HABITAT- AND PREY-SELECTION OF IMPERIAL EAGLES (*AQUILA HELIACA*)

Outlines of PhD Thesis

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INTRODUCTION

Change in the size of a given animal population is affected by the number of birth, death, immigration and emigration of individuals. These factors are determined by environmental variables (i.e. availability of breeding and foraging habitats, presence of predators or other risk factors, stochastic events etc.) and also by individual behavioural decisions as responses to them. In the present thesis I compared two coexisting nesting habitat selection strategy observable simultaneously in a population of eastern imperial eagles (*Aquila heliaca*).

Eastern imperial eagle is a Vulnerable raptor distributed in the Eurasian forest-steppe zone and reaching the western limit of its range in the Carpathian basin, in Central Europe. Here, the Hungarian, Slovakian, Austrian and Czech breeding pairs are forming the largest unified population of the species outside Russia and Kazakhstan, and they are separated by more than 500 km from the nearest neighbouring populations. The population in the Carpathian Basin after a century of decline reached its lowest size by the 1970's, when a population survey and conservation programme started in both Hungary and Slovakia. The continuous monitoring has revealed a significant increase in the population size during the last 25 years, which happened in parallel with the expansion of breeding range. Till the late 1980's the few nesting sites of the species were recorded in remote, undisturbed mountainous forests and pairs were foraging on open habitats even 10-15 km further from their nest sites. Surprisingly, in 1989 two new breeding pairs were discovered in a completely different lowland habitat type, where they nested on isolated trees and shelterbelts at open agricultural fields. From this time an exponential increase of the population at this new habitat type has been detected in parallel with the stability, or even slow decrease in some regions, of traditional mountainous breeding pairs. By 2009 most (85%) of the population could be found in the lowland habitats of the Great Hungarian Plain.

Recently the Hungarian population of imperial eagles seems to be far from reaching its maximal size, as I show, the exponential growth has not slowed, there are no signs of decrease in fecundity, and still only a fraction of suitable habitats are occupied by the species. Therefore a maturing individual can decide where to settle for breeding, i.e. to choose between two coexisting nesting habitat selection strategy observable simultaneously in the population.

AIMS OF THE THESIS

The studies presented in the thesis investigate the relationship between the recently changed habitat selection strategy (i.e. lowland expansion and abandonment of mountains) and some other aspects of population biology of imperial eagles in Hungary.

Chapter 2.1 summarizes the detected changes in population dynamics, breeding success and mortality factors of the Hungarian imperial eagle population during the last decade.

Chapter 2.2 investigates whether the expansion of imperial eagles is not hindered significantly by the well-developed infrastructural network at the lowland habitats.

Chapter 3.1 compares of prey composition in traditional and freshly occupied breeding habitats and discusses the possible effects of diet on reproductive success.

Chapter 3.2 investigates how density, age structure and habitat type could affect simultaneously the reproductive success of imperial eagles.

Chapter 4.1 presents an improved method of DNA extraction from shed feathers, and discusses how the application of this novel method can add to the study of eagles, and other bird species difficult to handle.

Chapter 4.2 estimates the mortality rates of breeding imperial eagles at the two habitat types, by non-invasive genetic sampling of individuals.

METHODS

The active and potential breeding territories of imperial eagles in Hungary were monitored thoroughly within the framework of the Hungarian Imperial Eagle Working Group during the study period. Number and location breeding pairs, age of the breeding birds (adult or non-adult), breeding success (i.e. number of fledglings), causes of breeding failures and mortalities were recorded in a monthly basis during the breeding season (February-August) in all territories between 1989 and 2009. Prey remains and shed feathers of adult breeding imperial eagles were collected under nests and roost sites two occasions yearly, in June, when nestlings were ringed as a part of the population monitoring protocol and following fledging between July and September. All data on breeding territories were gathered and analysed in GIS database.

For the estimation of turnover rates we identified breeding females by DNA analyses. DNA was extracted from non-invasively collected shed feathers by a novel method presented in the thesis. Molecular sexing and microsatellite fragment analyses were executed to identify and track individual specimens.

