 and 10 species different per km^2, and mainly between 1.1 and 10 species for most of the townships. Three other areas indicate a higher biodiversity than the average, such as Gotland with 26.33 species, Lysekil with 38.44 species and Hallstahammar the maximum with 173.89 species different per km^2.

These two figures have an opposite distribution whereas protected areas and municipalities with a high richness should be supplementary. Townships with an important percentage of natural reserves are situated in the North part of Sweden, where municipalities have an area largest and around the Scandinavian mountain range. However, biodiversity should be more important in these areas, whereas it is the South of the country which has the "apparent" highest number of different species.

However if we look at figure 56 and figure 57, species richness and species richness divided by the number of observation points, they have not similar distribution. This map illustrates which municipalities count a lot of species observed compare to their species richness. Low values mean that volunteers' collection was concentrated in some municipalities which do not have real species richness present in these areas. It is the case of Västerbotten, Jämtland, Gotland, Stockholm, Uppsala, Södermanland, and Östergötland. Almost all northern part Sweden contains a number of observation points important compare to its corrected species richness. Areas which appear with real species richness (after correction by the number of observation points) are: the West of Skåne, the North-West of Västra Götaland, Värmland, Dalarna and Gävleborg. This map corrects species richness influenced by the number of observation. The aim is to understand where is located high biodiversity without depend on volunteer interest for an area. The West of Skåne, Kalmar, the North of Västra Götaland, Värmland, Örebro, Västmanland, and Gävleborg, could be more observed by volunteers, and may be not all species are collected in these areas. For example, by comparison between figure 5 and figure 61, Skåne counts a lot of observation by naturalist interested by Animals kingdom, but not by Fungi or Plants kingdom. Therefore, Animals observations are covered in Skåne, but volunteers specialized in Fungi or Plants could improve their observations in this area.

Figure 55: Distribution in percentage of protected areas per "kommun".
Figure 56: Distribution of species richness sum per km^2 in Sweden.
Figure 57: Distribution of species richness divided by number of observation points per km^2 in Sweden.

Figure 55:

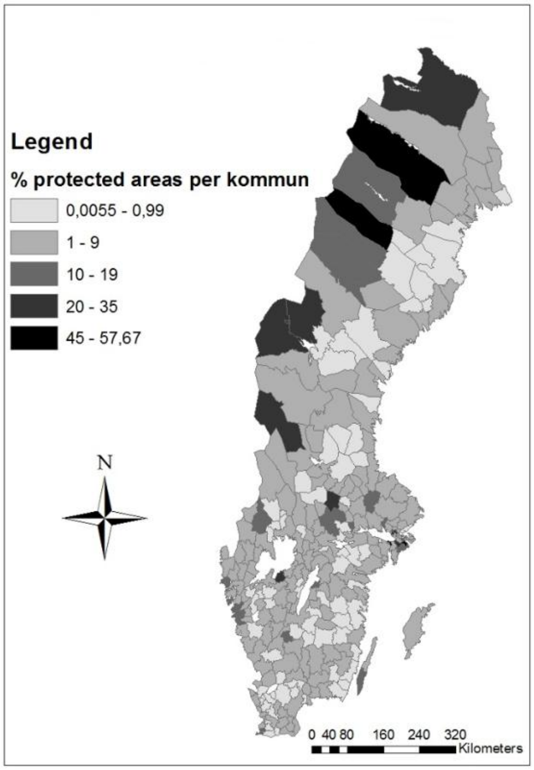


Figure 56:

