Empirical correlations between anthropogenic factors and occurrences of herpetofauna species and protected areas effectiveness on controlling anthropogenic factors for herpetofauna in Crete, Greece

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Empirical correlations between anthropogenic factors and occurrences of herpetofauna species and protected areas effectiveness on controlling anthropogenic factors for herpetofauna in Crete, Greece

by

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Abstract

Amphibians and reptiles have been declining for decades. Both of species are considered as vulnerable groups species. Anthropogenic activities are one group of the greatest threats for herpetofauna species. To protect vulnerable species from disturbances generated by human beings, establishing protected areas is a way that has been widely used. In Crete, herpetofauna species are now facing the impacts from different types of human activities, and whether the Cretan protected network can control those anthropogenic factors is still not clearly known. Thus, this study assessed the empirical correlations between anthropogenic factors and the occurrences of herpetofauna species, and checked if Cretan protected areas can control anthropogenic factors for herpetofauna species.

MaxEnt model was used in this study to generate suitable-habitat maps for each herpetofauna species. Two types of suitable-habitat maps were generated: one modelled with environmental factors only, and the other one modelled with both anthropogenic factors and environmental factors. Student-t test was the statistical method to perform the suitable-habitat area comparisons between the two types of suitable-habitat maps.

Through comparing two types of suitable-habitat areas and analysing response curves of important anthropogenic factors, a generally negative correlation between anthropogenic factors and herpetofauna species occurrences was found. However, for few specific herpetofauna species, anthropogenic factors have positive effects and for another few specific species, anthropogenic factors have almost no effects on them. By comparing the two types of suitable-habitat areas that within the protected network and checking whether each important anthropogenic factors occurring within protected areas or not, Cretan protected network was found that cannot protect herpetofauna species from anthropogenic impacts very effectively. It can control agricultural cultivation, impact of highway and human population inside protected areas well, but cannot control livestock breeding, impact of secondary roads and impact of tourism thoroughly.

Keywords:

herpetofauna, MaxEnt, anthropogenic factors, protected areas, Crete

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Chapter 1 Introduction

1.1 Background introduction

Worldwide amphibians and reptiles have been declining since 1990s (Lovich et al., 2009). Both groups of species are considered as highly vulnerable, and 20-30% of the species are facing threats and extinctions (Benayas et al., 2006; Brandon et al., 2005). The percentage of facing extinction for herpetofauna species (20-30%) is higher than the one for bird species (12%) and at the same level with the percentage for all mammals (25%) (Brandon, et al., 2005). Most of herpetofauna species are not good at colonizing and have very limited ability of long-distance migration (Benayas, et al., 2006). Thus, they are very sensitive and vulnerable when facing even temporary threats or changes (Benayas, et al., 2006). Moreover, as mentioned by Valakos et al. (2008a) in their study, reptiles are the first group of vertebrate species that truly adapted to terrestrial life (Valakos, et al., 2008a). Also, reptile species have scaly skin and their bones are stronger than amphibian species, thus reptiles have a relatively strong body protection (Valakos, et al., 2008a). While different from reptile species, amphibians cannot totally adapted to terrestrial life and still cannot live without aquatic environment since they can only live in the water at their larvae life stage (Valakos, et al., 2008a). Comparing with reptile species, amphibians normally have sensitive and scale-less soft skin and weaker bones, which cannot provide strong body protection for themselves and make them more sensitive to threats (Valakos, et al., 2008a).

There are several reasons that lead to herpetofauna species decline, as shown in figure 1-1. Natural disasters, such as earthquake and flood, lead to herpetofauna population within a region sharply decline in a short time period (IUCN, 2011 a, 2011 b). Other reasons, for instance disease and accidental mortality, threat herpetofauna individuals of their health and safety thus lead to their population decline (IUCN, 2011 a, 2011 b). Except those reasons above, anthropogenic activities are also considered as one group of the greatest threats for herpetofauna species (Benayas, et al., 2006; IUCN, 2011 a, 2011 b).



Figure 1-1 General problem tree for the issue of herpetofauna decline

There are four types of anthropogenic activities, which are tourism, agriculture, traffic and residential developments, have been testified that have effects on herpetofauna individuals and herpetofauna habitat changes. Tourism and residential developments result in habitat loss, since the construction of buildings and tourism facilities alter the natural environment to an artificial environment (Benayas, et al., 2006; Hecnar & M.'Closkey, 1998). Besides, noise generated by tourists and the disturbances come from vehicles and steps of tourists have negative effects on body condition of herpetofauna individuals (Amo et al., 2006; French et al., 2010). Road traffic causes mortality of herpetofauna individuals when they cross or stay on the road (Hels & Buchwald, 2001). Road traffic also leads to the isolation of herpetofauna populations, for they divide large habitat areas into small isolated pieces thus interrupt the migration of herpetofauna species. (Hels & Buchwald, 2001; Woltz et al., 2008). Agriculture development causes habitat condition changes and degradation, because the original vegetation (e.g. forests and dense shrubs) and rocks will be removed in order to cultivate crops or forage grass (Maisonneuve & Rioux, 2001; Ribeiro et al., 2009).

To conserve those species whose abundances are declining, knowledge about occurrence of those species is essential (Greaves et al., 2006). For most of species, the possibility of occurrence in a

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certain area can be predicted by species distribution models (SDMs). Until now, SDMs are becoming an important method and have been widely used (Hanspach et al., 2010; Johnson & Gillingham, 2008). SDMs are techniques that using the relationship between species occurrence and environmental conditions to model the geographical ranges of suitable-habitat for the certain species(Varela et al., 2011). However, with the increase of human activities and the development of human society, many anthropogenic impacts have been generated, which means the occurrence of species might not only relate to environmental conditions but also might rely on anthropogenic factors. Similarly as SDMs can connect species occurrence with environmental conditions, SDMs could also become a tool to investigate empirical relationships between species occurrence and anthropogenic factors when anthropogenic factors are involved in building the models.

Based on species occurrence possibilities, suitable-habitat areas of that species can be defined. Using a certain threshold, areas with occurrence possibility values higher than the threshold will be defined as suitable-habitat areas for that species (Ottaviani et al., 2004). In a region where a species occur, when new factors which do not exist within that region before are introduced into that region, the area of suitable-habitat for that species may change (Giordano et al., 2010). This suitable-habitat area change could indicate how the species react to the new factors (Giordano, et al., 2010) thus indicate the correlation between the occurrence of that species and the new factors. However, the suitable-habitat area change might not only relate to the new introduced factors. According to the study of Reside et al. (2011), the area change of suitable-habitat could also relate to the SDMs discrimination ability between suitable-habitat and unsuitable-habitat, which means when the SDM becomes more discriminative, suitable-habitat area will become smaller. Thus, the interpretation of the suitable-habitat area change needs to be executed with caution.

A variety of SDMs have been applied to simulate the distributions of species. There are several commonly used SDMs, such as Generalized Linear Models (GLMs), Generalized Additive Models (GAMs) and Boosted Regression Trees (BRT) (Elith et al., 2008; Friedman et al., 2000; Guisan et al., 2002). GLMs and GAMs are based on an assumed relationship between the mean of the response variable and the linear combination of the explanatory variables (Guisan, et al., 2002). BRT use boosting technique to combine large numbers of relatively simple regression tree models thus to optimize predictive performance, and it can fit complex nonlinear relationships between

explanatory variables (Elith, et al., 2008). GLMs and GAMs were initially built to conduct presence species data together with absence species data (Guisan, et al., 2002). Similarly, BRT also request both presence and absence species data (Elith, et al., 2008).

However, actual species absence data can only seldom be proved (Ottaviani, et al., 2004). For plant species, their absence data might can be achieved by plant census (Ottaviani, et al., 2004). But for animal species, the detection of animal individuals can often be influenced by elusive behavior and activity patterns of animals and the poor accessibility of their habitats, thus the species absence data can hardly be verified by field surveys (Ottaviani, et al., 2004). Thus, SDMs using presence-only species data have been paid more attentions to (Ottaviani, et al., 2004; D. Stockwell & Peters, 1999).

There are two widely used SDMs using presence-only species data in recent years: Genetic Algorithm for Rule-set Production (GARP) and Maximum Entropy (MaxEnt) (Anderson & Gonzalez Jr, 2011; D. Stockwell & Peters, 1999).

