Wandering stars: age-related habitat use and dispersal of Javan Hawk-eagles (*Spizaetus bartelsi*)

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Summary

Natal dispersal and philopatry have rarely been studied in tropical forest raptors. Especially with respect to endangered species with fragmented distributions more knowledge of dispersal and age-related habitat preferences is needed for proper management. We conducted an island-wide study on age-related habitat preferences of the endangered Javan Hawk-eagle (*Spizaetus bartelsi*), Indonesia's national bird. The Javan Hawk-eagle is a true forest eagle, but is occasionally observed in non-forested areas. On the basis of 95 visual encounters in 50 localities in the period 1980–2002, we established that there were no age-related differences in geographical, altitudinal or climatic distribution. In habitat preferences, however, juveniles and immatures are proportionally more often recorded in open and disturbed habitats than adults, which seem to have a greater preference for evergreen forest. These results indicate that the prime habitat for adult Javan Hawk-eagles is evergreen forest and to a lesser degree secondary forest, with juveniles dispersing out of their natal territory into different habitat types, including seemingly unsuitable types. In their habitat choice, immatures tend to be more similar to adults than to juveniles, which is an indication that their dispersal takes place into habitats that are more suitable for establishing a breeding territory.

Key words: Falconiformes, *Spizaetus bartelsi*, habitat preferences, philopatry, raptors.

Zusammenfassung

Wandering Stars: Alterskorrelierte Habitatnutzung und Ausbreitung des Javahaubenadlers (*Spizaetus bartelsi*)

Philopatrie und die Ausbreitung von Jungtieren sind bei tropischen Raubvögeln bislang kaum untersucht, obwohl gerade für bedrohte Arten mit fragmentierten Verbreitungsgebieten ein besserer Kenntnisstand über die Ausbreitungsmuster und altersbedingte Unterschiede in den Habitatvorlieben für ein effektives Management notwendig wäre. In der Zeit zwischen 1980 und 2002 führten wir eine inselweite Studie über altersbedingte Habitatpräferenzen des Javahaubenadlers (*Spizaetus bartelsi*) durch. Diese Art, Indonesiens Nationalvogel, ist auf Waldgebiete spezialisiert, kann aber gelegentlich auch in unbewaldeten Gebieten beobachtet werden. Die Analyse von 95 Sichtbeobachtungen an 50 Fund-

orten zeigte keine altersbedingten Unterschiede in der geographischen, höhenbedingten oder klimatischen Verbreitung, wies aber dagegen auf eine unterschiedliche Habitatwahl juveniler und subadulter Adler hin. Diese wurden signifikant häufiger in offenen und degradierten Gebieten beobachtet, während die adulten Tiere eine stärkere Präferenz für geschlossene Regenwaldgebiete aufwiesen. Die Fortpflanzung des Javaadlers findet meist im Regenwald statt, und die frisch ausgeflogen Tiere zeigen ähnliche Habitatvorlieben wie die Adulti. Dies bestätigt, dass der Regenwald den primären Lebensraum des Javaadlers darstellt und die Jungtiere sich in andere, darunter auch anscheinend weniger geeignete, Habitate ausbreiten. Die subadulten Tiere zeigen dagegen Habitatpräferenzen, die stärker an die der Altvögel erinnern als an die der Juvenilen. Dies weist möglicherweise darauf hin, dass sie in dieser Lebensphase bereits Bereiche suchen, die als Brutterritorium geeignet sind.

Introduction

The island of Java (126,500 km^2), Indonesia's political and industrial centre, is one of the most densely populated areas in the world (114 million inhabitants, at an average population density of 862 per km^2; Whitten et al. 1996). At one time the island was probably completely covered by tropical forest, but the destruction of these forests dates back several centuries, probably to the 10th century AD (Whitten et al. 1996). Nowadays, less than 10% of the original forest remains. It has been replaced by a mosaic of cities and villages, agricultural land, cash crop and forest plantations (Teak *Tectona grandis*, Sumatran Pine *Pinus merkusi*, Rubber *Hevea brasiliensis*), rendering the natural forest areas into habitat islands. Rain forest only occurs in areas where the dry season is short, on Java coinciding with areas that have at least 30 rainy days during the four consecutive driest months of the year (van Steenis & Schippers-Lammertse 1968). This forest type is mostly found in the perhumid western and central parts of Java, and in small pockets in the seasonally dry east. In drier areas wet forest is replaced by moist or deciduous forest.