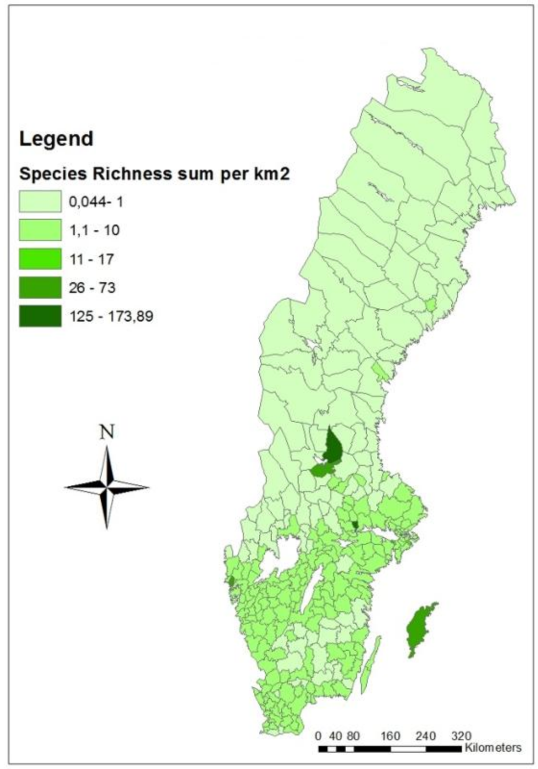
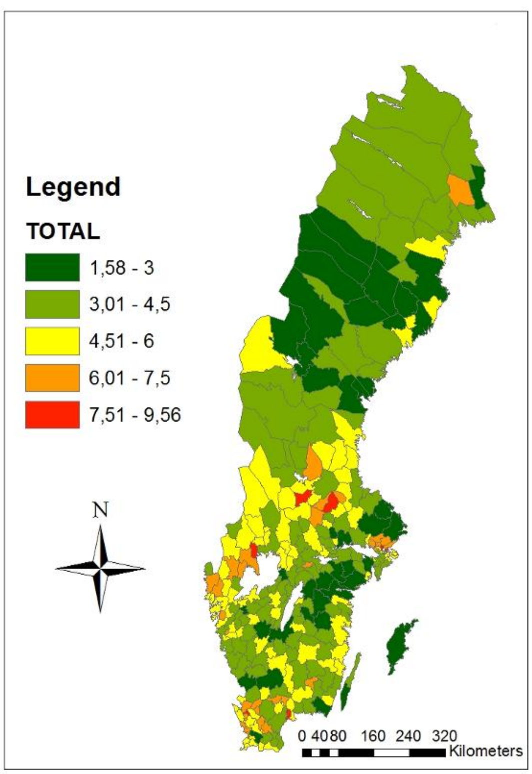


Figure 57:



6 DISCUSSION

6.1 Analysis of biodiversity distribution

6.1.1 Biodiversity overview

As seen previously, differences exist between taxonomic groups and between municipalities. Fungi, animals and plants do not have similar spatial distribution. However, in some areas such as Gotland, around Stockholm and Södermanland, Rättvik and Leksand, in the number of records was important for all the three kingdoms. We can notice that Fungi et Plants have a quite similar distribution of observation points, which can means that 1) volunteers interested in these groups look at same areas, 2) that some of them register the two kingdoms in the same time, or 3) that there is a biological reason causing this similar distribution. In Fungi, the number of collected species is the most important with 1 240 881 observations, followed by plants with 576 204, and then animals with 425 252 observations.

According to our results, the three first taxonomic groups with the highest species richness are Basidiomycetes, ascomycetes and Hexapods. In Plants, Bryophytes and Spermatophytes have the most important species richness. Shannon index have similar results, these five taxonomic groups quoted previously present the highest heterogeneity distribution.

For each group there are some municipalities which always have high number of observation points and “apparent” high species richness index (species richness not corrected). It is the case of Rättvik, Leksand, Hallstahammar, Gotland and Lysekil which present global high species richness index.

Looking at the corrected species richness, species biodiversity identifies different distribution. We accounted for a bias in species richness due to a large number of observations.
In Fungi, biodiversity is presented mainly in the South part of Sweden, from Dalarna and Gävleborg to Skåne. However, high biodiversity is also identified in the North part of Sweden, in Norrbotten for Ascomycetes.
In Animals, biodiversity is particularly important in Västra Götaland, Norrbotten, and border municipalities of Skåne and Kronoberg for Amphibians, Mammals, and Reptiles. Moreover if we look at biodiversity distribution, Amphibians and Reptiles have their highest corrected species richness situated in similar municipalities. We can suggest that some species of these two groups are spatially correlated and need similar climatic conditions and habitats. However, Amphibians are also highly represented in some

townships of the Scandinavian mountain range, whereas Reptiles are mostly absent. Arachnids and Hexapods are well distributed in almost all Sweden.

In Plants, each taxonomic group shows similar dynamics distribution. Corrected species richness is concentrated in the South part of Sweden, from Dalarna and Gävleborg to southern Skåne. Up to these two counties, Dalarna and Gävleborg, biodiversity is mostly low. Bryophytes, Ferns, Lycopods and Spermatophytes seem to have similar climatic condition needs, and same latitudinal limits. Highest biodiversity of these groups is represented in Skåne and from the South part of Dalarna and Gävleborg to Västra Götaland. It may have some correlations between some species of these four taxonomic groups in these areas.

