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INFLUENCE OF METEOROLOGICAL CONDITIONS ON FLIGHT ALTITUDES OF BIRDS

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1. INTRODUCTION

The flight altitudes of several groups of birds are influenced by meteorological conditions. For example, flight altitudes of soaring birds are related to environmental factors such as thermal convection and landscape (*e.g.* Pennycuick, 1998; Shannon *et al.* 2002; Shamoun-Baranes *et al.* 2003). The flight altitudes of swifts (*Apus apus*), insectivorous aerial foragers, are influenced by meteorological conditions (Gustafson *et al.* 1977; Backman & Alerstam, 2001) either directly or indirectly by influencing their aerial prey (*e.g.*Cucco & Malacarne, 1996; Chapman *et al.,* 2003). In addition to environmental factors, body structure, flight strategy and behavior (such as foraging, migration or roosting) may also be related to flight altitudes. Birds that rely on various forms of lift for flight or that forage on food sources vertically distributed in the atmospheric boundary layer may be more influenced by meteorological conditions than birds involved in active flight. The aim of this study was to model the influence of meteorological conditions on flight altitudes of birds and compare inter-specific variability in the relation between meteorological conditions and flight altitudes based on flight strategies. This study provides a unique opportunity to compare the influence of weather on different groups of birds under the same environmental conditions. The influence of weather on flight altitudes of birds has important implications for civil and military flight safety.

2. METHODS

Between April and August 2000, during 15 days, the flight altitudes of several species of birds were measured at De Peel (south-eastern Netherlands) using an Flycatcher radar with a fan beam antenna for selection and a pencil beam antenna for tracking of birds (fig. 1).

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The following species were studied as representatives of flight characteristic groups: the buzzard (*Buteo buteo*), a soaring bird; the swift (*Apus apus*), an obligatory aerial forager; and the black headed gull (*Larus ridibundus*) representing an intermediate group using both flapping and soaring/gliding flight.

Multiple linear regression models were built by fitting explanatory variables to maximum hourly flight altitude as the response variable. Explanatory variables included the meteorological variables summarized in Table 1 and time of day. Each species was analyzed separately. In order to keep models relatively simple, models were generally limited to four or five significant ($p \leq 0.05$) explanatory variables.

Figure 1: Flycatcher radar with pencil beam used to track single targets.

3. RESULTS

When comparing the vertical distribution of the three groups, buzzards flew highest 423 ± 252m (mean ± S.D.), followed by swifts 243 ± 201m and black headed gulls 182 ± 116m (fig. 2).

Maximum hourly flight altitudes of buzzards are related to relative humidity, maximum temperature, hourly boundary layer height and lifted index (r^2 = 0.50, p < 0.001, n = 96; fig. 3). Lifted index is a measure of atmospheric instability due to the difference between the temperature at a certain air layer and the temperature an air parcel would acquire when lifted from the surface to that layer; negative values indicate instability.

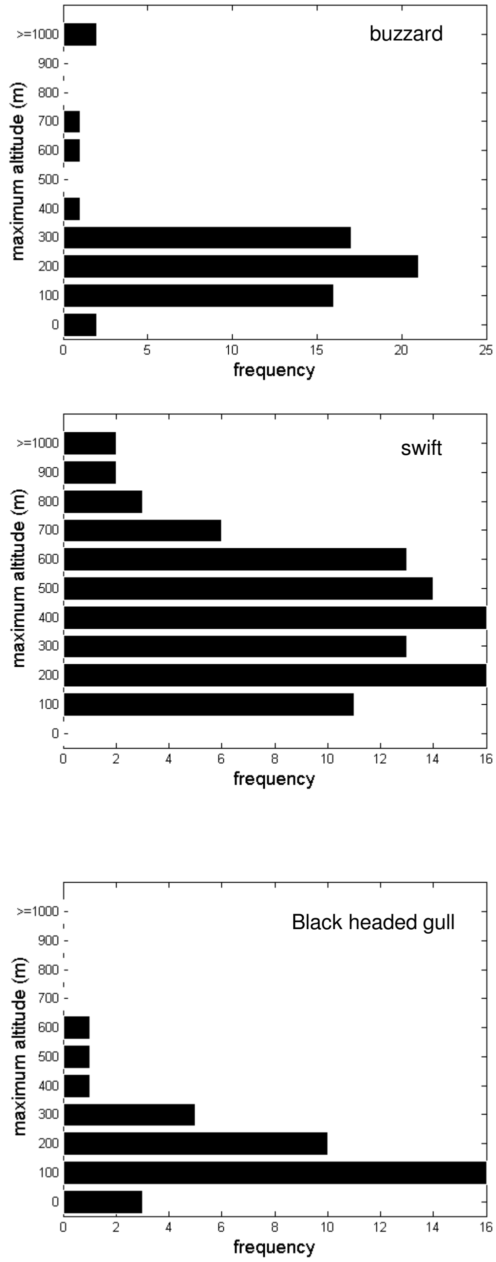

Figure 2: Frequency histogram of measured maximum hourly altitude distribution for the buzzard, swift and black-headed gull (top to bottom).

