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Post-fledging dependence period and maturation of flight skills in the Black Kite *Milvus migrans*

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The post-fledging dependence period of 15 radio-tagged juvenile Black Kites Milvus migrans, *was studied in the Doñana Biological Reserve (Spain). The juveniles fledged at a mean age of 48 days after hatching and continued to depend on their parents for 15–36 days more. During the whole period a progression was observed in the flight behaviour of the young, as an increase of both the total time spent flying and the use of more elaborate and energy-saving flight types such as gliding and soaring. Neither hunting nor manipulative play behaviour with objects was observed, although pursuits were recorded and considered as social play. Migratory restlessness seems to shorten the post-fledging dependence period as the season progresses. Juvenile departure was sudden and definitive, and family ties always broke before migration.*

Quantitative studies on the development of flying and maturation of behavioural patterns in raptors during the post-fledging dependence period are very scarce.[1–4] Available information indicates that there are great differences among species in the length of this period, and how adult behavioural patterns are perfected.[5,6] Data on the length of the post-fledging dependence period of the Black Kite *Milvus migrans* was provided by Makatsch[7] and Thiollay,[8] otherwise information is lacking. Thiollay[8] suggests that the dependence period could continue during migration, although Newton[6] considers it unlikely that any raptor species migrates in family groups. The present study describes and quantifies the beginning, duration and end of the post-fledging dependence period, flight progression and maturation of certain behavioural patterns in the Black Kite.

Study area

The study was carried out at the Doñana Biological Reserve included in the Doñana National Park, south-west Spain (37°N, 6°30'W). A more detailed description of the area can be found in Valverde,[9,10] Allier *et al.*[11] and Rogers & Myers.[12]

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Three main biotopes can be distinguished in the study area: firstly, Mediterranean scrubland formed by *Halimium* spp., *Cistus libanotis* and *Erica* spp. With scattered Cork Oaks *Quercus suber* and small Stone Pine *Pinus pinea* woods; secondly, the marsh, mainly covered by *Scirpus* spp, which remains flooded during winter, though almost dry throughout the season when we carried out our research; and thirdly, the coastal sand dunes with vegetation mainly of *Ammophila arenaria, Corema album* and *Juniperus phoenicea*.

The climate is Mediterranean with Atlantic influence. There was no rainfall during the study period and the temperature range was 9–42°C.

The population of Black Kites at the Reserve consisted of 80 breeding pairs. The nests were mainly on Cork Oaks near the marsh border.

MATERIALS AND METHODS

The post-fledging dependence periods of 15 juvenile Black Kites, belonging to 8 breeding pairs, were studied during the summers of 1985 and 1986. Two of the pairs reared 3 young, 3 reared 2 young and the other 3 reared only 1. Of the 15 juveniles studied, 9 were fitted with radio-transmitters attached with a back-pack harness[13] and plastic coloured wings-tags,[14] 4 only with wing-tags and 2 were not marked as they left the nest very early in the season. One of the juveniles was killed by a carnivore and for 3 of the remaining 14 only partial information was gathered, so they are not included in all analyses. During 1986, 3 adult males of the breeding pairs studied were similarly marked with radio-transmitters and wing-tags. Tagging allowed individual recognition of the birds. As all the nests were checked every 2–5 days for other studies, hatching dates were known or could easily be calculated for all the juveniles.

Observations started at the end of June, when the chicks were 34–57 days old, and ended when all the juveniles had left the area (13 August 1985 and 19 August 1986). In 1985, each family was monitored during one complete day in every 4, until 13 August, after which only the presence of tagged juveniles in the nesting areas was checked daily in order to establish departure dates. In 1986, each family was watched for 8 complete days in 4 groups of 2 consecutive days at first flight, after first flight, in the middle of the post-fledging period, and close to the departure date (see Bustamante[15] for more details). Some juveniles departed before expected, so there are fewer than 8 observation days for them. Observations were made continuously from a vehicle parked on average 235 m from the nest, from dawn to dusk (6.30–20.30 GMT). Data were recorded on tape and also on previously designed record cards. Total observation time was 849 hours, averaging 106 hours per family unit.