In a general point of view, high biodiversity is localized in the South part of Sweden. Because of the scale used, this result probably reflects gamma diversity, linked with habitat heterogeneity. A possible explanation of concentration of high biodiversity in southern Sweden is that the South is more fragmented than the North. A fragmented area may have more different habitats, which increase biodiversity heterogeneity.

6.1.2 Comparison between protected areas distribution and "apparent" high biodiversity distribution

According to the Environmental Code, provides by the Swedish Environmental Protection Agency, 1999, protected areas should:

- Protect human health and the environment against damage and detriment.
- Protect and preserve valuable natural and cultural environments.
- Preserve biodiversity.
- Have long term good management in ecological, social, cultural and economic terms of the use of land, water and physical environment in general.
- Re-use and recycle raw materials and energy to maintained natural cycles.

The largest protected areas include unexploited mountains, natural forests, natural mires and unexploited archipelagos, and mainly of them are localized in the mountain areas and the pre-mountain (Swedish Environmental Protection Agency, 1999). The distribution of protected areas is not equal in the country. In fact, 46 % of open mountain areas have a protection, whereas open land has only 3.1 % of protected areas. Moreover, 7.5 % of the forests are protected, and 77 % of the protected forest areas are located in mountain range (Swedish Environmental Protection Agency, 1999). That is why in our figure 58, municipalities with high percentage of protection are situated in the North of Sweden, especially in Swedish mountains. Yet, Sweden possesses most of the intact oldgrowth forests and wetlands of Europe, in particular due to its low population density 22/people/km^2, the environmental code, and priority to establish protected areas of large natural forests (Swedish Environmental Protection Agency, 1999).

We may explain protected areas concentration is the North part of Sweden by historic and socio-economic factors. For example, ecologists had and have a particular interest for large subarctic mammals. Some protected areas may be created in order to protect these charismatic animals. Moreover, it is simpler to manage national park or natural reserves in areas, where there is a low density of people and economic activities.

If we look at a local scale, based in our study, some areas should be more protected due to their high biodiversity. As seen previously, the West of Skåne, the North-West of Västra Götaland, Värmland, Dalarna and Gävleborg could contain higher percentage of protected areas in their municipalities. In fact, these municipalities have a low percentage of protected areas, with less than 10% of national park and natural reserves in their areas. Biodiversity monitoring could be improved in these counties in order to conserve their high species richness.

However to protect biodiversity it is important to understand its dynamics. In fact, in southern Sweden, agricultural landscape is a lot represented, and most of species such as insects or wild plants are link to agriculture not intensive. An adaptive solution to protect biodiversity in the South part of Sweden can be more efficiency than create protected areas. Agri-environmental schemes can be a solution to protect biodiversity linked to agriculture (Smith, 2010). They aim at reducing agricultural intensity or restoring ecological heterogeneity. Schemes focus on biodiversity protection and preservation of semi-natural pastures (Smith, 2010).

6.1.3 Analysis of municipalities with high observation points and high species richness index

As seen previously, most of the protected areas are situated in the North of Sweden, especially in the mountain range. Therefore its distribution is not equal in the territory, and some municipalities, according to our result, deserve a higher percentage of protection planning. Our results of observation points and species richness index indicate some municipalities with higher biodiversity than the average, in not corrected richness and evenness. In fact, five municipalities have particular high observations:Rättvik, Leksand, Gotland, Hallstahammar and Lysekil. This might reveal where favorite areas of volunteers to observe species are located. Localization of protected areas cannot explain this interest for Rättvik, Leksand, Gotland, Hallstahammar and Lysekil, because their percentage of protected areas is low. This observation may be explained by protection measures different from the ones granted by national park or natural reserves.
We may explain volunteers' interest for Rättvik and Leksand by their varieties of landscape. Indeed, these municipalities are composed of lakes, traditional cultivated areas of farmland and a deep forest with bear, wolves, lynx, and elks (Rättviks kommun, 2008-

2012). Different habitats are present in these areas, which may explain high number of observation points for almost each taxonomic group. This richness might also cause a higher number of visitors who tend to report observations, leading to high apparent species richness for several taxa. However, no protection project was found to explain high interest granted by volunteers for these municipalities.
Gotland is also characterized by high number of observations. It is features unique calcareous landscapes and different habitat such as forests, meadows, wetlands and coast which can explain volunteers' interest (Smitterberg).
Concerning Hallstahammar or Lysekil, no special explanation was found to explain their high species richness index. However, Lysekil which is on the seashore contains a lot of natural reserves but for marine ecosystem and not for terrestrial ecosystem (Seabased at the Lysekil Test Site, 2011). Hallstahammar has an environmental project. In fact, in 2009 a company HeidelbergCement elaborated a guideline of biodiversity management. Rehabilitation plans to improve biodiversity protection in and around quarries should be set up by 2020 (Sustainability report 2010/2011).