GARP relates species presence points to those of points that are randomly sampled from the remaining areas within the study region to develop a series of decision rules that can best summarizing those explanatory variables that are associated with the species presence (Adjemiana et al., 2006). MaxEnt is a machine learning method which depends on finding the probability distribution of maximum entropy to estimate a target probability distribution for a certain species (Phillips et al., 2006). It has been proved to be a well-performed model when only presence data of species are available (Phillips, et al., 2006). Besides, MaxEnt also performs well when a relatively small sample size is used (Kuemmerle et al., 2010). Comparing with GARP, MaxEnt has been proved that have better discrimination of suitablehabitat and unsuitable-habitat (Phillips, et al., 2006) and better performance when sample sizes of presence-only data are small (Hernandez et al., 2006).

To protect vulnerable species, such as amphibian and reptile species, from disturbances generated by human beings, establishing protected areas is a way that has been widely used (Catullo et al., 2008). Nonetheless, the effectiveness of protected areas can often be questioned for the reason that many protected areas are build more based on social-economic and aesthetic criteria rather than ecological criteria (Catullo, et al., 2008; Oldfield et al., 2004). Therefore, whether protected areas can really control those disturbances which are generated by humans should be a question worth thinking about.

1.2 Research problem

Crete, the largest island of Greece, has 15 herpetofauna species (3 amphibian species and 12 reptile species), including one species, listed in the IUCN Red List of Threatened Species as "Endangered", and one endemic species (Valakos, et al., 2008a). Most of the herpetofauna species are included in the Appendix II of Bern Convention (Valakos, et al., 2008a). Species listed as "Endangered" in the IUCN Red List are considered to be facing a very high risk of extinction in the wild (IUCN, 2011 c). The Appendix II of Bern Convention lists the fauna species that need to be strictly protected (Council of Europe, 2011). According to the study of Valakos et al. (2008a), Cretan herpetofauna species are now facing different human activities, for instance, tourism, residential development, traffic development and agriculture development, that arise within the assessing island. Consequently, the correlations between anthropogenic factors and the occurrence of herpetofauna species is important.

Although in Crete, numbers of protected areas have been built under Natura 2000 protected network (Boteva et al., 2004), but the effectiveness of the Cretan protected network on controlling anthropogenic factors is still not clearly known. Thus, checking if Cretan protected areas can control anthropogenic factors for herpetofauna species is seemed to be necessary for further protected area planning.

Moreover, as stated in chapter 1.1, amphibian species are more sensitive to threats than reptile species. Therefore, assessing if anthropogenic factors affect amphibian species and reptile species differently and checking if the Cretan protected network controls anthropogenic factors equally well for amphibian species and for reptile species are reasonable and necessary for protecting Cretan herpetofauna species thoroughly.

1.3 Objectives

1.3.1 General objectives

Assess the empirical correlations between anthropogenic factors and the occurrences of herpetofauna species; and check if Cretan protected areas can control anthropogenic factors for herpetofauna species.

1.3.2 Specific objectives

To achieve the overall objective, four specific objectives are defined as below:

- 1) Assess the correlations between human factors and the occurrences of herpetofauna species.
- Assess if anthropogenic factors affect the occurrences of amphibian species differently from the occurrences of reptile species.
- 3) Check if the Cretan protected network can control anthropogenic factors that have a correlation with the herpetofauna species.
- 4) Check if the Cretan protected network controls anthropogenic factors equally well for amphibian species and for reptile species.

1.4 Research questions

1.4.1 General research questions

How are the empirical correlations between anthropogenic factors and the occurrences of herpetofauna species in Crete, and whether Cretan protected areas can control anthropogenic factors for herpetofauna species?

1.4.2 Specific research questions

- 1) How do suitable-habitat areas change for herpetofauna species when including anthropogenic factors comparing with when excluding anthropogenic factors?
- 2) Is there any significant difference between the correlation of anthropogenic factors on amphibian species and the correlation on the occurrences of reptile species?
- 3) How do suitable-habitat areas within the protected network change for herpetofauna species when including anthropogenic factors comparing with when excluding anthropogenic factors?

4) Can the Cretan protected network control anthropogenic factors equally well for amphibian species and for reptile species?

1.5 Hypotheses

Hypothesis 1:

H1: Suitable-habitat areas of herpetofauna species when exclude human factors are significantly larger than suitable-habitat areas when include human factors.

Hypothesis 2:

H1: The area differences between suitable-habitat areas when exclude human factors and suitable-habitat areas when include human factors for amphibian species are significantly larger than the ones for reptile species.

Hypothesis 3:

H1: Suitable-habitat area within the protected network for herpetofauna species when exclude human factors are significantly larger the ones when include human factors.

Hypothesis 4:

H1: The area differences between suitable-habitat area within the protected network when exclude human factors and suitable-habitat area within the protected network when include human factors for amphibian species are significantly larger than the area differences for reptile species.

Chapter 1

Chapter 2 Methods

2.1 Study area



Figure 2-1 Map of Crete showing the location of Crete and the main cities in the island

The study area for this research is Crete, the largest island of Greece and the fifth largest island of Mediterranean Sea with an area of 8,336 km² (Vitsakis, 2009). The climate there is Mediterranean climate with mild winter and hot and dry summer (Vitsakis, 2009). Because of the highly heterogeneous and unique geography and the long-time isolation from mainland Europe, Asia, and Africa, Crete has a unique diversity of fauna (Vitsakis, 2009). In Crete, 15 herpetofauna species are found, including 3 amphibian species and 12 reptile species. Most of the species can be seen throughout the island (Valakos, et al., 2008a). Crete has 6 principal cities and a total local population of more than 620000 (Vitsakis, 2009). Agriculture including livestock breeding and tourism are the main economic activities of Crete (Vitsakis, 2009).

2.2 Research approach

There are three main steps in this study: data preparation, modelling process and interpretation and statistic process. The framework of this study is shown in figure 2-2. Each of these three steps will be explained below, respectively.



Figure 2-2 Flowchart of framework

2.2.1 Data preparation

2.2.1.1 Anthropogenic factors

As mentioned in chapter 1 above, there are four types of human activities, which are residential development, agriculture development, traffic development and tourism, could influence herpetofauna species. For these four types of human activities, representative indicators were collected during field work in Crete (12th September-2nd October, 2011).

Residential development normally leads to the concentration and growth of human population and the altering of natural areas to residence areas (Xu & Coors, 2012). Thus, population density and build-up area distribution could be the representative indicators of residential development. Population data of Crete was provided by the National History Museum of Crete and was achieved during field work in Crete. The population data was first obtained as polygon data with population numbers per polygon, and each polygon is a municipality. Then the data was converted to density values per 1km² by using the population number of one municipality divided by the area (km²) of that municipality. The generated population density layer was a raster map with continuous values in 1km² resolution. Build-up area layer was created by reclassifying the CORINE Land Cover 2000 map into a binary map. All the sub-classes below artificial surfaces class were classified into a "build-up" class, and all other classes were grouped into a "non-build up" class. Build-up area layer was also a raster map in 1km² resolution but with categorical dummy values (1 and 0). CORINE Land Cover 2000 map was obtained from European Environment Agency (EEA) website. The CORINE map was generated by using computer-assisted image interpretation of earth observation satellite images (EEA, 2004). It mapped the whole European territory into 44 different types of land cover (EEA, 2004). The legend of the original CORINE Land Cover 2000 map is shown in appendix 1.

The representative indicators of agriculture development were livestock density and agricultural cultivation area distribution. Livestock data of Crete was first obtained as polygon data with livestock number of each livestock species per polygon (municipality). The data was achieved during field work in Crete from the National Statistical Service of Greece through the help of the staffs from the University of Crete. Among all the livestock species in Crete, only four pastured livestock species were taken into account. The four pastured livestock species are cattle, goat, equidae and sheep. Number of each kind of pastured livestock in each municipality was converted to livestock unit value first. Then the total livestock unit value of each municipality was calculated by summing up the livestock unit values of the four pastured livestock species. Finally, livestock density (in livestock units per 1km²) was calculated using the total livestock unit value of each municipality divided by the area of that municipality. The generated livestock density layer was a raster map with continuous values in 1km² resolution. Livestock unit is a reference unit that facilitates the aggregation of livestock from various species and ages as one convention (Eurostat (European Commission), 2010). It is based on the nutritional or feed requirement of each type of livestock unit coefficients are shown in table 2-1 below.

