**EURAPMON SHORT VISIT GRANT REPORT**

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# ARE POPULATIONS OF MIGRATORY RAPTOR SPECIES THAT DID NOT RESPOND TO CLIMATE CHANGE DECLINING?

**-Purpose of the visit**

The aim of the visit was to work at the preparation of a paper concerning variation of migratory phenology of raptors in relation to climate changes. Particularly, I assessed the species-specific ability of migratory raptors to respond to climate change according to their ecological and demographical characteristics. This research also highlights the importance of long-term monitoring programs at migratory bottlenecks to estimate the effect of climate change on bird populations.

**-Description of the work carried out during the visit**

The Fundación Migres is active in long-term monitoring project at the Strait of Gibraltar. This site is of paramount importance for migrating raptors and storks belonging to the populations of western Europe that winter in south-Saharan Africa (Zalles and Bildstein 2000). Since soaring birds show morphological traits that don't allow them to use long powered flapping flights they tend to follow land masses during their movements. In particular they move mostly exploiting thermal currents that, at European latitudes, are generated mostly on land during daytime (Kerlinger 1989). Since raptors and storks are funnelled at the Strait of Gibraltar it is possible to use visual counts of migratory birds in order to monitor their passage. Counts of soaring birds at the bottleneck sites are important to detect population trends (Bildstein 2006). As written before among the activities of the Fundación Migres one of the most important is counting migrating birds during boreal autumn (Programa Migres 2009). Systematic observations at the Strait of Gibraltar started in 1999. During my short visit I analyzed the results of this long-term monitoring project in order to detect trends in population size and to investigate species-specific responses to climate changes. As a matter of fact changes in the phenology of organisms are considered to be a result of climate change, and this is true also for migratory birds that could shift the breeding period in order to improve their fitness. In particular, during this study, our research questions were:

- Is there a shift in the migration timing of soaring birds migrating at the Strait?
- Are there differences in numbers of raptors and storks counted at during the study period?
- Which are the inter-specific differences?
- Which are the causes of these inter-specific differences?

Data set

We used a dataset comprising 13 years of migration counts, from 1999 to 2011, with the same data recording methodology used during the whole period. Two watchpoints were used at the same time: Algarrobo and Cazalla, located on the eastern and on the western side of the Strait respectively. In the analysis we considered only Accipitriformes and storks, since soaring species are likely to concentrate at the bottlenecks while other raptors (i.e. falcons) migrate on a broader front over the Mediterranean and therefore the passage of these species could be more influenced by other features (i.e. wind conditions) in comparison to Accipitriformes and storks. (Meyer et al. 2000). Nine species of Accipitriformes and two species of storks were considered in the analysis. Annual counts in the study period average 240.000 individuals.

Data analysis

We used a Quantile Regression analysis to evaluate the phenological shift. In QR analysis the full data set consists of daily observations of individual birds using passing dates as a function of year.