6.2 Limitations of the study

6.2.1 Limitation associated to the data

GBIF is a useful tool for biodiversity research, because of its free access to biodiversity data, via Internet (GBIF, 1996). It is a global database with participation of countries and organization, which shows an inventory of an important number of species (GBIF, 1996). Species are collected with their coordinates with possibility to have spatial information, and analyze species distribution with maps.
The fact that species information is collected by volunteers is the main limitation on GBIF usefulness. Indeed records indicate where species are present but not where species are absent. This is the main difference between standardized collection methods and volunteers' collection methods. With standardized collection methods, expert volunteers used routes at fixed locations sampled, and have to collect all species. Therefore if a species is not collected, we can suppose that species is absent in the area. Whereas with non-standardized collection, volunteers only collect species of interest: absence of observation does not necessarily reflect absence of a species. Many reasons can explain absence of a species with volunteers' collection, called pseudo-absence. These pseudo-absences have to be analyzed with precaution.

In addition, some data was impossible to download, such as birds, Bryopsida class in Bryophytes, some Fungi families, which limited our taxonomic group analysis. The database is in free access and all groups need should be easy to download. This further limits the interest of the database. Moreover, some quality difference exists between taxonomic data. Some groups are more observed, and their registration is more complete and accurate (with geographic coordinates and without doubts about species names) than others. It is interesting to note that the data we used here came from the Swedish initiative “ArtPortalen” (species portal). However, the way the website of that initiative is devised makes it extremely difficult to have an access to a large amount of data, as it is usually required for scientific research. It could be advisable that more computer science was included in devising such geo-database to favor access to the scientific community and the public.

Animals are the one that have the lowest percentage of points used for analysis, with 85.5% of the data. Only Hexapods and Myriapods contain more than 90 % of data used. Mammals contain 44 241 observation points, but only 42 % could be utilized due to a lack of geographic coordinates. It is likely that observations of mammals are often reported by volunteers with less experience or expertise, as many mammals are easy to identify and have a high subjective importance. We can assume that less experienced observers are more likely to forget to report spatial location. In addition, because animals move (and observers might move too, for instance in a car), it is likely that many observers do not feel comfortable assigning precise spatial locations. Arachnids should also use a more methodical way for its collect (71.9% of its data used for 49 597 points observed).

About 88% of the fungi data was directly usable. Basidiomycetes are the most represented of Fungi, with 887 819 observation points, and 91.9 % of its data used for analysis. Volunteers which record Fungi may use the same method as the one used for the Basidiomycetes, in order to improve species collection. Basidiomycetes may illustrate a quite real distribution of its biodiversity.

Plants records the greater percentage with 91.6 % of collected data used. This group contains a lot of observation points, and a quite low percentage of data without geographic coordinates or with question marks. The maximum of data unusable is 6.8% for Lycopods, which is less than 10%. Therefore, Plants seems a lot observed and contained quite complete information. .

The main reason of data loss is the lack of geographic coordinates during collect. For example, for Fungi and Mammals we lost more than 50% of the data because of that. Therefore, half of the data is not use which biased our distribution results for these groups. The data collection of these two groups should be improved in order to measure their real biodiversity distribution. The first step to improve GBIF data is to specify to volunteers to collect geographic coordinates for each species observed.

Another drawback of GBIF is that there is no possibility to measure biodiversity evolution on a time scale. In fact, the date when species are observed is not specified for most of data. To evaluate biodiversity and choose protected area, time scale is an important factor. For monitoring conservation it is essential to observe biodiversity evolution to detect areas which lose biodiversity to act quickly. Without this component, we can identify high biodiversity area, but we cannot see which one are the most threatened by loss of biodiversity. Time scale can be an interesting factor to get in order to improve our study.

There are many ways that may be recommended to improve naturalist data quality. Studies like this one might be useful to identify gaps in observations for different taxa, and an initiative like Artportalen could emit recommendations to focus on some taxa. Asking volunteers to always provide spatial and temporal data is of course a must, and we can only emphasize the point that an observation without spatial references is useless for many analyses.