In the last remnants of rain forest and moist forest, one of the most endangered birds of prey remains, the Javan Hawk-eagle (Collar et al. 2001). Always described as being (very) rare (Kuroda 1936, Brown & Amadon 1968),

until recently the species was one of the world's least known raptors. Basic data on feeding behaviour, geographical distribution, habitat preference, and breeding. were completely lacking (Brown & Amadon 1968, Ferguson-Lees & Christie 2001). In the early 1990's the Javan Hawk-eagle was declared Indonesian's national rare animal (Widyastuti 1993), and overnight the bird became very well known to the general public. Javan Hawk-eagles were depicted on banners, stamps, telephone directories, and came in great demand by zoos and unscrupulous collectors (Sözer et al. 1998). Simultaneously, the species' rise to fame made it the focal point for a number of conservation related projects (van Balen et al. 2000). Currently the eagle is among the most studied birds in Indonesia, with numerous students and local clubs collecting data on the species' biology (van Balen 1998, van Balen et al. 1999, 2001, Setiadi et al. 2000).

Like most endemic birds on Java, the Javan Hawk-eagle is an evergreen forest specialist. Just like the forest it lives in, populations of Javan Hawk-eagles appear severely fragmented and isolated from one another (van Balen et al. 1999, 2001). However, on Java some 17 % of the agricultural land consists of home gardens, and their forest-like structure more or less mimics natural forest (Whitten et al. 1996). Therefore, aggregations of smaller forest areas may be considered as composites cemented by mature plantations and certain types

of agricultural land (van Balen et al. 2000). The presence of Javan Hawk-eagle in small long-isolated forest patches (van Balen et al. 2000) which on their own may not be large enough to support a viable eagle population, suggests that the surrounding (non-forest) habitat acts to increase the effective size of the small forest areas. Moreover, vast stands of plantations may increase connectivity, i.e. the degree to which the landscape facilitates or impedes movement among resource patches (Taylor 1993). Since in many tropical forest raptors adults are exceedingly sedentary (Ferguson-Lees & Christie 2001), juveniles and immatures may be dispersers.

Habitat selection and natal dispersal by juvenile and immature raptors have been widely studied in Europe and Northern America (e.g. Ferrer 1993, Ferrer & Harte 1997, Miller & Smallwood 1997, Manosa et al. 1998, Newton & Rothery 2000, Real & Manosa 2001, Forero et al. 2002) but hardly any data are available on tropical forest raptors (c. f. Thiollay 1994, van Balen 1998). The aim of this paper is to report on differential habitat use by juvenile and adult Javan Hawk-eagles, and to discuss the evidence of juvenile dispersal in this species.

Material and methods

Data acquisition

As tropical forest raptors are notoriously difficult to observe (e.g. Thiollay 1989), we chose to assess the presence of Hawk-eagles by scanning large areas from vantage-points, searching the sky and canopy, and by surveys along transects and established trails in the forest. Inside forest areas the presence of the species was ascertained mostly by our listening for their characteristic vocalisations (Nijman & Sözer 1997).

Javan Hawk-eagles were studied in the framework of a general survey on forest birds on Java in 1980–1981 and 1984–1997, and during special raptor surveys in 1994–2002. The presence of the species was assessed in numerous small forest areas (< 50 km^2) and in 34 sizeable forest blocks (> 50 km^2) with known historical or expected occurrence of Javan Hawk-eagles. In total the investi-

gated forest areas cover > 8500 km^2, i. e., $> 80\%$ of the remaining forest on Java. The majority of forest areas were visited at least twice, while a survey typically lasted between several days and several months. In all we spent > 700 field-days throughout Java surveying inside natural forest areas.