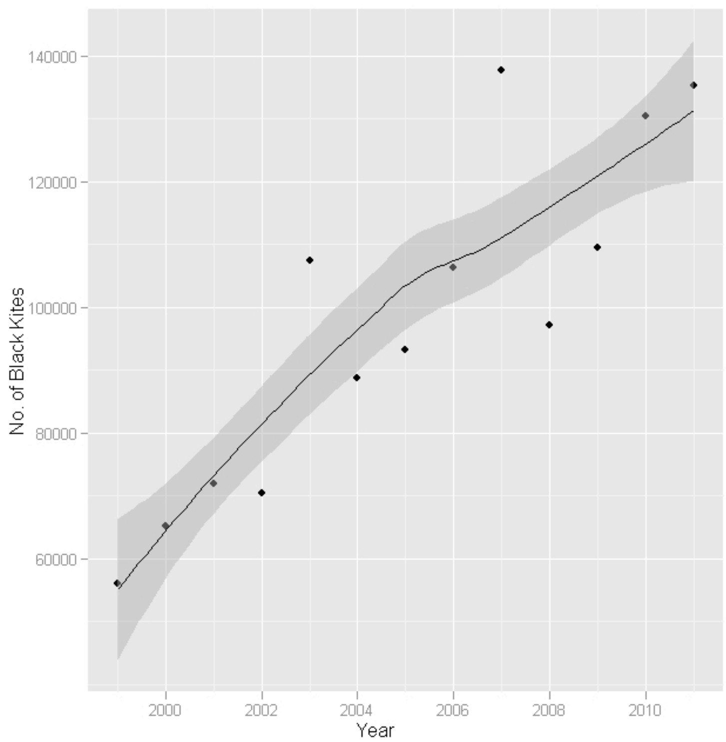
Compared to other methods QR has advantageous statistical properties, because all data points are considered simultaneously and are therefore not influenced by autocorrelation (Tøttrup et al. 2006). Many species of birds show bimodal distribution of migration with more than one boot of movements due to the passage of individuals belonging to different age and sex classes (Finlayson 1992). For this reason we have chosen to consider variation in the 50th percentiles of passage of every species as suggested by previous studies (Filippi-Codaccioni et al. 2010). On the other hand first appearance dates and other methods relying on a small portion of the total phenological distribution have aroused major criticism (Miller-Rushing et al. 2008). The 50th percentile of passage was therefore used to determine if there was a phenological shift. However we repeated the QR analysis also considering the other percentiles (10th, 25th, 75th, 90th) to verify if there were different effects on the different periods of the migration.
To determine trends of birds migrating at the Strait we used Pearson's correlation analysis considering yearly numbers of raptors observed at the Strait, a Shapiro-Wilk test was run before it to test for normality assumption.
To investigate inter-specific differences and causes of the shifts in phenology, linear models were used. Linear regression was tested using ANOVAs. The slope resulted from the Quantile Regression Analysis of the 50th percentile was used as dependent variable in the model. As independent variables we used the following ones:
- We obtained estimates of European population trends of breeding birds during the period 1990–2000, using an assessment by BirdLife International (2004) on a seven-point scale: large decline (-3), moderate decline (-2), small decline (-1), stable (0), small increase (+1), moderate increase (+2), and large increase (+3). A previous study compared these qualitative assessments with quantitative ones showing a strong relationship (Møller et al. 2008).
- Trends in numbers of migratory raptors counted at the Strait, measured as Pearson's correlation coefficients between years and numbers of raptors observed at the Strait, were considered in the analysis to evaluate an eventual relationship of these trends with the shifts in phenology .
- We used European population size of each species (BirdLife 2004), because larger populations may give rise to a larger number of heterozygous loci, which may facilitate phenological response to climate change (Møller et al. 2008).
-The northernmost breeding latitude was used as variable according to data presented on the EBCC atlas of the European breeding birds (Hagemeijer and Blair 1997) in order to search for differences ought to different raptor spatial distributions.
-We used also the body mass (kg) of the birds using data reported in a previous paper (Bruderer & Boldt 2001).
-We also included information on the breeding ecology of the species to verify if the reproductive effort plays a role in explaining inter-specific differences on phenological trends. In particular we used the mean of the clutch size (N.), the duration (days) of the breeding period and the generation length (Cramp & Simmons 1980, BirdLife 2004). Generation length is defined as "the average age of the parents of the current cohort (i.e. newborn individuals in the population)" and is calculated using the following equation: $GL = ((2-m)/2m)+b$
Where $m$ is the mean of adult mortality in a stable population and b is the mean age at first breeding in a stable population (BirdLife 2004).
-Finally the degree of ecological specialization was taken from the appendix 4 of BirdLife international (2004) according to the Tucker and Evans (1997) classification. We assigned a value to species that are strictly linked to a particular habitat (1) and another values (0) to species that live in different kind of habitats. We used also the ecological specialization as continuous variable, because using dichotomous variables as continuous predictors is similar to using a dummy variable in standard regression analyses (Møller et al. 2008).
Before running the linear models, correlation analysis was run to avoid collinearity of variables. We applied to the full model (containing all the above mentioned predictors) a "drop1" stepwise model selection procedure to achieve the final model, eliminating predictors one at a time that did not

improve goodness of fit to the data by a model comparison. Best models were choosen according to the values of the adjusted R-squared.
Since there were differences in the magnitude of the shift among different phases of the migratory distribution,with a general higher degree of shift in the early phases compare with the later part of the migration phenological distribution, we also developed a set of models using the slope of the QR analysis for the other quantiles (10, 25, 75, 90) as dependent variables.
In order to check if our results were in accordance with those obtained in other watchsites from the same migratory route, we run a model using the published data from the Pyrenees watchsite. This is the only site from which it is available an analysis of the shift of migratory dates of soaring birds. We used data of the 11 species of Accipitriformes reported in the paper of Filippi-Coddaccioni and colleagues (2010). In this model we used all the predictors used for the other models and the values of phenological slopes reported in that study which corresponded to the $50^{th}$ percentile.