All observed juvenile flights were classified as to type and direction, and timed with a stopwatch, and the location of the juvenile was mapped at each move. Daily home ranges were later measured on the map with a digital planimeter. Home range was considered to be the minimum convex polygon which included all daily locations of each juvenile.[16] Statistical analysis was carried out using BMDP statistical package.[17]

RESULTS

Beginning and length of the post-fledging dependence period

Juveniles started their first flights 42–62 days after hatching ($\bar{x} = 48$ days, s.d. = 4.5, $n = 13$) and continued to depend on their parents 15–36 days more.

On average, the last hatched chicks of multiple broods made their first flight at an older age and had shorter post-fledging periods than their older siblings (Table 1), although differences are not statistically significant, probably due to small sample sizes. Single brood chicks made their first flight at a significantly older age than elder siblings of multiple broods ($t = 2.81$, df = 8, $P < 0.05$) and had shorter, although not statistically significant, dependence periods. In 4 of the multiple broods, the post-fledging period was shorter for the younger sibling, although the differences are not statistically significant.

Table 1. Age at first flight and length of post-fledging dependence period for Black Kite chicks in different brood conditions

	Age at first flight			*Length of post-fledging dependance period*		
	n	$\bar{x}$	*s.d.*	n	$\bar{x}$	*s.d.*
Single brood chick	3	48.8	1.04	3	24.2	7.94
Older chicks of multiple broods	7	45.5	2.68	6	29.7	5.00
Last chicks of multiple broods	4	50.6	7.04	4	27.9	4.09
Total	14	47.7	4.52	13	27.8	5.49

Table 2. Regression coefficients on juvenile age of the variables FF (daily percentage of exclusively flapping flights), GF (daily percentage of flights in which gliding is used) and CF (daily percentage of flights in which circling or soaring is used), NDF (number of daily flights), HR (home range size), and of the variables log-transformed TTF (Total daily time flying, in seconds), MFD (mean flight duration, in seconds) and MAXFD (Maximum flight duration, in seconds). Sample sizes in brackets to the left of the coefficients

Juveniles		*FF*	*GF*	*CF*		*NDF*	*HR*	*TTF*	*MAXFD*	*MFD*
J1A003	(n = 7)	−1.607	1.464	0.161	(n = 8)	1.362*	0.017†	0.129	0.099*	0.079*
J1A161	(n = 7)	−2.875	1.589	1.259	(n = 8)	0.862†	0.347*	0.132†	0.118†	0.091*
J2A161	(n = 6)	−1.490	0.587	0.922	(n = 7)	0.759†	0.227*	0.143*	0.106	0.093
J1A157	(n = 6)	−3.150†	2.064	1.064	(n = 7)	1.211†	0.151†	0.165*	0.135*	0.106*
J2A157	(n = 4)	−1.250	1.325	0.000	(n = 5)	1.255†	0.213	0.232	0.170	0.148
JIPMAR	(n = 5)	−0.680	0.212	0.969	(n = 6)	0.027	0.164*	0.040	0.042	0.039
J1A137	(n = 4)	−3.649	1.783	1.815	(n = 5)	0.692	0.127	0.220	0.158	0.176
J2A137	(n = 6)	−2.460	1.670	0.725	(n = 7)	1.254*	1.048	0.204†	0.185†	0.152†
J1A165	(n = 6)	−1.375	0.666	0.725	(n = 7)	0.648	1.241*	0.116*	0.117*	0.097*
J2A165	(n = 6)	−1.508*	0.845	0.663	(n = 7)	0.900†	0.098*	0.138*	0.142†	0.122†
J3A191	(n = 6)	−2.942	1.692	1.267	(n = 7)	0.856	0.455	0.169†	0.147†	0.125†
Pooled	(n = 63)	−1.231‡	0.705†	0.530‡	(n = 74)	0.735‡	0.255‡	0.119‡	0.106‡	0.089‡

* = $P < 0.05$
† = $P < 0.01$
‡ = $P < 0.001$

Development of flight skills

First flights were short, straight flapping flights between adjacent perches. Gliding flights, usually interspersed with wing flapping, were first seen at a mean age of 56 days (s.d. = 5.8, n = 11), and circling and soaring at a mean age of 63 days (s.d. = 7.7, n = 12) after hatching. The frequency of these more elaborate flights increased with age, while exclusively flapping flights decreased (Table 2).