Following the methodology of Nijman (in press), for each bird the habitat in which it was first encountered (either perched or flying) was recorded. In general the habitats recognised covered substantial areas and only rarely was it not possible to assign a recording to one habitat type. In those cases each of the two habitats involved received halve a score. Each recording was assigned an altitude for the habitat in or above which the bird was recorded. Javan Hawk-eagles are territorial and frequently perform aerial displays (Nijman et al. 2000) over specific sites. Likewise, certain (prominent) trees are used habitually more often than others. In order to reduce bias from pseudo-replication, individual birds encountered on subsequent days at (nearly) the same site were included only once in the analysis as these recordings were not considered independent.

We distinguished four age-classes: (i) fledglings, (ii) juveniles, (iii) immatures, and (iv) adults. Fledglings are similar to juveniles but are recognisable by their not yet fully developed plumage. Juveniles are cinnamon-brown with dark brown wings and have a bluish grey iris. Immatures are darker brown than juveniles and the banding pattern on the flanks appears, while the iris has turned yellow. Javan Hawk-eagles are considered adult by us if the banding pattern on the underside is complete. In flight, from below, adults show a distinctive banding pattern on wings and tail, this is less pronounced on the wings in immatures and incomplete on both wings and tail in juveniles. The wings of juveniles appear white with grey-buff primaries and cinnamon brown underwing-coverts, whilst the white patch in between is triangular, with the tip at the carpal joint.

Habitat types

Javan Hawk-eagles occur from sea level up to 3000 m (Ferguson-Lees & Christie 2001, Nijman in press). Lowland is defined as altitudes < 1200 m and montane as > 1200 m. On Java, generally, the 1200 m altitude line is the approximate upper limit where the lowland forest formation gives way to the montane forest formation (Whitten et al. 1996) and where the lowland avifauna is almost completely re-

placed by the montane one (S. van Balen & V. Nijman unpubl. data).

In the present study, four habitat types were recognised, from the more open to the more dense:

(1) Cultivated Land: includes grassland, second growth, agricultural land – including tea plantations and wet rice-fields - and village areas. (2) Woodland: includes open woodland, large clearings and small forest fragments, and young tree plantations (Sumatran Pine, Rubber). (3) Secondary Forest: includes highly degraded natural forest with dense undergrowth and dominated by isolated trees, secondary forest either heavily logged or naturally disturbed (slopes, volcanic activities), (sub)mature tree plantations (Sumatran Pine, Rubber, Damar or Kauri *Agathis dammara*, and Mahogany *Swietenia* sp.). (4) Evergreen forest: includes submature, moderately disturbed evergreen natural forest with largely continuous canopy, and tall undisturbed forest. Occurs mainly in the western and central part of Java, and on the wetter slopes of high mountains in the east.

Analysis

As part of the study was aimed at maximising encounters, unequal time was spent in the different habitats with a bias towards the wetter and less disturbed types. Furthermore, detectablity of eagles, both visually and aurally, seemed to differ significantly between habitats and between observation sites. However, the likelihood of detecting any of the four age-classes within habitats and within sites probably differed little. Although fledglings and juveniles at times emitted continuous calls (van Balen 1991), other age-classes could be fairly vocal as well. Hence, it is justifiable to compare habitat preferences and habitat use between the different age-classes directly.

As a quantitative measure of similarity between habitat use of the different age-classes, we calculated the Euclidean distance between each of the age-classes (after Krebs 1999):

$$\Delta jk = \sqrt{\sum_{i=1}^{n}(X_{ij} - X_{ik})^2} \qquad \text{(equation 1)}$$

where Δjk = Euclidean distance between samples j and k; X_{ij} = percentage of individuals of age-class j in habitat class i; X_{ik} = percentage of individuals of age-class k in habitat class i; and n = total number

of habitat classes (both lowland and montane). Euclidean distances vary from 0 (identical distributions) to infinity, and thus are actually measures of dissimilarity.