**- Description of the main results obtained**

Looking at the trends of numbers of raptors migrating at the Strait, there are some species showing a marked increase, as in the case of the Black Kites (Fig. 3), while others are stable. Among the studied species no one showed a decline in the observed numbers.

Figure 1 – Trend of Black kites observed at the Strait during the study period. Points are total numbers of raptors observed each year of observations while the smoothed line indicates the trend during the study period.




The Quantile Regression analysis shows that there was a shift in the dates of migration (Tab. 1). There were differences among the studied species as well as, as written before, differences in the different phases of migration. It is interesting that the last two quantiles are, in general, more stable that the other ones. This probably reflects a stronger tendency in older individuals to advance their migratory dates since in raptor species adult birds usually migrate later than juveniles. As a matter of fact juveniles are inexperienced individuals, therefore they could tend to follow more than adults their innate information (i.e. response to day length).

Table 1 – Values of the slopes calculated by Quantile Regression analysis for the studied species for each quantiles.

| | QUANTILES | | | | |
|---|---|---|---|---|---|
| | **10** | **25** | **50** | **75** | **90** |
| Black Kite | -0,1 | -0,22 | 0,25 | 0,34 | 0,44 |
| Sparrowhawk | -0,6 | -0,43 | -0,34 | -0,17 | -0,29 |
| Short-toed Eagle | -0,5 | -0,34 | 0 | 0 | 0 |
| White Stork | 0 | -0,09 | 0 | -0,34 | -0,17 |
| Black Stork | -0,2 | -0,1 | -0,12 | 0 | 0 |
| Marsh Harrier | -0,67 | -0,6 | -0,5 | -0,13 | 0 |
| Montagu's Harrier | -1,25 | -0,67 | -0,27 | -0,55 | -0,4 |
| Booted Eagle | -0,5 | -0,71 | -0,29 | -0,12 | 0 |
| Egyptian Vulture | -0,22 | -0,1 | 0,12 | 0 | -0,23 |
| Honey Buzzard | 0 | 0 | 0 | 0 | 0 |
| Osprey | -0,09 | 0,18 | 0 | 0,12 | 0,34 |

The results of QR analysis showed a different answer among the different studied species. In Figure 1 and 2 are reported the cases of Montagu's Harrier (*Circus pygargus*) and Honey Buzzards (*Pernis apivorus*). The first species showed a significant shift in migration dates while the latter is much more stable (Fig. 2-3).