Of course, standardized collection methods produce better data than free observations. They can use for instance routes at fixed locations sampled by expert volunteers every year. With standardized methods, all areas will be observed, and not only the ones favored by naturalists. However, they are costly, and it is unrealistic to think that many taxa will be covered soon; it is maybe a long term goal to aim for.

More synthetic initiatives, such as Nature Index, a tool proposed by the Norwegian government, might also improve our capacity to measure biodiversity patterns in space and time. According to Aslaksen, 2012, Nature Index aim is to assist environmental managers and policymakers to elaborate effective policy objectives in biodiversity and monitoring priorities. Information from researchers is translated to policymakers and the general public with a comprehensive overview, so that monitoring of conservation can be understood and applied at a global level. To improve monitoring biodiversity it is important to elaborate a common framework for measuring biodiversity between different researchers, institutions and approaches. A reference state was defined for each indicator, linked to nine ecosystems, to compare them on a common scale, which means that all indicators are scaled on a range from 0 to 1. An Internet database was created, with a selection values observation and uncertainties, and results are communicated to public which can improve biodiversity research by the accessibility of a quality database (Aslaksen, 2012). This initiative should be useful for policy and scientific community because the accessibility for environmental management is improved, and it can motivate scientists to conduct studies to evaluate causes and threats to biodiversity. The Swedish Government could imitate the Norwegian Government because its scientists need to synthesize biodiversity knowledge for improve environmental policy, and need an access to a complete and effective database to act quickly on threatened areas. This initiative can improve research in biodiversity, which is as seen previously, difficult to collect a quality database with a public access.

6.2.2 Limitation associated to biodiversity and indices

Biodiversity conservation is confronted to its complexity, and the large number of components which are part of the process of it (McCann, 2000). Biodiversity concept does not have a rigorous theory. Scientifics recognize its feedbacks on ecosystem function and structure, but cause/effect relationships are not all understood and quantifiable (Lister, 1997).

In this study, species richness and Shannon index were used to measure biodiversity per municipalities. Species richness is often combined with the evenness of species distribution and the most known and used is the Shannon index (Duelli, 2003). Different opinions exist about the importance of one compare to the other one. According to Duelli, 2003, some recent studies show that biodiversity student will consider evenness to be a greater indicator than species numbers. At the scale we adoptedspecies richness can be stronglycorrelated with habitat heterogeneity (Duelli, 2003). More trophic levels will normally include more species, and an ecosystem with high structural diversity will contain more ecological niches (Duelli, 2003). However, it does not work for all taxonomic groups, and whether species richness or evenness is more useful isstill debated. Four of our taxonomic groups, Hexapods, Spermatophytes, Ascomyta and Basidiomycetes had in every municipalities a Shannon index higher than 1.5, which means that for these groups all species have an even distribution, and may present a potential correlation between them.These two indices are used a lot in ecology, and have a long history of application compare to some news indices, showing their efficiency (Lamb, 2009). A large part of the literature explains and uses these indicators, which facilitates comparison with other studies and understanding (Gallardo, 2011). Another advantage is that compare to some other indicators, their interpretation is quite easy to understand (Gallardo, 2011).

However, some processes of biodiversity are not taken in consideration. It is the case for non native invasive species which increase the value of diversity indices (Lamb, 2009). Species richness and Shannon index are indices of quantity of biodiversity, but it does not give any information about quality of species found such as presence of endemic species or threatened species (Bernes, 1994). Moreover, these indices consider all species as functionally equivalent, without taking in consideration trophic interactions or other mechanisms that might make one species more important than others for the ecosystem functioning (Bernes, 1994).

Another disadvantage is that Shannon index and species richness do not have a clear relation with human impacts, one of the main reason which explains loss of biodiversity (Gallardo, 2011). For Shannon index results, it is not related to the ecological role of species, which makes it difficult to relate to higher scale processes (Gallardo, 2011). And one the most important problem of this index, it is that Shannon index is dependent of sampling effort. With an important sampling, Shannon index will be effective and will

show evenness or not of a taxonomic group, but the other side, with a low sampling the index will be not effective (Gallardo, 2011).
We will see in the next part how to improve measure of biodiversity in order to enhance monitoring conservation.