Since most data collected were not normally distributed, non-parametric tests were used (Siegel 1956). For testing whether observed frequencies of occurrence were homogeneously distributed over all classes, and whether significant differences existed between the different classes, χ^2-tests were performed. When samples sizes were too small, a G-test of goodness of fit for single classification frequency distributions was carried out. To obtain a better approximation to χ^2, William's correction to G was applied ($G_{adj.}$: Sokal & Rohlf 1995). $G_{adj.}$ values were compared with critical values of the χ^2-distribution (Table C in Siegel 1956). Significance was assumed when $p < 0.05$ in a two-tailed test, and trends are mentioned when $0.05 < p < 0.10$.

Results

Distribution and numbers

We recorded Javan Hawk-eagles in 50 localities across the island. Frequently the birds were recorded aurally only, but 95 Javan Hawk-eagles were seen well enough to be aged. These included 43 adults, 24 immatures, 23 juveniles and five fledglings (Table 1). Apart from fledglings, which were recorded in western Java only, there seemed to be no differences in the distributions of the different age-classes over the island. For instance, juveniles and immatures were not proportionally more frequently recorded in the dry eastern Java (east of 110° longitude) than in the wet western half ($\chi^2 = 1.3$, df = 1, $p > 0.30$). The climate on Java, and especially the amount of rainfall, can differ greatly over relatively short distances, but climate did not seem to influence the relative distribution of the different age-classes. The number of birds observed in wet compared to drier areas did not differ between age-classes ($\chi^2 = 0.7$, df = 1, $p > 0.50$).

Overall, the encounter rate was < 0.2 bird per day^{-1}, but this average was strongly influenced by surveys in forest areas where the spe-

Table 1. Differential habitat use by age-classes of Javan Hawk-eagles *Spizaetus bartelsi* (1980–2002). For descriptions of habitat types and age-classes see text; lowland is < 1200 m asl, montane is >1200 m asl.
Tab. 1. Habitatnutzung verschiedener Altersklassen des Javahaubenadlers, *Spizaetus bartelsi*, zwischen 1980 und 2002. Beschreibungen der Lebensräumtypen und Altersklassen, siehe Text. Tieflandgebiete sind definiert als <1200 m üNN, Hochlandgebiete (montan) liegen >1200 m üNN.

Habitat	Altitude	Adult	Immature	Juvenile	Fledgling
Cultivated Land	lowland	2	1	1	0
	montane	3	2	2	0
Woodland	lowland	0	3	4	0
	montane	0	0	0	0
Secondary Forest	lowland	8	6	6	0
	montane	3	3	3	2
Evergreen Forest	lowland	14	5	4	2
	montane	13	4	3	1
Total		43	24	23	5

cies was proved not to be present. Median encounter rate in nine study areas (> 50 km^2), which were distributed over the entire island, was 0.3 birds day^{-1}, ranging from a low 0.1 bird day^{-1} in the deciduous forest of Alas Purwo National Park (East Java) to a high of 0.9 birds day^{-1} in for example the rain forests of Halimun National Park (West Java). Given the length of the study and the amount of ground covered, the total number of birds recorded was low. This is in part due to the conservative methodology employed, i.e. birds encountered on different days at similar localities were included only once in the analysis, but in part this was also due to the genuine rarity of the species (c. f. Thiollay & Meyburg 1988).

Habitat use

The Euclidean distances indicate that juveniles and immatures are very similar to one another in habitat use, as are, albeit to a lesser degree, fledglings and adults (Table 2). Since in their habitat choice fledglings are not independent from their (adult) parents, we restrict our subsequent analysis to the other age-classes.