Figure 2 - Phenological shifts in Montagu's Harrier as shown by QR analysis

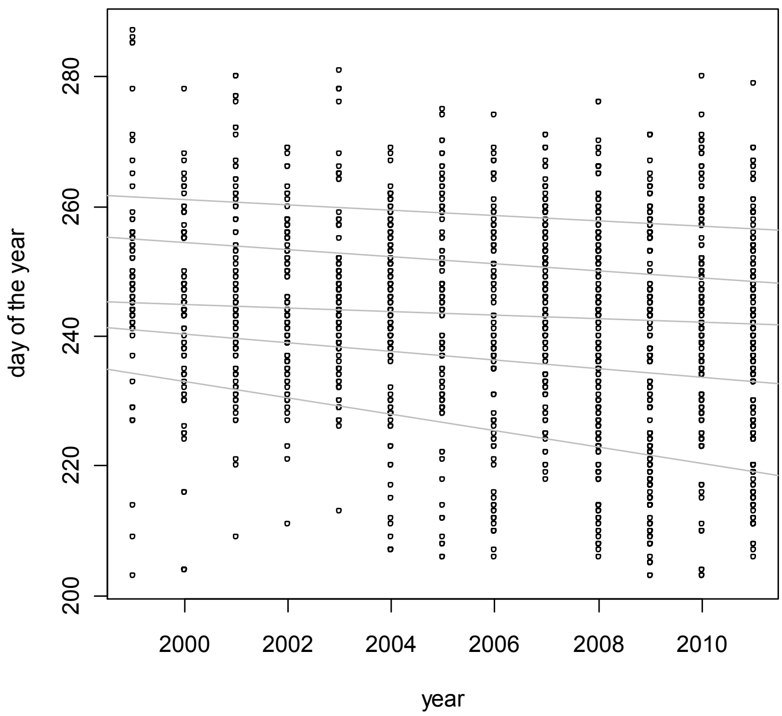
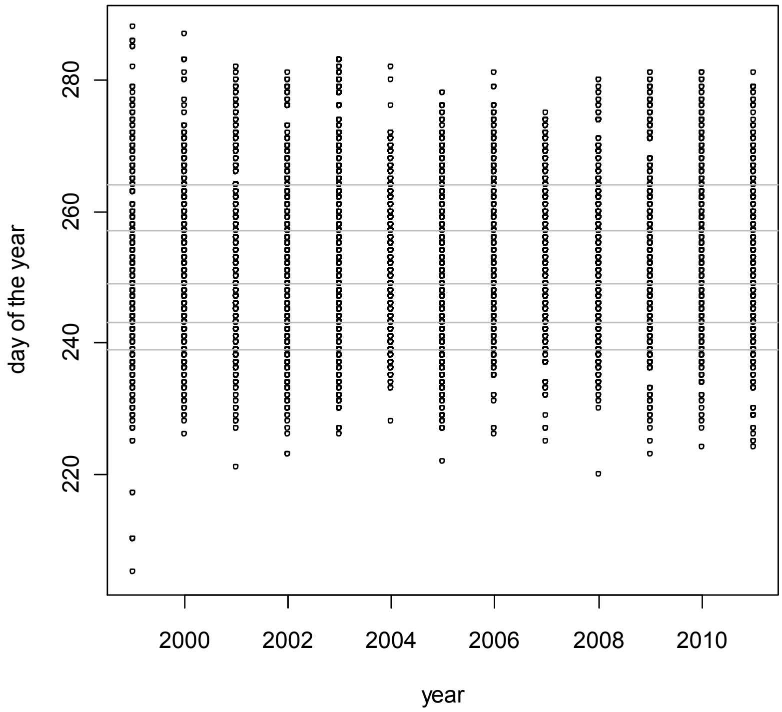


Figure 3 - Phenological shifts in Honey Buzzards as shown by QR analysis




Attending to the inter-specific variation in the phenological shift, it is possible to note that the main variables explaining these differences are the population trends and the body mass of the birds (Tab.2).

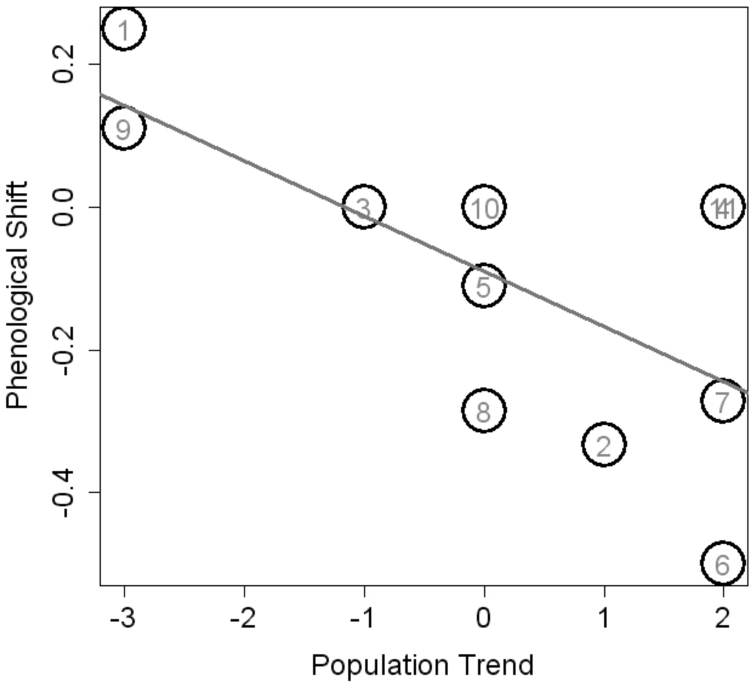
Table 2 – Results of the linear model testing the inter-specific variation of the migratory phenology. Asterisks indicate the significant terms.

| Explanatory Terms | Estimate | *P* |
|---|---|---|
| Population Trend | -0.1 | <0.01** |
| Body Mass | 0.1 | <0.05* |
| North Limit latitude | 0.02 | 0.06 |
| Habitat specialization | - | n.s. |