Agricultural cultivation area layer was created similarly as build-up area layer, which by reclassifying the CORINE Land Cover 2000 map into a binary map. All sub-classes belonging to the agricultural area class were classified into an "agricultural cultivation" class, and all the other classes were classified into a "non-agricultural cultivation" class. The final agricultural cultivation area layer was a map in 1km² resolution with categorical dummy values (1 and 0).

Livestock species	Livestock unit coefficient
Cattle, heifers	0.8
Cattle, male	1.0
Sheep	0.1
Goat	0.1
Equidae	0.8

Table 2-1	Livestock	unit coeffi	cient for e	each j	pastured	1 livestock
species in	Crete (Eu	rostat (Eu	ropean Co	ommi	ssion), 2	2010)

The indicators of traffic development were distances to highway, primary roads and secondary roads. These three layers were created by calculating Euclidean distance to highway, primary roads and secondary roads respectively using a shapefile of those roads in Crete. The shapefile was obtained from the University of Crete during field work. The final distance to highway layer, distance to primary roads layer and distance to secondary roads layer were raster maps with continuous values in 1km2 resolution.

Impact of tourism was represented by a layer which contained the information of hotels locations and hotels beds numbers. The layer

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was named as "potential tourism impact layer". Tourism could affect natural environment from two aspects, which are impact of tourism facilities constructions and impact of tourist activities (Bushell & Eagles, 2007). Tourism facilities constructions always alter the natural environment to an artificial environment, while tourist activities may disturb natural species individuals (Bushell & Eagles, 2007; Hecnar & M.'Closkey, 1998). More tourists lead to more tourist activities (Bushell & Eagles, 2007), thus may generate more disturbances. Accommodation facilities, such as hotels, are one type of the necessary facilities for tourism (Bushell & Eagles, 2007). The locations of hotels could indicate where the natural environment has been altered to artificial environment. Moreover, the beds number of each hotel can show how many tourists accommodate there. Large beds numbers indicate large tourist numbers thus indicate large scale tourism impact.

The data and information about hotels in Crete were initially provided as a series of lists contain the address and beds number of each hotel. These data were obtained during field work from the offices of the Greek National Tourist Organization in Crete with the help of the staffs from the University of Crete. Firstly, the locations of all the hotels were digitized manually according to their addresses by using Google Earth. Then Inverse Distance Weighted (IDW) interpolation was used to generate potential tourism impact layer based on hotels beds numbers.

IDW interpolation is a kind of interpolation method that assigns values to unknown data points based on the values of known data points and the distances between unknown data points and known data points. The closer the unknown data point is to the known data point, the more similar value with that known data point will be assigned to the unknown data point (He et al., 2008). Since IDW interpolation method was founded, it has become to one of the most commonly used technique (He, et al., 2008), and also has been widely and successfully applied to many science fields, such as ecology and geology (He, et al., 2008; Robinson & Metternicht, 2006).

Normally, tourists have more activities in areas that near their destinations than in areas that far away from their destinations (Bushell & Eagles, 2007). Also, they normally choose to accommodate in the hotels that near their destinations (Bushell & Eagles, 2007). Therefore, it could be to some extent considered as that the areas near hotels have more tourist activities consequently more affected by tourism than the areas far away from hotels.

According to this, the closer a point is to a hotel, the higher impact values should be assigned to. Thus, the IDW interpolation is applicable and suitable for generating the potential tourism impact layer.

2.2.1.2 Environmental factors

What environmental factors would be involved in the modeling process in this research was decided according to whether the factor was relevant for herpetofauna species and the study area or not. Also, data availability is another issue to decide the involved environmental factors.

Temperature, precipitation, solar radiation and Normalized Difference Vegetation Index (NDVI) have been proved that have significant correlations with the distributions of herpetofauna species and activities of herpetofauna individuals (Nicholson et al., 2005; Skidmore et al., 2006). Geological factors are related to herpetofauna habitats conditions thus affect the inhabitation preferences of herpetofauna species (Means & Simberloff, 1987). Topographical factors has been stated as necessary factors for SDMs in the areas with heterogeneous geography condition (Guisan et al., 1999). In Crete, highly heterogeneous landscape can be found, from mountainous regions up to more than 2000 meters high to plain regions just above sea level. Thus, topographical factors are necessary factors for this study area. The available topographical data for Crete are altitude and aspect.

The involved environmental factors are listed in table 2-1 below. BIOCLIM climate data are derived from the monthly temperature and rainfall values (Hijmans et al., 2005). It generates more biologically meaningful variables about temperature and precipitation (Hijmans, et al., 2005). BIOCLIM climate data contains 19 factors represent annual trends, seasonality and extreme or limiting environmental conditions. All the 19 factors are listed in appendix 2-2. Geology factor is in categorical values. It contains 13 categories with value from 1 to 13. Each value represents one type of geological condition. All 13 categories are listed in appendix 2-2. Radiation data contains 12 factors of monthly radiation data calculated by averaging radiation value of each month in ten years (1981-1990) and 1 factor of annual radiation calculated by averaging total radiation in that ten years. NDVI average data was calculated by averaging all the 10 days synthesis in ten years (1998-2008).

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Finally, all the factors were converted into raster layers in 1km2 resolution with WGS 1984 UTM Zone 35N projected coordinate system.

Table 2-2 Involved environmental factors

Factor name	Туре	Resolution	Source	Other description
Altitude	raster file	1km ²	USGS/SRTM*	Continuous values
Aspect	raster file	1km ²	USGS/SRTM*	Continuous values
BIOCLIM climate data	raster file	1km ²	Worldclim, Hijmans <i>et al.</i>	Continuous values
Geology	vector file (polygon)		NHMC*	Categorical values
NDVI average	raster file	1km ²	VITO*/Spot images	Continuous values
Radiation	raster file	1km ²	ESRA*	Continuous values

*USGS/SRTM: United States Geological Survey/Shuttle Radar Topography Mission; NHMC: National History Museum of Crete; VITO: Flemish Institute for Technological Research; ESRA: European Solar Radiation Atlas

2.2.1.3 Herpetofauna species data

Species	Class	Number of presence	Species	Class	Number of presence
		points			points
Bufo viridis	Amphibia	86	Elaphe situla	Reptilia	37
Caretta caretta	Reptilia	24	Mauremys rivulata	Reptilia	85
Chalcides ocellatus	Reptilia	125	Natrix tessellata	Reptilia	15
Coluber gemonensis	Reptilia	65	Podarcis erhardii	Reptilia	118
Cyrtopodion kotschyi	Reptilia	17	Rana cretensis	Amphibia	71
Lacerta trilineata	Reptilia	164	Tarentola mauritanica	Reptilia	25
Hemidactylus turcicus	Reptilia	68	Telescopus fallax	Reptilia	14
Hyla arborea	Amphibia	31			

Table 2-3 Herpetofauna species in Crete

Some of the Cretan herpetofauna species presence data were collected in the field during fieldwork (12th September-2nd October, 2011) by recording the latitude and longitude of the point where the species individual was found. The other part of species presence data

were provided by the University of Crete. The data were collected by herpetologists and staffs work in the University of Crete. The earliest species presence data was recorded in 1999, and the latest was recorded in 2011. The number of presence points varies a lot from species to species. The number of presence points for each Cretan herpetofauna species was listed in table 2-3.

All the species presence data were converted into WGS 1984 UTM Zone 35N projected coordinate system.

2.2.1.4 Cretan protected areas data

Official protected areas in Crete belong to Natura 2000 network. Natura 2000 is a network of nature protection areas within European Union region, which aims at assuring the long-term survival of Europe's most valuable and threatened species and habitats (Environment Directorate-General of the European Commission, 2012). The data was obtained from the website of European Environment Agency as a shapefile for the whole Greece, and then protected areas in Crete were clipped out.

2.2.2 Modelling process

2.2.2.1 Multi-collinearity test

Before species distribution modelling in MaxEnt, multi-collinearity test was done to select proper explanatory variables for modelling process. Multi-collenearity test is to check if the explanatory variables involved in the model are correlated with each other consequently negatively affects model performance. The multi-collinearity can be detected by calculating the Variance Inflation factors (VIF) value of each environmental and anthropogenic factor. The VIF value is calculated as the equation below:

$$VIF = \frac{1}{(1 - R_i^2)}$$

where R_i^2 is the multiple coefficient of determination in a regression of the ith predictor on all the other predictors (Craney & Surles, 2002). VIF values higher than 10 are considered to lead to problematic levels of multi-collinearity (Craney & Surles, 2002). Only factors with continuous values and factors with dummy values (0 and 1) were involved in multi-collinearity test, factor with categorical values (geology factor) is not included. Factors with VIF values that higher than 10 were not used in the model. The selected factors are showing in table 2-4 below.