For all juveniles studied, there was an increase with age in the number of daily flights (NDF), total daily time flying (TTF), mean flight duration (MFD), maximum flight duration (MAXFD) and home range size (HR). As some variables (TTF, MFD and MAXFD) tended to have more of an exponential increase than a linear one, they were log-transformed before calculating regression coefficients, although for some individuals log-transformation did not always improve linearization because of small sample size.

Total daily time flying (TTF) was significantly correlated with age for the greatest number of individuals (8 of 11). The increase of TTF with age was due to an increased number of daily flights (NDF) (partial correlation $r = 0.499$, $P < 0.01$, $n = 77$) and to an increase in the mean flight duration (MFD) (partial correlation $r = 0.866$, $P < 0.01$, $n = 77$). There was a significant negative partial correlation between NDF and MFD ($r = -0.276$, $P < 0.05$, $n = 77$). This suggests that juveniles either increased the number of daily flights or the mean flight duration as they grew older. Juvenile home ranges (HR) also generally increase with age, but HR regression coefficients for each juvenile had no significant correlation with those of other flight progression variables (NDF, TTF, MFD and MAXFD) possibly because the increases in HR were affected by the spatial arrangement of suitable perches in the nesting area, as has been noted for other raptors.[13,18]

Juveniles that fledged later in the season tended to increase NDF at a faster rate and had a shorter post-fledging dependence period. There were significant correlations between the NDF regression coefficients for each juvenile and its fledging date ($r = 0.717$, $P < 0.05$, $n = 11$), and between post-fledging length and fledging date ($r = -0.583$, $P < 0.05$, $n = 13$).

Acquisition of hunting skills

We never knew for certain whether or not tagged juveniles had caught prey by themselves during the post-fledging dependence period, but typical adult hunting behaviour (slow gliding-flapping at low height with typical head movements) was not seen. The only record of juveniles hunting is of a ringed 75-day-old caught with a bow-net trap baited with meat located 900 m from his nest, and a possible insect capture in flight by a dependent juvenile near his nest.

None of the juveniles was observed following adults to their usual hunting grounds in the marsh or practising prey-catching movements, as has been described for other raptor species.[2,19–24] However, juveniles were seen to pursue other kites (adults or juveniles), or other raptors during the last weeks of the post-fledging dependence period. These pursuits were towards raptors whether carrying food or not, and once towards a kite carrying a piece of paper in its talons. In these pursuits—usually involving several kites—the birds dived, rolled upside-down and grasped the object or the other bird's talons.

Once the juveniles have left the nesting area and are not being fed by the adults they must start searching for food. These events are probably simultaneous. Apparently, juveniles did not search for food before independence as the percentage of total observation time spent flying by juveniles during the days immediately before departure (7.9%, s.d. = 6.3, n = 14 days, 7060 min) is much lower than that of hunting adults (64.2% of 8394 min of incomplete observation periods during 17 days). Also, adult daily home ranges during this season (F. Hiraldo, unpublished) are 100–1000 times bigger than juvenile home ranges (9.6 Ha., s.d. = 13.8, n = 14 days) at the end of the post-fledging dependence period.

Leaving the nesting area

Juveniles left the nesting area 63–84 days after hatching ($\bar{x}$ = 76 days, s.d. = 5.5, n = 13). Our data indicated that different members of the family left the nesting area independently, possibly to start migration. The interval of time between sibling departure ranged from 0 to 12 days (Table 3). It seemed that adults tended to stay several days longer than their offspring in the nesting area. In all the cases observed (n = 5), the first member of the family to depart was the eldest sibling or siblings.

The 3 tagged adults left the area on migration independently of their offspring. One of them left the same day as the last hatched juvenile but at a different time and in a different direction.

None of the tagged juveniles returned after leaving the nesting area, nor could they be located within a radius of 20 km from the nest during the days following departure. The adults, on the other hand, occasionally left the nesting area for several days, returning once or more before starting their migration.