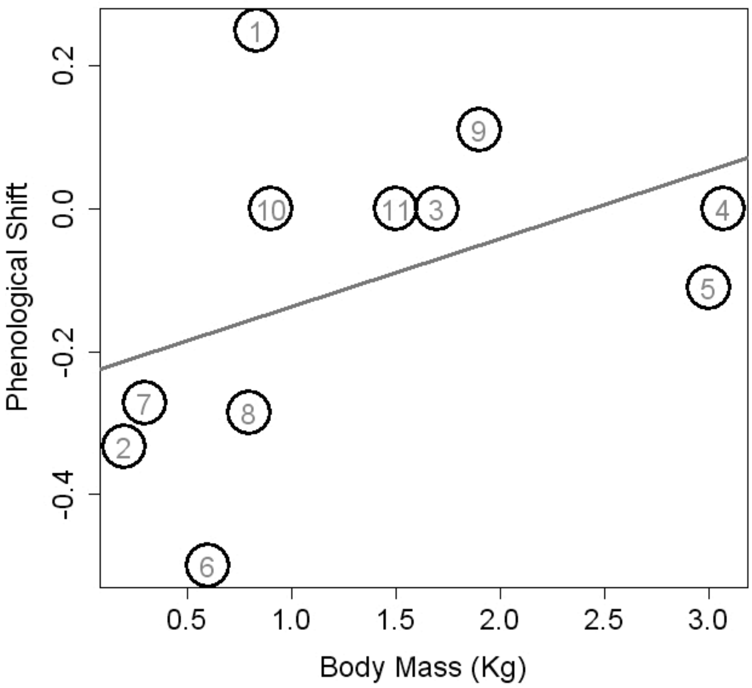
As showed by Møeller and colleagues (2008) species that are not advancing their migratory dates are declining and this is true also in our study case (Fig. 4a). Moreover, for the first time we reported that the body mass of the bird is a significant predictor of changing in migratory behaviour of birds in relation to climate change (Fig. 4b). Previous studies rely mostly on passerines, species that show a limited range of body mass. On the other hand, the species here studied show significant differences in their weights. The results suggest that species with a smaller size are more likely to advance their migratory dates while larger species have a more stable phenology. This could be explained by the fact that larger birds can feed on a wider range of preys and can fast for more days.

Figure 4 – Relationship between phenological shifts and populations trends (a) and body mass (b). Studied species are represented using numbers within the circles.

a)




b)




Looking at the inter-specific differences in the early phases of migration ($10^{th}$ and $25^{th}$ percentiles) the results showed that the annual trend in counts at the Strait is also significant, with negative values in the estimated coefficient, probably because the advance of the dates in the early phases of

migration is more evident in species that show increasing numbers of individuals observed at the Strait. On the other hand, considering the slope of the 75$^{th}$ Quantile, inter-specific differences were linked mostly to population trends (E: -0.1; P<0.01). However, regarding the 90$^{th}$ Quantile the variables were not significant also if the latitude of the northern limit of the breeding range is close to significance (P = 0.053) with a positive regression coefficient.
Using the same variables to explain inter-specific differences of soaring raptors migrating at the Pyrenees the results were quite similar to those from the Strait of Gibraltar. However there was no relationship between phenological shifts and the Population Trends (Tab. 3).

Table 3 – Results from the linear regression model testing the inter-specific variation of the migratory phenology of raptors at the Pyrenees.

| Explanatory Terms | Estimate | *P* |
|---|---|---|
| Counts | - 6.679e+00 | 0.00381 ** |
| Pop. size | -2.621e07 | 0.06313 |
| Body Mass | 2.917e 01 | 0.01812 * |
| Habitat spec. | -4.337e01 | 0.00814 ** |

- **Projected publications/articles resulting or to result from your grant**

The analysis and the results just mentioned above will be the base of a paper that the applicant together with the staff of the Fundación Migres started to prepare during the Short-visit exchange. To our knowledge, this is the first time that it is highlighted the importance of the body mass in explaining the response of an organism to climate change. Although it is not the only finding of the current research, it is the most relevant, as already showed before.

- **Future collaboration with host institution**

After the present paper will be ready to be submitted to a scientific journal, the applicant could also remain collaborating with Fundación Migres in the production of new high quality scientific papers both through new field work or analyzing data already collected.

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