Table 2-4 Selected factors using in MaxEnt model

Factor name	VIF value	Factor name	VIF value
Agricultural area	1.60	Potential tourism impact	1.39
Altitude	7.47	Livestock density	1.23
Aspect	1.03	NDVI average	2.71
Max temperature – min temperature (BIO 07)	6.22	Distance to secondary roads	1.91
Max precipitation (BIO 13)	2.96	Population density	1.36
Min precipitation (BIO 14)	8.98	Annual radiation	3.27
Build-up area	1.24	Distance to primary roads	1.54
Distance to highway	2.04	Geology	\

2.2.2.2 Species distribution modeling using MaxEnt

MaxEnt was chosen as the SDM in this study because of its good discrimination of suitable-habitat and unsuitable-habitat (Phillips, et al., 2006) and good performance when sample sizes of presence-only data are small (Hernandez et al., 2006).

All the involved anthropogenic factor layers and environmental factor layers were in WGS 1984 UTM Zone 35N projected coordinate system and 1km² special resolution.

According to previous studies, samples with species presence points less than 30 are considered as small sample size samples (Boitani et al., 2011; Moilanen et al., 2009). For large sample size, bootstrap validation method can provide highly accurate validation results, but cannot perform well when dealing with small size samples (Moore & McCabe, 2006). Different from bootstrap method, cross-validation is a markedly superior validation method for small sample size data sets (Goutte, 1997). Therefore, for those species with presence points less than 30, Cross-validation was used, while for species with presence points more than 30, bootstrap validation was used.

When doing species distributions modeling in MaxEnt, 75% present points were used as training points, and 25% present points were used as testing points for every species. Thus, when modeling for

species with small sample size using cross-validation method, the replicate times was depended on the number of presence points of that species. Since the sample sizes of species with presence points more than 30 are not very large (<200), the models do not need to be replicated many times (Boitani, et al., 2011). Therefore, when modeling for species with presence points more than 30, models were replicated 5 times.

2.2.2.3 Model evaluation

In this study, to check the performances of MaxEnt species distribution models, True skill statistic (TSS) and Area under receiver operating characteristic curve (AUC) of test models were chosen as main assessments. Sensitivity and AUC of training models were also provided as subordinate assessments.

Sensitivity is also called as true positive rate. It is calculated as the equation below:

 $Sensitivity = \frac{True \ positive \ number}{(True \ positive \ number + False \ negative \ number)}$

where true positive number is the number of correctly predicted presence points, and the false negative number is the number of wrongly predicted presence points (Jones et al., 2010). Sensitivity is a necessary assessment for checking the performance of SDMs (Saatchi et al., 2008).

TSS is one of the most commonly used measures to assess models accuracy (Jones, et al., 2010). It is calculated as the equation below:

TSS = (sensitivity + specificity) - 1

where sensitivity is true positive rate and specificity is true negative rate (Jones, et al., 2010). TSS values normally are between 0 and 1, but in rare cases TSS values could be negative, which indicates the model is not better than a random model (Jones, et al., 2010). Similarly as sensitivity, specificity is calculated based on the number of correctly predicted absence points and the number of wrongly predicted absence points (Jones, et al., 2010).

Both sensitivity and TSS are threshold-dependent measure. In this study, equal sensitivity and specificity threshold was used. Equal sensitivity and specificity threshold is one of the most widely used threshold criteria (Jime´nez-Valverde & Lobo, 2007). Several studies

have stated that when dealing with species distribution models, equal sensitivity and specificity threshold can produce most accurate predictions of presence or non-presence comparing with other widely used threshold criteria, such as the fixed value 0.5 and Kappa maximization (Jime´nez-Valverde & Lobo, 2007; Liu et al., 2005). Hence, equal sensitivity and specificity threshold was chosen as the threshold criterion in this study.

Besides TSS, AUC is also used in this thesis to do accuracy assessment. AUC is obtained from the Receiver Operating Characteristic (ROC) curve (Jones, et al., 2010). It can show the discrimination of a model, that higher AUC value indicates the model is more discriminative (Anderson & Gonzalez Jr, 2011). ROC curve is generated by plotting sensitivity as a function of commission error (1-specificity), and the resulting area under the ROC curve is AUC (Jones, et al., 2010). AUC values are between 0 and 1. Different from TSS, AUC is a kind of threshold-independent measure (Jones, et al., 2010). It is also widely used as an accuracy assessing measure, and its reliability has been proved by many studies (Anderson & Gonzalez Jr, 2011; Jones, et al., 2010; Lippitt et al., 2008).

2.2.3 Interpretation and statistic process

Species distribution maps produced by MaxEnt model were converted into suitable-habitat maps showing presence and non-presence of the species based on equal sensitivity and specificity threshold. For each species, two types of suitable-habitat map were got: suitable-habitat map when excluding anthropogenic factors, and suitable-habitat map when including anthropogenic factors. Suitable-habitat area for both two types of suitable-habitat maps were calculated accordingly.

Then, the two suitable-habitat maps for each species were overlaid with Cretan protected network map to generate two maps showing the suitable-habitat areas within protected network for each species. Suitable-habitat area within protected network when excluding human factors and suitable-habitat area within protected network when including human factors were then calculated according to the two types of maps.

Suitable-habitat areas when excluding human factors were statistically compared with suitable-habitat areas when including human factors (hypothesis 1). It can show if human factors make suitable-habitat areas reduce or increase, thus can show whether human factors are positively related with herpetofauna occurrences or negatively related. Similarly, suitable-habitat areas within protected network when excluding human factors were statistically compared with the ones when including human factors (hypothesis 3). This can state that whether human factors make suitable-habitat areas within protected network shrink or not, consequently can state whether Cretan protected network can protect the species from human impacts or not. For instance, if suitable-habitat areas within protected network shrink when including human factors, it means that protected network cannot avoid the effects of human factors within protected areas, thus means the protected network cannot control anthropogenic factors very effectively for herpetofauna species.

Suitable-habitat area change and area change of suitable-habitat within protected network for each species were calculated as below:

Suitable habitat area change

= suitable habitat area when including human factors - suitable habitat area when excluding human factors

Area change of suitable habitat within protected network = suitable habitat area within protected network when includinghuman factors - suitable habitat area within protected network when excludinghuman factors

Then suitable-habitat area changes for amphibian species were statistically compared with the changes for reptile species (hypothesis 2). It can indicate if anthropogenic factors affect these two groups of species equally or not. Also, area changes of suitable-habitat within protected network for amphibian species were statistically compared with the area changes for reptile species (hypothesis 4). This can show whether Cretan protect network protecting amphibian species and reptile species from human impacts equally.

Student t-test was used to test hypotheses 1 to 4. T-test requests normally distributed values, thus normality test was performed in advance for each value groups listed in table 2-5.

Since sample sizes for all the value groups were small (<50 samples), Shapiro-Wilk test was used to assess normality.

Methods

Table 2-5 Results of Shapiro-Wilk test (Confidence Interval 95%) for each group of values

	Shapiro-Wilk			
Value groups	Statistic	Degree of freedom	Significance	
Group 1: Suitable-habitat area when excluding human factors for every herpetofauna species	0.943	15	0.417	
Group 2 : Suitable-habitat area when including human factors for every herpetofauna species	0.975	15	0.923	
Group 3 : Suitable-habitat area within the protected network when excluding human factors for every herpetofauna species	0.908	15	0.128	
Group 4 : Suitable-habitat area within the protected network when including human factors for every herpetofauna species	0.965	15	0.771	
Group 5 : Suitable-habitat area changes for every amphibian species	0.918	3	0.445	
Group 6 : Suitable-habitat area changes for every reptile species	0.939	12	0.482	
Group 7 : Area changes of suitable- habitat area within the protected network for every amphibian species	0.863	3	0.275	
Group 8 : Area changes of suitable- habitat area within the protected network for every reptile species	0.962	12	0.801	

Table 2-5 shows that at 95% confidence interval level, Shapiro-Wilk significances for all the value groups were greater than 0.05, which means all the values within the same value group were normally distributed. Consequently, student t-tests can be used to test hypotheses 1 to 4 in this study.