Some three-fifth of the Javan Hawk-eagles were observed in lowland habitats. There was a significant difference in the proportion of records in lowland vs. montane for the four habitat types recognised ($G_{adj.} = 12.9$, df = 3, p < 0.01); e.g. the ratio lowland to montane

birds in woodland differed significantly from that of the other habitat types combined ($G_{adj.} = 7.2$, df = 1, p < 0.01), but this may simply reflect a difference in survey effort between altitudinal zones within habitat types and does not necessary reflect a preference on the part of the eagle. The distribution of the age-classes over lowland and montane habitats was fairly uniform and no age-related difference in altitudinal preferences was apparent ($\chi^2 = 0.9$, df = 2, p > 0.50). Subsequently, in the investigation of differential habitat preferences between age-classes, both altitude categories were pooled.

Numerically, Javan Hawk-eagles were recorded mostly in Secondary Forest and Evergreen Forest. The distribution of immatures and juveniles over the four habitat types was almost identical ($G_{adj.} = 0.5$, df = 3, p > 0.70).

Table 2. Euclidean distances as a measure of dissimilarity in habitat choice between different age-classes of Javan Hawk-eagles *Spizaetus bartelsi*.
Tab. 2. Euclidische Distanzen zwischen Altersklassen des Javahaubenadlers, *Spizaetus bartelsi*. Die Werte wurden berechnet anhand der Beobachtungen zur Lebensraumnutzung und zeigen proportional die Unterschiede in der Habitatpräferenz.

	Adult	Immature	Juvenile	Fledgling
Adult	0			
Immature	23.5	0		
Juvenile	30.3	7.1	0	
Fledgling	27.3	36.1	41.1	0

Adult Javan Hawk-eagles differed in their distribution over habitats from juveniles and immatures combined ($G_{adj.} = 9.8$, df = 3, $p < 0.05$); the difference was significant for juveniles ($G_{adj.} = 8.4$, df = 3, $p < 0.05$), but not for immatures ($G_{adj.} = 6.0$, df = 3, $p < 0.10$). Although in comparison to immatures and juveniles combined adults were more often observed in Evergreen Forest than in other forest types, the difference was not significant ($\chi^2 = 3.3$, df = 1, $p < 0.10$). Immatures and juveniles were significantly more observed in Woodland compared to the other habitat types than adults ($\chi^2 = 7.8$, df = 1, $p < 0.01$). The ratio of immatures and adults observed in Woodland to those observed in the other habitat types was higher than it was in adults.

Discussion

If the differences in the number of observations of Javan Hawk-eagles of each age-class was a reflection of differential habitat use, as we believe it was, there seemed to be little divergence between age-classes in terms of altitude or climate. Immatures and juveniles were fairly uniform in their distribution over habitats (as also reported for Bonelli's Eagles *Hieraaetus fasciatus*, Real & Manosa 2001); adults differed in their habitat preferences from juveniles and less so from immatures. Fledglings were recorded only in Evergreen and Secondary Forest, the habitat in which most breeding has been reported (Nijman et al. 2000). Adults tended to have a greater preference for Evergreen Forest than immatures and juveniles, and conversely, immatures and juveniles had a greater preference for Woodland than adults. We interpret these results such that the prime habitat for adult Javan Hawk-eagles is Evergreen Forest and to a lesser degree Secondary Forest. The largest contrast between any of the age-classes was between adults and juveniles, and this suggests that, after a prolonged fledging period (Nijman et al. 2000), juveniles disperse out of their natal territory into different habitat types. Given the large degree of habitat

fragmentation, this leads to a relatively large proportion of juveniles being observed in the more open habitats, i.e. Cultivated Land and Woodland.

Although the difference in habitat use between juveniles and immatures is small, immatures tend to be more similar to adults, and this may indicate that they disperse into habitats that are eventually more suitable for breeding. This latter behaviour may also include dispersal from temporary settling areas back to natal population areas with the possible aim of exploring opportunities for pair formation where a vacancy has occurred in the breeding population (c. f. Ferrer 1993).