Departure seems to be a sudden and definitive change in juvenile behaviour. Of the 2 juveniles observed during departure, the first

Table 3. Minimum observed difference within family groups between the departure date of each individual, expressed as number of days after the departure of the first one to leave

Family groups	*First young*	*Second young*	*Third young*	*Adult male*	*Adult female*
A003	0*			–	–
A161	0*	0*		–	–
A157	–	0*		–	–
A101	0*			2*	–
PMAR	0*			9*	2
A137	0	6	+	6	6
A165	0*	0*		2	–
A191	0	0	12*	12*	9

* Equipped with transmitter.
– Missing data.
+ Died before departure.

was located 19 km from the nest flying SE, when previously he had not moved more than 100 m from the nest. The second was followed during 9 h of continuous flight and lost 60 km east of the nest flying SE towards the Straits of Gibraltar. He changed from one day to the next from flying 7.4% of the observation time (n = 840 min) to 72.3% (n = 549 min), and with a change in maximum flight duration (MAXFD) from 25 to 398 min.

DISCUSSION

Both the beginning and length of the post-fledging dependence period appear to be highly variable in the Black Kite as has been noted for other raptors.[3,19] Flight feathers at fledging are not fully developed, and their growth continues for another 18 days.[5] It is probable that differences in age at fledging were in part due to intrinsic brood factors, since the first and last hatched chicks of a brood have different growth rates, and in part due to the 'quality' of the parents, since the eldest chicks of multiple broods fly at a younger age (and have higher skeletal and muscular growth rates) than chicks of single broods (F. Hiraldo, P. Veiga & M. Mañez, unpublished). Other factors such as weather and laying date could also affect age at fledging. Juveniles fledged later in the season had significantly shorter post-fledging dependence periods and a faster increase in number of daily flights. Several authors have suggested that migration could shorten post-fledging dependence.[5,25] Sherrod[26] also found that post-fledging dependence was much shorter in a migratory population of Peregrine Falcon *Falco peregrinus* than in a sedentary one.

Flight progression was similar to that observed in other raptors.[2,4] There was an increase in time spent flying, and a gradual change to gliding and soaring which are of lower energetic cost than wing-flapping.[27] Brown & Amadon[5] have related this to the fact that flight feathers are still growing and the quills are not yet hard enough for powerful flight. However, it seems probable that flapping can generate as much or even more strain on the feather quills as gliding. Nevertheless, feather growth is probably relevant since a high wing load during the first days of flight might constrain the efficiency of gliding.[28,29] Once juveniles have a good command of lower energetic-cost flight, it is logical that they should try to reduce energy costs, especially if, as has been usually,[30,31] but not always,[32] observed in other species, juvenile survival is related to body weight at the time of fledging.

The usual prey of the kite is carrion, insects and inexperienced young animals, and does not need complex capture techniques or manipulation. This could be the reason for the lack of observations of play behaviour involving manipulation of objects, suggested as a mechanism to acquire skills in prey capture[22] and or to train the muscles necessary for this activity.[33] Raptor species in which this behaviour has been recorded (*Falco* spp.,[26,34] *Circus cyaneus*,[13,23] *Buteo* spp.,[24] F. Hiraldo, M. Delibes & R.R. Estrella, unpublished) generally specialize in catching faster prey and have more elaborate capture techniques. Likewise, there did not seem to be any kind of learning through observation nor 'teaching' by adults, who usually searched for prey far away from the nest, and were never followed by the juveniles.

It is possible that pursuit of kites or other raptors by juveniles (usually near the end of the post-fledging dependence period) is a kind of social play similar to that described for other raptors,[2,21] and that it could serve to improve flying and hunting techniques. This type of play behaviour is in accordance with the flight skill required for kleptoparasitism, sometimes used by the species.[5] In conclusion, during the Black Kite post-fledging dependence period, the most important aspect seems to be the gradual improvement of flight skills, without active learning of hunting techniques. It seems probable that a good command of soaring and gliding flight is essential for the young to acquire independence, but experience of hunting is not.

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