As mentioned in chapter 1.1, according to the study of Reside *et al.* (2011), the area change of suitable-habitat is negatively related to the change of model discrimination, which means when the model discrimination becomes higher, suitable-habitat area will become smaller. AUC is a sign which can show the discrimination of a model (Jones, et al., 2010). In this study, area comparisons were used between modelled suitable-habitat areas when excluding human factors and when including human factors to assess if human factors affect herpetofauna species occurrences. Thus, checking AUC changes between these two types of models seems to be necessary for ascertaining whether the area shrinking of suitable-habitat are related to AUC changes or not.

Normality tests showed that test and training models AUC when using only environmental factors (see table 3-1) and test and training models AUC when using both environmental and human factors (see table 3-2) were all normally distributed (Shapiro-Wilk test, 95% confidence interval, Sig.=0.683, 0.841, 0.653, 0.207 respectively). Hence, one-tail paired t-tests were used for checking if test models AUC when including human factors were significantly higher than test models AUC when excluding human factors, and also the same for training models AUC.

To know the empirical correlations between anthropogenic factors and herpetofauna occurrence more doubtlessly, except statistically comparing suitable-habitat areas when excluding human factors and when including human factors, the response curves of important anthropogenic factors were also analysed. Response curve of each factor for each species shows how that species response to that factor (positive response, negative response or complex response). Then by summarizing those responses, the correlations between anthropogenic factors and herpetofauna occurrence could be indicated.

The important anthropogenic factors for each herpetofauna species were judged according to Jackknife test results (see appendix 3). Jackknife test is a function provided by MaxEnt to tell which factors are more important for a certain species. The importance of a factor for a model should not be judged by looking at how useful it is when it is isolated, instead, it should be judged by looking at how much useful information the factor contributes to the model when it cooperating with other factors. Thus, the importance of factors should be judged by losses of model gain when the variable is left out of the model. The more the model gain is reduced when excluding one factor, the more important that factor is.

Methods

Important anthropogenic factors were selected through jackknife test by comparing the model gain when excluding one anthropogenic factor with the full model gain. If the full model gain was reduced visibly when excluding that factor, that factor was considered as important anthropogenic factor. Then the response curves of those important anthropogenic factors were analysed to know how the species response to the factors.

To check more doubtlessly if Cretan protected network can protect herpetofauna species from anthropogenic factors, statistically comparison of two types of suitable-habitat areas that within the protected network was not the only measure in this study. Whether each important human factors occurring within protected areas or not was also checked in this thesis. This was conducted by overlaying each important anthropogenic factor map with Cretan protected network map. If anthropogenic factors occurring within protected areas, it means the protected network still have some defects on controlling anthropogenic factors inside protected areas, consequently means protected network cannot protect herpetofauna species from anthropogenic factors very effectively.

Chapter 2

Chapter 3 Results

3.1 Species distribution models evaluation

Table 3-1 shows the performance of models using only environmental factors, while table 3-2 shows the performance of models using both environmental factors and anthropogenic factors.

Species	Test	models	Training models		
opecies	Sensitivity	TSS	AUC	Sensitivity	AUC
Bufo viridis	0.686	0.372	0.755	0.829	0.838
Caretta caretta	1.000	1.000	0.973	0.906	0.988
Chalcides ocellatus	0.694	0.388	0.753	0.862	0.874
Coluber gemonensis	0.689	0.378	0.738	0.887	0.886
Cyrtopodion kotschyi	0.625	0.250	0.590	0.937	0.863
Elaphe situla	0.640	0.280	0.754	0.855	0.888
Hemidactylus turcicus	0.760	0.520	0.837	0.887	0.912
Hyla arborea	0.600	0.200	0.677	0.960	0.917
Lacerta trilineata	0.627	0.254	0.671	0.848	0.824
Mauremys rivulata	0.822	0.644	0.878	0.853	0.914
Natrix tessellata	0.778	0.556	0.838	0.944	0.928
Podarcis erhardii	0.831	0.662	0.901	0.877	0.938
Rana cretensis	0.700	0.400	0.757	0.846	0.853
Tarentola mauritanica	0.937	0.874	0.961	0.750	0.981
Telescopus fallax	0.667	0.334	0.703	1.000	0.926

Table 3-1 Performances of models using only environmental factors

Enocioc	Test	Training models			
Species	Sensitivity	TSS	AUC	Sensitivity	AUC
Bufo viridis	0.657	0.314	0.742	0.871	0.833
Caretta caretta	1.000	1.000	0.975	0.937	0.994
Chalcides ocellatus	0.789	0.578	0.871	0.827	0.900
Coluber gemonensis	0.822	0.644	0.866	0.900	0.935
Cyrtopodion kotschyi	0.542	0.084	0.606	0.937	0.873
Elaphe situla	0.720	0.440	0.724	0.989	0.958
Hemidactylus turcicus	0.740	0.480	0.777	0.953	0.950
Hyla arborea	0.733	0.466	0.760	0.940	0.943
Lacerta trilineata	0.664	0.328	0.724	0.884	0.867
Mauremys rivulata	0.774	0.548	0.791	0.953	0.950
Natrix tessellata	0.778	0.556	0.855	1.000	0.949
Podarcis erhardii	0.863	0.726	0.938	0.933	0.968
Rana cretensis	0.714	0.428	0.803	0.874	0.899
Tarentola mauritanica	0.937	0.874	0.961	0.825	0.986
Telescopus fallax	0.556	0.112	0.615	1.000	0.949

Table 3-2 Performances of models using both environmental factors and anthropogenic factors

According to table 3-1 and table 3-2, all the species distribution models were better than random (AUC>0.5). Models with AUC value lower than 0.7 were considered as "not good"; models with AUC value between 0.7 and 0.8 were treated as "fair"; models with AUC value between 0.8 and 0.9 were "good", and models with AUC value higher than 0.9 were "excellent" (Howell et al., 2011). Moreover, models can also be judged by TSS value as: TSS values lower than 0.2 were "not good", between 0.2 and 0.6 were "fair" and higher than 0.6 were "good" (Jones, et al., 2010).

For most of the species, models performances were fairly moderate (AUC values higher than 0.7 and TSS values higher than 0.2). However, there are few models that were "not good". In table 3-1 and table 3-2, AUC values lower than 0.7 and TSS values lower than 0.2, which means models were "not good", were highlighted in red color. When using only environmental factors (table 3-1), models of Cyrtopodion kotschyi, Hyla arborea and Lacerta trilineata were considered as not good, while when using both environmental factors and anthropogenic factors (table 3-2), models of Cyrtopodion kotschyi and Telescopus fallax were not good.

Results

3.2 Correlation between anthropogenic *factors and occurrences of Cretan herpetofauna species*

Hypothesis 1:

H1: Suitable-habitat areas of herpetofauna species when exclude human factors are significantly larger than suitable-habitat areas when include human factors.

Hypothesis 2:

H1: The area differences between suitable-habitat areas when exclude human factors and suitable-habitat areas when include human factors for amphibian species are significantly larger than the ones for reptile species.

In order to test hypothesis 1, one-tail paired t-test was used. For hypothesis 2, since the variance of value group 5 (see table 2-5) and the variance of value group 6 (see table 2-5) were not significantly different (p=0.600, using f-test, 95% confidence interval), t-test (one-tail) assuming equal variances was chosen as the method of testing this hypothesis. Results are showing in table 3-3.

Table 3-3 Results of t-test with 95% confidence interv
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	t statistical value	t critical value	Significance
Hypothesis 1	4.002	1.761	6.553 × 10 ⁻⁴
Hypothesis 2	0.926	1.771	0.186

According to table 3-3, at 95% confidence interval level, the significance value for hypothesis 1 is lower than 0.05, but the significance value for hypothesis 2 is higher than 0.05. It shows that the null hypothesis of hypothesis 1 should be rejected, while the null hypothesis of hypothesis 2 cannot be rejected. Thus, generally for all the herpetofauna species, suitable-habitat areas when excluding anthropogenic factors are significantly larger than suitable-habitat areas when including anthropogenic factors. While there is no significant difference between suitable-habitat area changes for amphibian species and suitable-habitat area changes for reptile species.

