Supplementary Material

Relation between travel strategy and social organization of migrating birds with special consideration of formation flight in the northern bald ibis
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Supplementary Methods:

We consider the effects of a human-led migration on (a) the aerodynamics during the flight, (b) the general flight pattern, (c) group composition, and (d) the social behaviour of the birds.

(a) Aerodynamics

For most of the time during the human-guided migration, the birds fly in a relatively large distance to the ultralight aircraft. It even happens, from time to time, that the distance between aircraft and birds is that great that the pilot loses sight of the birds. During the human-led migration the mean distance of the birds to the aircraft was 38 ± 17 m, which makes it highly unlikely that the birds could gain any aerodynamic from the parachute of the aircraft. At times when the birds were closer to the aircraft, they were usually observed flying parallel to it but very rarely behind it.

(b) Migration Pattern

Concerning the general migration patterns we tried to mimic the natural migration patterns in terms of leg-length (average 206 km), flight speed (average ground speed 50 km/h) and altitude (0-2250m a.s.l.), flight time (mean 4:10h, maximum5:38) and flight/rest ratio (1:3) as closely as possible. Our understanding of the 'natural' migration patterns of northern bald ibis are primarily based on (i) observations of the migratory behaviour of the wild populations in Morocco and Syria (Waldrappteam managed to equip birds in pre-war Syria with GPS trackers, which allowed us to track their migration route over 3000 km via Jordan and Saudi Arabia towards Ethiopia: average observed leg length: 240km); (ii) published data from other comparable species, (iii) experience during nine previous human guided migration (where during over 70 migratory legs, we gained considerable experience about the appropriate travel speed at which birds were able to follow comfortable and did not get

quickly exhausted), and (iv) GPS tracking records from independently migrating birds released over the last years (e.g. average leg length 150-300km, duration up to 8:00h).

(c) Group Composition

In one aspect the method of human-guided migration has a substantial effect on the birds: the composition of the flock with respect to number of animals, age and sex distribution. This was fully determined by the researchers. In this respect we did exert a strong influence on the long-term social behaviour pattern of the birds. Yet, the incidence during the fourth and final leg of the migration, where after one hour the entire flock of birds abandoned following the ultralight aircraft and twelve birds continued flying for another five hours and twenty minutes, while two birds left the flock within the first hour shows that on a fine temporal scale (which is the one we are concerned with, here) the birds do obviously have a certain 'freedom' to make their own behavioural decisions. In order to give the reader the possibility to compare whether and in what respect human-guided and unaccompanied flights differed we presented all data and analysis for human guided and independent flight separately.

(d) Social Behaviour

Birds were raised socially, in clutch sizes as observed under natural conditions. The social behaviour as well as the foraging behaviour of the hand raised birds was closely monitored by members of Waldrappteam over all the years. This includes in addition to ad-libitum observations, sampling protocols for agonistic and socio-positive interactions and socio-spatial (nearest-neighbour) data. As far as we can judge they developed 'normal' social behaviour towards their group members, as we could not see any obvious differences in their social behaviour in comparison with zoo populations or a free flying population at Burghausen, Germany. Throughout the whole migration the birds were provisioned with sufficient amounts of food. This means that we potentially reduced within-group competition for food resources. However, as northern bald ibis feed on small insects which they swallow at once, their foraging style creates scramble competition, which is less prone to lead to social conflict over food. During resting days birds were confined to a 6 by 12 meter aviary. While this aviary was rather spacious, it is still possible that the restricted space influenced social affiliations of the birds.