6.3 Future perspectives to improve our study in biodiversity conservation

As seen previously, biodiversity is a complex indicator, and there are different approaches to measure it. In this study, inventories were used to measure abundance and heterogeneity of species, with two different indicators, species richness and Shannon indices. However, different researches were done with different approaches to calculate biodiversity.
The focus on species richness is based on the fact that areas having more species must be protected as a priority. However, there is a debate about the efficiency of species richness. Patterns of species richness among taxa are not necessarily correlated with area containing rare or threatened species (Jennings, 2008). A study of Jennings, 2008, proposes to associate species richness to composition of species in order to improve priorities in conservation planning. This article aim is to maintain assemblages of coevolved species in typical habitat. Identities of species are evaluated in order to have species composition of regions, and analyze representativeness or distinctiveness of a region. The representativeness of a region is *the proportion of species present in the region of interest and in the other regions around* (Jennings, 2008). The distinctiveness of a region means that *the proportion of its species occurs only in the region of interest* (Jennings, 2008). This measure appears as additional information of species richness about patterns of biodiversity. Taking in consideration species composition is an important factor to understand how is typical or distinct an area by its species, and can improve conservation planning based on species richness (Jennings, 2008).
Species also differ in their effects on ecosystem, functions, and it has been suggested by Lister that some species ('keystone species') are more important to protect than others (Lister, 1997). However, when it comes to ecosystem functions recent studies have shown that it could be more effective to focus on life-history traits present in a community rather than individual species (Diaz, 2001). In fact, in Diaz article, the study proposes to include both number and composition of genotypes, species functional landscapes in a delimited area, to measure biodiversity (Diaz, 2011). According to Diaz a lot of study focuses on species richness but other components such as functional diversity have been studied in only few cases. However, if the links between plant diversity and ecosystem functioning is still debate, the author suggests to improve research in functional diversity because it can affect ecosystem dynamics and stability. The article proposes to connect findings of these two approaches in order to improve conservation planning of biodiversity and ecosystem services (Diaz, 2001).

Biodiversity conservation has limited resources that are why we have to set priorities about where to establish protected areas (Faith, 1992). The different researches and approach are important to improve conservation, in order to elaborate efficient biodiversity monitoring. Species richness, evenness, composition species, presence of endemic species, keys species or threatened species, are different factor of biodiversity that could be taken in consideration to elaborate conservation planning. All these indicators should be combined together.

In this effort, species inventories are absolutely needed. However, this approach needs a significant amount of time, presents some biased if data is not well collected, and can be expensive (Gillespie, 2008). An interesting study proposes to measure from space patterns of species occurrence and movements and modeling species distributions and patterns of diversity (Gillespie, 2008). Modeling of species richness, alpha diversity and beta diversity were elaborated, using land cover classifications, landscape metrics, measures of productivity and measures of heterogeneity. This article combined different scales of biodiversity measuring, which show a different approach from the one analyzed in our study, where analysis is realized at gamma diversity scale. To analyze species distribution, models evaluate presence, absence, or abundance data within landscapes, regions or continents, and include topography and climatic variables. This approach is a quicker way to analyze biodiversity than with inventories, but it is still expensive to acquire high resolution imagery. Moreover, it is difficult to identity animals from space because species size is smaller than the largest pixel of current public access satellites, 0,6m (Gillespie, 2008). This study presents a different approach of biodiversity measuring and can offer a large point of view of biodiversity distribution and can be supplementary to our approach, particularly when one accounts for the limitations in existing schemes such as GBIF.

7 CONCLUSION

In this study we analyzed biodiversity patterns in Swedish municipalities, using The Global Biodiversity Information database and biodiversity indices. The aim was to identify areas with high biodiversity and compare them to protected areas already set up. Our results showed that the areas with the highest biodiversity are not necessarily the ones with a high level of protection.

Our database used, GBIF, was not complete and presents some biased, in fact a large part of the work in this study was to make data usable. Difference of data quality between taxa was sometime important, such as for Mammals which had less than 50% of their data accessible for analysis. The Swedish initiative Artdatabanken (Artportalen), which collects volunteer-based observations, could play a stronger role in standardizing the data and making it available for the scientific community. In the longer term, standardized designs would significantly improve the quality of data, but they are costly.

Our results, based on GBIF database, showed a mismatch between municipalities with high biodiversity and municipalities with a high percentage of protected areas. We detected some counties and townships characterized by high species richness and high evenness for most of the taxonomic group, but having low protection of biodiversity represented by natural reserves or national parks. It is the case for municipalities in the West of Skåne, the North-West of Västra Götaland, Värmland, Dalarna and Gävleborg. However in our study not all components of biodiversity are taken in consideration. To measure biodiversity is complex. The usefulness of different approaches, such as the keystone species approach, is sill debated. Here, species richness and evenness were chosen, as they are widely used and well understood by the scientific community. Biodiversity indices research is still in research and in improvement, new indices more complete and efficient should be found to ameliorate localization of biodiversity hotspot and its protection. Gamma diversity was used to evaluate biodiversity of Swedish municipalities, but the other levels of diversity, alpha and gamma are also important, and results will be not similar with these different scales of analysis. Research should be effectuated at the three levels because information differs with this change of scale.