As mentioned in chapter 2.2.3, AUC enhancing might be related with suitable-habitat area reducing. Consequently, AUC changes between the models within anthropogenic factors and the models without anthropogenic factors were checked using one-tail paired t-test. The results show that the test models AUC when including human factors were not significantly different from the ones when excluding human factors (95% confidence interval, p=0.199), however, the training models AUC when including human factors were significantly higher than the ones when excluding human factors (95% confidence interval, p=3.518 \times 10-5).

Thus, to know the empirical correlations between anthropogenic factors and herpetofauna occurrence more doubtlessly, the response curves of important anthropogenic factors were also analysed.

According to species distribution maps, jackknife test and response curves of important human factors for each species (appendix 3), the summary result of important human factors for each species and effects of those important human factors for each species were achieved. The result is shown below in table 3-4.

From table 3-4 it can be seen that most of the human factors have negative effects on most of herpetofauna species. However, for few species, human factors have positive effects; and other few species are not affected by human activities very much. For instance, agricultural area factor has positive effect on *Telescopus fallax* while *Rana cretensis* is not affected by human activities very much, since there is no important human factor for this species. Another thing need to be paid attention to is the effect of livestock density factor. For some species, livestock density factor could have positive effects when the density value is low, but when the density value becomes high, it has negative effects.

Table 3-4 Important human factors for each species and the effect of each important human factor

Species	Important human factors	Effects*
Bufo viridis	Livestock density Secondary roads	unimodal -
Caretta caretta	Livestock density	-
Chalcides ocellatus	Livestock density	-
Coluber gemonensis	Potential tourism impact (represented by hotels beds numbers)	-
Cyrtopodion kotschyi	Agricultural cultivation	-
Elaphe situla	Livestock density Population density	unimodal +
Hemidactylus turcicus	no important human factor	
Hyla arborea	Potential tourism impact (represented by hotels beds numbers)	-
Lacerta trilineata	Potential tourism impact (represented by hotels beds numbers)	-
	Livestock density	-
Mauremys rivulata	Livestock density	-
Natrix tessellata	no important human factor	
Podarcis erhardii	Secondary roads Highway Population density	- - -
Rana cretensis	no important human factor	
Tarentola mauritanica	Secondary roads Population density	- +
Telescopus fallax	Agricultural cultivation	+

* "+" represents positive effect, "-" represents negative effect, "unimodal" for Bufo viridis and Elaphe situla means that when livestock density is in low density level, it has positive effect, but when it is in high density level, it has negative effect.

3.3 Cretan protected network effectiveness of preventing anthropogenic impacts for herpetofauna

Hypothesis 3:

H1: Suitable-habitat area within the protected network for herpetofauna species when exclude human factors are significantly larger the ones when include human factors.

Hypothesis 4:

H1: The area differences between suitable-habitat area within the protected network when exclude human factors and suitable-habitat area within the protected network when include human factors for amphibian species are significantly larger than the area differences for reptile species.

For testing hypothesis 3, one-tail paired t-test was used. For hypothesis 4, since the variance of value group 7 (see table 2-5) and the variance of value group 8 (see table 2-5) were not significantly different (p=0.246, using f-test, 95% confidence interval), t-test (one-tail) assuming equal variances was used. Results are shown in table 3-5.

	t statistical value	t critical value	Significance
Hypothesis 3	3.736	1.761	1.107 ×10-3
Hypothesis 4	1.216	1.771	0.123

Table 3-5 Results of t-test with 95% confidence interval

From table 3-5 it can be seen that significance values for hypothesis 3 is lower than 0.05 (95% confidence interval), which means the null hypothesis of hypothesis 3 should be rejected. However, the significance value for hypothesis 4 is higher than 0.05 (95% confidence interval), which means the null hypothesis of hypothesis 4 cannot be rejected. Therefore, generally for all the herpetofauna species, suitable-habitat areas within the protected network when excluding anthropogenic factors are significantly larger than suitable-habitat areas within the protected network when including anthropogenic factors. However, there is no significant difference between area changes of suitable-habitat within the protected

network for amphibian species and the area changes for reptile species.

In order to know more doubtlessly about if Cretan protected network could control anthropogenic factors effectively or not for herpetofauna species, checking whether each important human factors occurring within protected areas or not was also conducted in this study.

After overlaying the maps of important anthropogenic factors with Cretan Natura 2000 protected network map, whether the anthropogenic factors occurring within protected areas or not can be known, as shown in figure 3-1. For all the Cretan herpetofauna species, on a basis of the results in chapter 3.2, build-up area factor and distance to primary roads factor are not important anthropogenic factors. Therefore, these two anthropogenic factors are not included in the analysis below.

From figure 3-1 it can be seen that within Cretan Natura 2000 protected network, almost no agricultural area and high population density area can be found (see figure 3-1 (d) and (e)). The only highway in Crete is located along the northern coast line, and the distances between the national highway and most of Cretan protected areas are not very low (see figure 3-1 (c)). This shows that most of Cretan protected areas could effectively avoid the effect of the highway. But for distance to secondary roads factor, livestock density factor and potential tourism impact factor, there are still some areas with high livestock density (see figure 3-1 (b), light cream colour to red colour) or high hotels beds numbers (see figure 3-1(f), light brown colour to yellow colour) exist within the protected areas. Areas very close to secondary roads (see figure 3-1 (a), dark brown colour) can also be found within some protected areas.



Figure 3-1 Distributions of all the important anthropogenic factors throughout Crete and within Natura 2000 protected network

Chapter 4 Discussions

4.1 Species distribution models evaluation

For most of the species, models performances were fairly moderate (AUC values higher than 0.7 and TSS values higher than 0.2). However, as mentioned above, models of few species performed not well.

For species Cyrtopodion kotschyi and Telescopus fallax, low AUC and TSS values are most probably because of insufficient present points. It is found by Philips *et al.* (2004) that the accuracy of MaxEnt model will increase when extending the present points sample size, and generally, the accuracy could reach the maximum when 40-50 present points are used. In this study, only 17 and 14 present points were available for species Cyrtopodion kotschyi and Telescopus fallax respectively, which are much less than 40-50 present points.

For species Hyla arborea and Lacerta trilineata, the reason for "not good" models performances might be that these two species are generalist species. According to Valakos *et al.* (2008d), Hyla arborea can be found all across mainland Greece and large islands including Crete. Lacerta trilineata is one of the most widespread lacertids and can be found throughout Greece (Valakos et al., 2008e). The widespread distributions across whole Crete of these two species could indicate that these two species do not have strong preferences of environmental conditions, which means models for widespread species cannot perform that accurately (D. R. B. Stockwell & Peterson, 2002).

4.2 Effects of anthropogenic factors on Cretan herpetofauna species

The study of Reside *et al.* (2011) has demonstrated that the area change of suitable-habitat area is negatively related to the change of AUC. Nevertheless, it is also mentioned in the same study of Reside *et al.* (2011) that AUC decreasing is not the only factor that related to suitable-habitat area increasing, and only rarely related with it. Besides, few other studies indicate that AUC changes could also be positively related with suitable-habitat area changes (Garzón et al., 2006; Lippitt, et al., 2008). Consequently, it seems like that the exact relationship between AUC changes and suitable-habitat area changes need to be studied more.

From the results in chapter 3.2, a generally negative correlation between anthropogenic factors and herpetofauna species occurrences were found. However, for few specific herpetofauna species, anthropogenic factors have positive effects and for another few specific species, anthropogenic factors have almost no effects on them. Moreover, the impacts of anthropogenic activities on amphibian species and on reptile species were found as invariantly.

Previous studies have demonstrated that anthropogenic factors have the capacity to affect natural species populations (Benayas, et al., 2006; French, et al., 2010). For herpetofauna species, all the anthropogenic factors involved in this study are related to habitat loss of these species, which results in population decline. Agriculture, for instance, will lead to soil condition and vegetation type changes. In order to cultivate crops or forage grass, original vegetation (e.g. forests and dense shrubs) and rocks will be removed, consequently lead to lack of shelters and habitat fragmentation for herpetofauna (Maisonneuve & Rioux, 2001; Ribeiro, et al., 2009). Developments of residence and transportation, as well as tourism development, totally change the habitat conditions, since constructions of roads and buildings will alter the natural environment to an artificial environment which is suitable for human being (Benayas, et al., 2006; Fahrig et al., 1995; Hecnar & M.'Closkey, 1998).