The distribution of any given age-class over the different habitats does not necessarily imply a preference for the habitat type in which the birds are recorded most often. It is quite possible that all age-classes have a preference for evergreen forest, but that the younger age-classes are forced into the less favoured, more open, habitats. In many species, territorial behaviour has a profound influence on habitat distributions (Fretwell & Lucas 1970) with the exclusion of younger (and smaller) individuals by older ones as a frequent outcome (e.g. Petit & Petit 1996). Given the territoriality observed in the adults, this is conceivable for Javan Hawk-eagles, but at present data on social interactions are lacking.

We know of few studies that report on juvenile dispersal and age-related habitat preferences in tropical forest raptors, and Asian *Spizaetus* species in particular (summarised in Ferguson-Lees & Christie 2001), although juveniles of some species have been reported wandering far from their natal territories. Immatures of Changeable and Mountain Hawk-eagles (*S. cirrhatus* and *S. nipalensis*) are known to disperse over considerable distances, especially in the more seasonal parts of their range (Indian subcontinent, Indo-china, Japan), but movements of the more tropical members of the genus (*S. nanus, S. alboniger, S. lanceolatus*) are probably shorter (Ferguson-Lees &

Christie 2001, S. van Balen & V. Nijman, unpubl. data).

Natal dispersal and differential habitat preferences between adults, immatures and juveniles are of central relevance to the demography and genetic structure of populations and an understanding of them is crucial for managing threatened species with fragmented distributions (Boudjemadi et al. 1999), such as the endangered Javan Hawk-eagle (Collar et al. 2001). Our study demonstrates that juvenile and immature Javan Hawk-eagles are proportionally more often found in more open habitats than adults. Given that adult pairs are exceedingly sedentary, confined as they are to the last remaining pockets of wet forest on the island, this suggests that juveniles and immatures are the prime dispersers. Small breeding populations (< 5 pairs) in long-isolated (> 100 years) forest fragments, of which a number exist on Java (van Balen et al. 2001), may thus be less isolated than previously assumed.

Although the degree of philopatry may vary between populations (e.g. wet western part of Java and drier eastern part), the frequent recording of juveniles and immatures in Woodland and Cultivated Land brings this age-class in closer contact with people than adults, making them more vulnerable to persecution (van Balen 1991, Sözer et al. 1998).

Our study should be seen as a first step in understanding natal dispersal, philopatry and habitat preferences of juvenile and immature Javan Hawk-eagles. Few systematic studies conducted on the species, or other South-east Asian *Spizaetus* species, age individuals (cf. van Balen et al. 2001), and even fewer sex them. In many (temperate) raptors there is a sex difference in natal dispersal (e.g., Newton 1979, Negro 1997). An experienced observer can sex Javan Hawk-eagles as females are larger and more robust than males (Nijman & Sözer 1996), and it would be worth investigating this possibility in Javan Hawk-eagles and indeed other tropical forest raptors.

References

Boudjemadi, K., Lecomte, J. & Clobert, J. (1999): Influence of connectivity on demography and dispersal in two contrasting habitats: an experimental approach. J. Animal Ecol. 68: 1207–1224.

Balen, S. van (1991): The Java Hawk Eagle *Spizaetus bartelsi*. Birds of Prey Bull. 4: 33–40.

Balen, S. van (1998): Tropical forest raptors in Indonesia: recent information on distribution, status and conservation. J. Raptor Res. 32: 56–63.

Balen, S. van, Nijman, V. & Sözer, R. (1999): Distribution and conservation of the endemic Javan Hawk-eagle *Spizaetus bartelsi*. Bird Conserv. Intern. 9: 333–349.

Balen, S. van, Nijman, V. & Prins, H.H.T. (2000): The Javan Hawk-eagle: misconceptions about rareness and threat. Biol. Conserv. 96: 297–304.

Balen, S. van, Nijman, V. & Sözer, R. (2001): Conservation of the endemic Javan hawk-eagle *Spizaetus bartelsi* Stresemann, 1924 (Aves: Falconiformes): density, age-structure and population numbers. Contrib. Zool. 70: 161–173.

Brown, L. & Amadon, D. (1968): Eagles, hawks and falcons of the World. Feltham.