Many studies exist about biodiversity and to improve this research it is important to try different approach and method, such as in this study, in order to evaluate its efficiency. However, biodiversity definition is still debated which made its evaluation more complex. With climate change and its impacts on biodiversity it has become urgent to properly measure biodiversity in order to conserve and protect the threatened ecosystems.

8. REFERENCES

Alatalo, R.V. 1981. Problems in the measurement of evenness in ecology. *Oikos* 37: 199-204.

ArtPortalen. Retrieved 28 June, 2013, from: https://www.artportalen.se/Home/About.

Aslaksen, L., E. Framstad, P.A. Garnsjordet, S. Nyb and O. Skarpaas. 2012. Knowledge gathering and communication on biodiversity: Developing the Norwegian Nature Index. *Norsk Geografisk Tidsskrift-Norwegian Journal of Geography* 66(5): 300-308. DOI:10.1080/00291951.2012.744092.

Balvanera, P., A.B Pfisterer, N.Buchmann, J.S. He, T. Nakashizuka, D. Raffaelli, and B. Schmid. 2006. Quantifying the evidence for biodiversity effects on ecosystem functioning and services. *Ecology Letters* 9: 1146-1156.

Bernes, C. 1994. *Biological diversity in Sweden: a country study (Monitor 14)*. Swedish Environmental Protection Agency, 280 pp.

BIP. 2010. Biodiversity Indicators Partnership. Retrieved 15 June, 2013, from: http://www.bipindicators.net/.

CBD.1992. Text of the Convention on Biological Diversity. Retrieved 15 May, 2013, from: http://www.cbd.int/convention/convention.shtml.

Dana, G.V., A.R. Kapuscinski, and J.S. Donaldson. 2012. Integrating diverse scientific and practitioner knowledge in ecological risk analysis: A case study of biodiversity risk assessment in South Africa. *Journal of Environmental Management* 98: 134-146.

Diaz, S., and M. Cabido. 2001. Vive la difference: plant functional diversity matters to ecosystem processes. *TRENDS in Ecology and Evolution* 16: 646-655.

Diekmann, M. 1994. Deciduous forest vegetation in Boreo-nemoral Scandinavia. Doctoral thesis. Svenska Vaxtgeografiska Sällskapet: Uppsala University.

Duelli, P., and M.K. Obrist. 2003. Biodiversity indicators: the choice of values and measures. *Agriculture, Ecosystems and Environment* 98: 87-98.

Eglington, S.M., D.G. Noble, and R.J. Fuller. 2012. A meta-analysis of spatial relationships in species richness across taxa: Birds as indicators of wider biodiversity in temperate regions. *Journal for Nature Conservation* 20(5): 301-309.

Faith, D.P. 1992. Conservation evaluation and phylogenetic diversity. *Biological Conservation* 61: 1-10.

Fisher, B., R.K. Turner, and P. Morling. 2009. Defining and classifying ecosystem services for decision making. *Ecological Economics* 68: 643-653.

Gallardo, B., S. Gascón, X. Quintana, and F.A. Comín. 2011. How to choose a biodiversity indicator-Redundancy and complementarity of biodiversity metrics in a freshwater ecosystem. *Ecological Indicators* 11(5): 1177-1184.

GBIF. 1996. Global Biodiversity Information Facility. Retrieved 21 February, 2013, from: http://www.gbif.org/.

Gillespie, T.W., G.M. Foody, D. Rocchini, A.P. Giorgi and S. Saatchi. 2008. Measuring and modelling biodiversity from space. *Progress in Physical Geography* 32(2): 203–221.

Halffter, G., and M. Rös. 2013. A strategy for measuring biodiversity. *Acta Zoológica Mexicana* 29(2): 400-411.

Janssen, M., E. Birnie, G. Bonsel. 2007. Evaluating the discriminatory power of EQ-5D, HUI2 and HUI3 in a US general population survey using Shannon's indices. *Quality of Life Research* 16(5): 895-904.

Jennings, M.D., J. Hoekstra, J. Higgins, and T. Boucher. 2008. A comparative measure of biodiversity based on species composition. *Biodiversity Conservation* 17: 833–840.