Besides habitat loss, anthropogenic factors also affect herpetofauna species on many other aspects. Utilizing chemical fertilizer and pesticide in agriculture has become widespread (Mann et al., 2009). Thus the effects of chemical pollution from agriculture on herpetofauna species have been paid more attentions to in resent studies, and several researchers demonstrated a negative effect of chemical agriculture pollution on herpetofauna populations (Mann, et al., 2009; Verderame et al., 2011). In Crete, olives and grapes are the main cultivated products, and in the central and eastern parts of Crete, potatoes are also one of the main agricultural products (Information from the interview of local resident Ms. Giamalaki). Chemical fertilizer and pesticide are commonly used for growing grapes and potatoes in Crete (Information from the interview of local resident Ms. Giamalaki). Therefore, Cretan herpetofauna species might be facing to the threats of chemical fertilizer and pesticide, especially in the regions where grapes and potatoes are large scaled cultivated.

Some studies stated that road traffic caused mortality of herpetofauna individuals when they cross or stay on the roads (Hels & Buchwald, 2001; Shwiff et al., 2007), while it also led to the

Discussions

isolation of herpetofauna populations and even led to interruption of herpetofauna gene flows (Seshadri & Ganesh, 2011; Woltz, et al., 2008). Mentioned by Valakos *et al.* (2008b), thousands of kilometers of new roads built across countryside in recent years and the accompanying increase of traffic have become to problems for herpetofauna species in whole Greece. Those newly built roads across countryside are mainly belong to secondary roads rather than primary roads (Information is from the interview of local resident Ms. Giamalaki). They divide large habitat areas into small isolated pieces thus interrupt the migration of herpetofauna species. Besides, secondary roads introduce more vehicular traffic to countryside than before they were built (Valakos, et al., 2008b). More roads killing of herpetofauna species have been observed throughout Greece (Valakos, et al., 2008b).

Except the impact on herpetofauna habitat, tourism development also brings numerous impacts to herpetofauna individuals. The noise generated by tourists and the disturbances come from vehicles and steps of tourists have negative effects on body condition of herpetofauna individuals and their immune responses (Amo, et al., 2006; French, et al., 2010). Tourism has become to the most serious problem for herpetofauna species in Greece, especially in the Aegean Sea region (Valakos, et al., 2008b). Large scales of noise and disturbance are generated by the large tourist population in this region especially along the coast line of the islands (Valakos, et al., 2008b). The large tourist population also put a severe burden on the limited freshwater resources on those islands (Valakos, et al., 2008b).

In table 3-4, some interesting cases were noticed where anthropogenic factors played positive roles for few species. For instance, livestock density factor has positive effect on Elaphe situla when it is at low density level, and population density also has positive effect on this species (see appendix 3 (6)). Elaphe situla is a kind of snake normally inhabits in Mediterranean maguis, and often can be found in pastureland and also in gardens and buildings (Böhme et al., 2009; Valakos et al., 2008g). Their occurrence in gardens and buildings can show that human habitations are often also suitable for this species. Besides, the forage grass used to raise livestock could provide suitable shelters and habitats for Elaphe situla. However, as number of livestock increasing to high level, the pasture area could become bared without vegetation cover and result in habitat loss of Elaphe situla. Thus, slight livestock density areas are suitable for Elaphe situla, but high livestock density is harmful for this species.

Another interesting case is Telescopus fallax, which agriculture areas have a positive effect on it (see appendix 3 (15)). Telescopus fallax prefers to inhabit in sunny areas with plants cover and sometimes close to human habitations (Agasyan et al., 2009; Valakos et al., 2008f). Since sufficient sunshine is available in agricultural areas in order to grow crops and cultivated areas are always covered by vegetation, thus, agricultural areas could be ideal habitats for Telescopus fallax. This could be the reason that more Telescopus fallax can be found in agricultural areas.

Besides those species which have negative responses to anthropogenic factors and other few species which positively respond to some anthropogenic factors, there are still another few species do not care human factors a lot, for instance, Hemidactylus turcicus (see appendix 3 (7)). Hemidactylus turcicus is a kind of extremely adaptable gecko species, and it is very common to find them in a great variety stony habitat, such as buildings and stones in fields and abandoned agricultural areas (Avci et al., 2009; Valakos et al., 2008c). They can adapt to the environment with human existence as well as to the environment without human beings. Thus. anthropogenic factors are not that important to this species.

Comparing reptile species with amphibian species, even though reptiles have scaly skin thus have better protections of their bodies, anthropogenic activities affect these two groups of species invariantly in Crete. As mentioned above, all the anthropogenic factors which were involved in this study are related to species habitat changes and loss. In Crete, anthropogenic activities, such as tourism, roads constructions and residential development, spread all over the island (Valakos, et al., 2008b). Consequently amphibian species and reptile species could be facing those threats of habitat changes and loss to the same extent. Moreover, in this study, the number of amphibian species and the number of reptile species were unbalanced. Only 3 amphibian species but 12 reptile species were involved in. This could result in statistical test to be less robust, thus cannot detect significant difference.

4.3 Cretan protected network effectiveness on controlling of anthropogenic factors for herpetofauna species

Establishing protected areas is the most widely used way to protect natural species and has been considered as the most effective method (Abellan et al., 2011; Catullo, et al., 2008). For herpetofauna

species, protected areas play an important role of maintaining their life forms (Kati et al., 2007). Besides, as discussed in previous paragraphs of this thesis, most of the herpetofauna species in Crete are negatively disturbed by anthropogenic factors. Consequently, how effective the Cretan protected network controlling anthropogenic factors is important for Cretan herpetofauna species.

From the results in chapter 3.3, it could be known that Cretan protected network cannot avoid the effects of anthropogenic factors within protected areas for herpetofauna species very well.

Cretan protected network can control agricultural cultivation, impact of highway within protected areas very well. However, it cannot control impact of secondary roads within protected areas thoroughly, since areas very close to secondary roads (see figure 3-1 (a), dark brown colour) can still be found within some protected areas. Few studies have demonstrated the harm of roads and traffic occurring within protected areas. Road-kills is one of the main reasons for mortality of fauna, including reptiles, in protected areas (Seshadri & Ganesh, 2011). Road can also cause habitat changes and fragmentation within protected areas for herpetofauna species (Seshadri & Ganesh, 2011; Woltz, et al., 2008). Among all the 39 Cretan Natura 2000 sites, one-third of the sites (13 sites) were demonstrated that they were negatively influenced by roads and motorways within those protected areas (EEA, 2011). Besides, within the other 26 sites, the knowledge about the influence of roads within protected areas for half of those sites were not clearly known (EEA, 2011).

For potential tourism impact factor, there are some areas with high hotels beds numbers exist within the protected areas (see figure 3-1 (f), light brown colour to yellow colour). Tourism has been stated that has serious disturbance on vegetation landscapes and species habitats in natural reserves (Zhang et al., 2012). The severity of this disturbance is to large extent decided by the behaviours of tourists (Bushell & Eagles, 2007). In Crete, there are mainly two types of tourists. One type of tourists is the ones who visit Crete only for enjoving the sunshine and beaches, and the other type is the ones who go to Crete for visiting or hiking within natural reserves intentionally (Information is from the interview of local resident Ms. Giamalaki). Since the second type of tourists visiting the protected areas intentionally, they might be more careful about vegetation landscape within protected areas and more careful about their behaviours. Thus, comparing these two types of tourists, the second type of tourists might generate fewer disturbances than the first type

of tourists. For those protected areas located in the middle of the island and far away from the sea, most of their visitors might be the second type of tourists. However, for those protected areas near the sea, some of their visitors might also be the first type of tourists, since these protected areas are close to their accommodations and they can easily reach there and visit incidentally. Therefore, the impacts of tourism on those Cretan protected areas located in the middle of the island might be less than the impacts on the ones located near the sea.

For human population density factor, there is almost no high population density area can be found within Cretan Natura 2000 protected areas (see figure 3-1(d)). For livestock density factor, there are several areas with high or middle livestock density can be found within the protected areas (see figure 3-1(b)), especially, an area with very high density (red and pink colours) can be seen within the protected area which located in the middle part of the island.