RESULTS

In *Chapter 2.1* I have shown that the population trends are completely different between the two habitats, as population size is exponentially increasing in lowlands, while slowly decreasing in mountains. The shift of the population towards the completely different habitats of the Hungarian Great Plain caused changes in the relative importance of mortality factors and productivity. In the new habitats eagles were frequently killed by persecution (especially poisoning) any by collision with vehicles. Nevertheless, productivity increased during the expansion, as two- and three-chick broods became more common compared to single-chick broods. Moreover, the increasing trend of the population has not yet diminished, therefore we predict further expansion of the species in the near future, although the novel threatening factors raise challenges for conservation.

In *Chapter 2.2* I have investigated the effects of infrastructural network on the habitat selection of imperial eagles in the lowland habitats. In the densest subpopulation of the species infrastructural network was proved to be a key factor affecting distribution. A prediction model built for the total potential breeding area of the species in East-Hungary showed that in spite of the relatively dense infrastructural network and the strong avoidance of them by the eagles, there are still several suitable habitats for the species, which are still not inhabited. The model predicted the location of those areas, which will be most probably avoided, and also those which most probably will be colonized by the eagles during further expansion of the population.

In *Chapter 3.1* the possible relationship between prey composition and reproductive success was analysed. I found great variability in diet composition of imperial eagles in East-Hungary, but in all regions hares, hamsters or pheasants dominated diet consisting of ca. 60 identified prey species. I have compared the productivity between the two most typically different regions, such as the hare-dominated Heves Plain and the hamster-dominated West-Zemplén region. I have found that productivity was significantly higher in the hare-dominated region, which suggests that this prey species could provide a better quality food supply than hamsters, which are ten times smaller and also their population size is more erratic.

In *Chapter 3.*2 I have analysed the simultaneous effects of habitat and age of breeding birds on the reproductive success of imperial eagles. We found that both age and habitat had significant effects on breeding success variables. We found that age-effect was more significant on the ratio of successful pairs, while habitat-effect was more evident on the number of fledglings per productive pair. We suppose that better feeding possibilities (closer foraging areas and larger prey density) could explain the higher fledging success in the lowlands. We also predicted that pairs inhabiting lowland agricultural areas would have a lower success rate due to higher human disturbance, but even if this trend was observable it had significant effect only in interaction with the age of the pairs, therefore adult pairs probably can adapt to higher disturbance levels even in the close vicinity of their nesting sites.

In *Chapter 4.1* I have shown a novel methodology developed for improved DNA analysis from non-invasively collected feathers. I proposed that not the basal tip of the feathers should be sampled, as done in all previous studies, but instead, the superior umbilicus part of the feather shaft, where an embedded blood clot provides a significantly more effective source of DNA.

In *Chapter 4.2*, with my co-authors, I estimated the turnover rate of breeding female imperial eagles in lowland and mountainous habitats of Hungary. We found that average turnover (24%) was much higher than expected, and also higher than in other populations. The two habitats also differed in their turnover rate, which was remarkably higher in the lowlands (29%) than in the mountains (11%). We cannot be sure if this high turnover rate is mostly caused by mortality, or by an unexpectedly high shift rate of breeding birds between territories, nevertheless till further research we can use turnover rate as a maximal estimation of mortality.

CONCLUSIONS

Population dynamics and nesting habitat

The results presented here show great differences in many aspects of population biology between traditional mountainous and recently colonized lowland habitats of imperial eagles. I have shown that population trends, possibilities of range expansion, prey composition, reproductive success and turnover rate of breeding birds are all different in the lowland habitats. Results suggest that these recently colonized habitats not inferior in quality, and further expansion of the species is probable.

Improved genetic analyses of birds

The methodology to extract DNA from samples containing small amount of DNA has been available for almost two decades, although non-invasively collected samples were still only exceptionally used in field studies of birds till the past few years, mostly due to methodological problems derived from low quality and quantity of obtainable DNA. The novel sampling method presented in Chapter 4.1 become generally used in genetic analysis of free-ranging birds during the last few years, and most probably greatly facilitated the rapid increase of such studies.

PUBLICATIONS

Published papers and manuscripts related to the thesis:

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