Jonathan, A. 2009. *Species Richness: Patterns in the Diversity of Life*. Springer Praxis Books/ Environmental Sciences, 386 pp.

Lamb, E.G., E. Bayne, G. Holloway, J. Schieck, S. Boutin, J. Herbers, and D.L. Haughland. 2009. Indices for monitoring biodiversity change: Are some more effective than others?. *Ecological Indicators* 9(3): 432-444.

Länsstyrelsernas GIS-tjänster. 2013. Retrieved 26 February, 2013, from: http://gis.lst.se

Lister, N.E. 1997. A systems approach to biodiversity conservation planning. *Environmental Monitoring and Assessment* 49: 123-155.

Lister, N.E. 1998. A systems approach to biodiversity conservation planning. *Environmental Monitoring and Assessment* 49: 123–155.

McCann, K.S. 2000. The diversity-stability debate. *Nature* 405: 228-233.

Millennium Ecosystem Assessment. 2005. *Ecosystems and Human Well-Being: Synthesis. Island Press*, Washington DC.

Oksanen, J., F.G. Blanchet, R. Kindt, P. Legendre, P.R. Minchin, R.B. O'Hara, G.L. Simpson, P. Solymos, et al. 2013. Package "vegan". *Community Ecology Package* 2: 0-8.

Ormsby, T., E.J. Napoleon, R. Burke, C. Groessl, L. Bowden. 2010. *Getting to know ArcGIS Desktop*. ESRI Press; Second Edition, for ArcGIS 10 edition, 592 pp.

Pereira, H.M., and H.D. Cooper. 2006. Towards the global monitoring of biodiversity change. *Trends in Ecology & Evolution* 21(3): 123-129.

Powledge, F. 2012. Biosphere II Is Back. *BioScience* 62(9).

Quammen, D. 1997. *The song of the Dodo: Island Biogeography in an Age of Extinctions.* Simon & Schuster, New York.

R Development Core Team. 2008. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Retrieved 4 June, 2013, from: http://www.R-project.org.

Rapport, D.J, R. Costanza, A.J. McMichael. 1997. Assessing ecosystem health. *Ecology and Evolution* 13(10): 397-402.

Rättviks kommun, 2008-2012. Retrieved 22 July, 2013, from: http://rattvik.se/movingtorattvik.

Rodrigues, A.S.L, and T.M. Brooks. 2007. Shortcuts for Biodiversity Conservation Planning: The Effectiveness of Surrogates. *Annual Review of Ecology, Evolution, and Systematics* 38: 713-737. DOI: 10.1146/annurev.ecolsys.38.091206.095737.

Rundlöf, M., H. Nilsson and H.G. Smith. 2008. Interacting effects of farming practice and landscape context on bumble bees. *Biological Conservation* 141(2): 417-426.

Seabased at the Lysekil Test Site. 2011. Seabased AB. Retrieved 26 July, 2013, from: http://mhk.pnnl.gov/wiki/index.php/Seabased_at_Lysekil.

Smith, H.G., E. Öckinger and M. Rundlöf. 2010. Biodiversity and the landscape ecology of agri-environment schemes. *Aspects of Applied Biology* 100.

Smitterberg. Explore the Nature on Gotland. Retrieved 25 July, 2013, from: www.gotlandnature.com/en/gotland/bird_watching_smitterbergs.shtml.

Sustainability report 2010/2011. HeidelbergCement Northern Europe. Retrieved 24 July, 2013, from: http://hcne-sustainability.nu/promoting-biodiversity-our-carries.

Svärd, L. 2013. Swedish environmental protection agency. Retrieved 16 August, 2013, from http://www.swedishepa.se/Environmental-objectives-and-cooperation/Swedens-environmental-objectives/The-national-environmental-objectives/A-Rich-Diversity-of-Plant-and-Animal-Life.

Sverige Kommungränser. 2012. Retrieved 25 February, 2013, from: http://arcgis.com/home/item.html?id=41f5d23fef8f410590f2d934c7dba81a

Tuomisto, H. 2010. A Diversity of beta diversities: straightening up a concept gone awry. Part 1. Defining beta diversity as a function of alpha and gamma diversity. *Ecography* 33(1): 2-22.

Vassiliki, K., P. Devillers, M. Dufrêne, A. Legakis, D. Vokou, and P. Lebrun. 2004. Testing the Value of Six Taxonomic Groups as Biodiversity Indicators at a Local Scale. *Conservation Biology* 18(3): 667-675.

Institutionen för naturgeografi och ekosystemvetenskap, Lunds Universitet.

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