However, there is an issue that might lead to inaccurate information, which is the conversion from human population number and livestock number to population density and livestock density. Original human population and livestock number were actual numbers per municipality, but the distribution of population and livestock within each municipality was unknown. Thus, if the population or livestock distribution within a large municipality is totally not even distribution, then when converting into population or livestock density, an area have very low population or livestock number in this municipality might be assigned a much higher population or livestock density value comparing with the reality. Therefore, the population density layer and livestock density layer might contain some information which is not that practical. Because of this issue, whether human habitations seldom occur within protected areas as figure 3-1(d) showing was checked further more. Similarly, whether there are protected areas that affected by livestock as figure 3-1(b) showing was also detected further more. In Crete, there are only 5 Natura 2000 sites among total 39 sites have human habitations occurrences within protected areas, and all of them are low intensity influenced by inside human habitations (EEA, 2011). More than half of the Cretan Natura 2000 sites (22 sites) are negatively affected by livestock breeding and grazing (EEA, 2011). The area with very high density (red and pink colours) in figure 3-1(b) is located within Oros Idi Protected Area (Natura 2000 code: GR4330005). This protected area has been stated that highly negatively influenced by livestock breeding and grazing, and livestock breeding and grazing activities cover 80% area of this protected area (EEA, 2011).

For Cretan Natura 2000 network, since tourism and agriculture including livestock breeding are the two main economical income sources of Crete (Vitsakis, 2009), and Crete is one of the most popular tourism destinations in Europe, totally avoiding the impact of tourism and livestock breeding within protected areas seems not possible. Thus, finding a proper way to compromise between protection and those two human factors is more reasonable and quite important for Cretan protected areas.

From results in chapter 3.3, no significant difference can be found between the effectiveness of Cretan protected areas for protecting amphibian species and for protecting reptile species from anthropogenic impacts.

Cretan protected areas are set under the Natura 2000 protected network. Most of the Cretan protected areas belong to Sites of Community Importance (SCI) areas under Habitat Directive, and the other few Cretan protected areas belong to Special Protection Areas (SPA) under Bird Directive. This means that Cretan protected areas are protecting species and species habitats generally and no protected area is special for either amphibian species or reptile species. Thus, this could be the reason that there is no difference between the effectiveness of Cretan protected areas on controlling anthropogenic factors for amphibian species and for reptile species. Also, the unbalanced numbers of amphibian species and reptile species involved in this study could be another reason that lead to statistical test to be less robust, thus cannot detect significant difference.

4.4 Error propagation

One of the issues that might lead to inaccurate information is the conversions from human population number and livestock number to population density and livestock density. It has been discussed in chapter 4.3. Except this, there are another two issues that might cause inaccurate information.

First, for potential tourism impact factor, the raster layer was generated by IDW interpolation using number of beds of each hotel in Crete. Using a point whose value is known as the center of a circle, IDW interpolation will assign same value to all the unknown points which have the same radius to the center. It means that IDW interpolation considers the impact of one hotel is equally distributed in every direction. However, in reality, the impact is not always like that in Crete. For a hotel located far away from coast lines in the middle of the island, the aim of tourists in that hotel might be visiting all the surrounding attractions such as nice landscapes and historical places. Thus, it is possible that their tracks distribute in a lot of directions, which means the impact of tourism could be to some extent equally distributed in every direction. But for a hotel built near the coast line, the purpose of tourists living in that hotel most probably is only visiting nearby beaches. Therefore, the impact of tourism in those directions which lead to beaches will be much greater than the ones lead to inland areas. Consequently, the potential tourism impact layer might not be able to provide accurate information of tourism impact in those areas which near coast lines in Crete.

The other issue is related to the involved livestock species when calculating total livestock unit number for each municipality. Four pastured livestock species, which were cattle, goat, equidae and sheep, were involved in this thesis. However, in Crete, not all the sheep are pastured. In mountain regions of Crete, sheep are pastured widely within certain areas surround the farm normally, but in flat regions, sheep are only feed within farms (Information is from the interview of local resident Ms. Giamalaki). Thus, the impact of pasturing sheep might be overestimated consequently lead to inaccurate information of those flat regions.

Chapter 5 Conclusions and recommendations

By species distribution modelling with environmental factors only and with both anthropogenic factors and environmental factors, two types of species distribution maps were generated respectively. Through statistically comparing suitable-habitat areas in these two types of maps and analysing response curves of important anthropogenic factors, a generally negative correlation between anthropogenic factors and herpetofauna species occurrence were found. However, for few specific herpetofauna species, anthropogenic factors have positive effects and for another few specific species, anthropogenic factors have almost no effects on them. The impacts of anthropogenic activities on amphibian species and on reptile species were found as invariantly by doing statistically comparison of suitable-habitat changes between these two groups of species.

Through statistically comparing the two types of suitable-habitat areas that within the protected network and checking whether each important human factors occurring within protected areas or not, Cretan protected network effectiveness of controlling anthropogenic factors for herpetofauna species was known. Protected areas in Crete were found that cannot protect herpetofauna species from anthropogenic impacts very effectively. Cretan protected network can control agricultural cultivation, impact of highway and human population inside protected areas very effectively, but cannot control livestock breeding, impact of secondary roads and tourism thoroughly. Also, after statistically comparing area changes of suitable-habitat within the protected network for amphibian species and for reptile species, no significant difference can be found between the effectiveness of Cretan protected areas for protecting amphibian species and for protecting reptile species from anthropogenic impacts.

The recommendations from this study are:

— When doing species distribution modeling, sample size of species presence data is important. Large sample size is recommended to be used; otherwise the performance of model tends to be not good. Besides, the results of species distribution modeling for generalist species should be utilized with caution, since for generalist species, the modeling results always tend to be not as good as specialist species.

- Knowledge about the exact relationship between AUC changes and suitable-habitat area changes should be completed, and this issue should be studied more.
- When dealing with data of anthropogenic factors, more detailed data will provide more accurate information and thus recommended to be used. For instance, comparing with population per municipality, population per village will provide more accurate information about population density.
- Controlling human activities in Crete, especially human activities happen inside protected areas, will generally be benefit for Cretan herpetofauna species. For Cretan protected network, finding a proper way to compromise between protection and agriculture development and tourism is reasonable and important.

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Appendices

Appendix 1

Appendix 1 Legend of CORINE Land Cover 2000 map



Appendix 2

Appendix 2-1 BIOCLIM climate data

BIO1: Annual Mean Temperature	BIO11: Mean Temperature of Coldest Quarter
BIO2 : Mean Diurnal Range (Mean of monthly (max temp - min temp))	BIO12: Annual Precipitation
BIO3: Isothermality (BIO2/BIO7) (*	BIO13: Precipitation of Wettest
100)	Month
BIO4: Temperature Seasonality (standard deviation *100)	BIO14: Precipitation of Driest Month
BIO5: Max Temperature of Warmest Month	BIO15: Precipitation Seasonality (Coefficient of Variation)
BIO6: Min Temperature of Coldest	BIO16: Precipitation of Wettest
Month	Quarter
BIO7: Temperature Annual Range	BIO17: Precipitation of Driest
(BIO5-BIO6)	Quarter
BIO8: Mean Temperature of Wettest	BIO18: Precipitation of
Quarter	Warmest Quarter
BIO9: Mean Temperature of Driest	BIO19: Precipitation of Coldest
Quarter	Quarter
BIO10: Mean Temperature of Warmest Quarter	

Appendices

Appendix 2-2 Geological conditions of Crete

Categorical value	Geological condition type
1	Quartenary sediments
2	Upper nappes flysch and schist
3	Pindos nappe flysch
4	Tripolitsa nappe flysch
5	Plattenkalc unit rocks (mainly carbonate)
6	Pindos nappe carbonate rocks
7	Trypali nappe carbonate rocks
8	Tripolitsa nappe carbonate rocks
9	Upper nappes carbonate rocks
10	Neogene limestone
11	Neogene sediments
12	Ophiolite rocks
13	Phylite - Quartzite nappe

Appendix 3

Appendix 3 Species distribution maps, jackknife test results and response curves of important anthropogenic factors for each herpetofauna speices

In appendix 3 jackknife results, "agricul_area" represents "agricultural cultivation area factor"; "hote_bed_1km" represents "potential tourism impact factor (represented by hotels beds numbers)"; "lvst_dens_1km" represents "livestock density factor"; "pop_dens_1km" represents "population density factor"; "radi_annual" represents "annual radiation factor".



Appendices



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