Maximum hourly flight altitudes of swifts are related to temperature, relative humidity, total cloud cover and lifted index ($r^2 = 0.49$, $p < 0.001$, $n = 60$; fig. 3). Maximum hourly flight altitudes of black-headed gulls are related to total cloud cover, minimum temperature below 9°C, sea level pressure, wind speed and hourly boundary layer height ($r^2 = 0.65$, $p < 0.001$, $n = 37$; fig. 3).

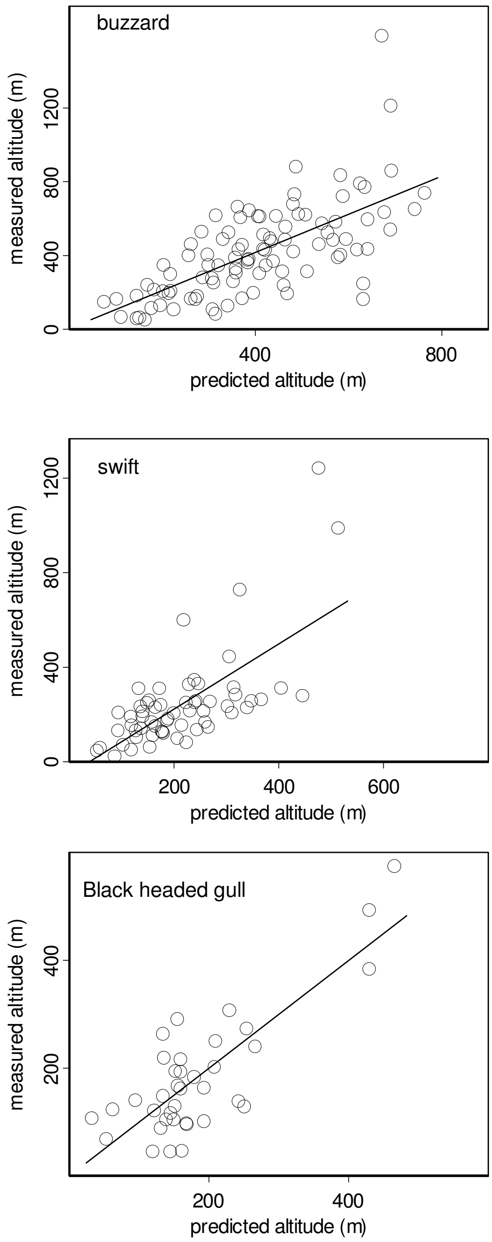

Figure 3: Scatter diagram of measured vs. predicted flight altitudes for buzzards ($\sqrt{y} = -0.21*var1 + 0.69*var5 + 0.01*var7 - 0.41*var9 + 15.45$); swifts ($\ln(y) = 0.12*var2 - 0.02*var1 - 1.08*var8 - 0.07*var9 + 5.97$); and black headed gulls ($y = -540.56*var8 + 26.93*var6 - 8.68*var3 - 24.64*var4 - 0.13*var7 + 9532$) (top to bottom).

Table 1: Meteorological variables used in models and their sources.

Variable	Var #	X daily	Source
Relative humidity	1	24	KNMI
Temperature	2	24	KNMI
Sea level pressure	3	24	KNMI
Wind speed	4	24	KNMI
Daily maximum temperature	5	1	Derived
Daily minimum temperature	6	1	Derived
Boundary layer height	7	24	ECMWF, integrated forecasting system
Total cloud cover	8	4	ECMWF, Era40 reanalysis
Best 4-layer lifted index	9	4	NCEP reanalysis

4. CONCLUSIONS

When comparing species groups, the vertical distribution of birds appears to be related to their flight strategy, which in turn is linked to their body size and wing structure (Hedenström 1993, Spaar 1997). Soaring birds fly higher than birds using a combination of flapping and gliding flight.

Meteorological variables strongly influence the flight altitudes of the groups of birds studied. Meteorological conditions that are associated with good soaring conditions such as lower relative humidity, higher ambient temperature, very low daily minimum temperature (usually related to clear skies and good mixing in the lower air layers during the day), higher boundary layer height, were related to higher flight altitudes of buzzards which are true soaring birds and the swifts which use soaring flight and depend on aerial prey. Gulls on the other hand showed a more complex relationship to meteorological conditions. Within a species, the choice of a particular flight strategy may be influenced by meteorological conditions, which is suggested by the results for the gull analysis.

Results of this study are being applied to the development of a Bird Avoidance Model aimed at predicting the 3-dimensional spatial and temporal distribution of birds in northwest Europe to improve military flight safety in the region.

5. REFERENCES

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6.ACKNOWLEDMENTS

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