Collar, N. J., Andreev, J. V., Chan, S., Crosby, M. J., Subramanya, S. & Tobias, J. A. (2001): Threatened birds of Asia: the BirdLife International red data book. Cambridge.

Ferguson-Lees, J. & Christie, D. A. (2001): Raptors of the world. London.

Ferrer, M. 1993. Juvenile dispersal behavior and natal philopatry of a long-lived raptor, the Spanish Imperial Eagle *Aquila adalberti*. Ibis 135: 132–138.

Ferrer, M. & Harte, M. (1997): Habitat selection by immature Spanish imperial eagles during the dispersal period. J. appl. Ecol. 34: 1359–1364.

Forero, M. G., Donazar, J. A. & Hiraldo, F. (2002): Causes and fitness consequences of natal dispersal in a population of black kites. Ecology 83: 858–872.

Fretwell, S. D. & Lucas Jr., H. L. (1970): On territorial behavior and other factors influencing habitat distributions in birds. Acta Biotheor. 19: 16–36.

Krebs, C. J. (1999): Ecological methodology, second edition. Benjamin Cummings, Menlo Park.

Kuroda, N. (1936): Birds of the island of Java. Privately published, Tokyo.

Manosa, S., Real, J. & Codina, J. (1998): Selection of settlement areas by juvenile Bonelli's Eagle in Catalonia. J. Raptor Res. 32: 208–214.

Miller, K. E. & Smallwood, J. A. (1997): Natal dispersal and philopatry of southeastern American Kestrels in Florida. Wilson Bull. 109: 226–232.

Negro, J. J., Hiraldo, F. & Donazar, J. A. (1997): Causes of natal dispersal in the lesser kestrel: inbreeding avoidance or resource competition? J. Animal Ecol. 66: 640–648.

Newton, I. (1979): Population ecology of raptors. Berkhamsted.

Newton, I. & Rothery, P. (2000): Post-fledging recovery and dispersal of ringed Eurasian Sparrowhawks *Accipiter nisus*. J. Avian Biol. 31: 226–236.

Nijman, V. (in press): Habitat segregation in two congeneric hawk-eagles (*Spizaetus bartelsi* and *S. cirrhatus*) in Java, Indonesia. J. Trop. Ecol.

Nijman, V., Balen, S. van & Sözer, R. (2000): Breeding biology of the Javan Hawk-eagle *Spizaetus bartelsi* in West Java, Indonesia. Emu 100: 125–132.

Nijman, V. & Sözer, R. (1996): Sexual dimorphism in the Javan Hawk-eagle *Spizaetus bartelsi*. Bull. Br. Ornithol. Cl. 116: 251–253.

Nijman, V. & Sözer, R. (1997): Field identification of the Javan Hawk Eagle *Spizaetus bartelsi*. Forktail 14: 13–16.

Petit, L. J. & Petit, D. R. (1996): Factors governing habitat selection by prothonotary warblers: field tests of the Fretwell-Lucas models. Ecol. Monogr. 66: 367–387.

Real, J. & Manosa, S. (2001): Dispersal of juvenile and immature Bonelli's Eagles in Northeastern Spain. J. Raptor Res. 35: 9–14.

Setiadi, A. P., Rakhman, Z., Nurwatha, P. F., Muchtar, M. & Raharjaningtrah, W. (2000): Distribusi, populasi, ekologi dan konservasi Elang Jawa *Spizaetus bartelsi* Stresemann 1924 di Jawa Barat bagian selatan. BP/FFI/BirdLife International/YPAL-HIMBO UNPAD, Bandung.

Siegel, S. (1956): Nonparametric statistics for the behavioral sciences. McGraw-Hill, Aukland.

Sokal, R. R. & Rohlf, F. J. (1995): Biometry. The principles and practise of statistics in biological research. New York.

Sözer, R., Nijman, V., Setiawan, I., van Balen S., Prawiradilaga, D. M. & Subijanto, J. (1998): Javan Hawk-eagle recovery plan. KMNLH/PHPA/LIPI/ BirdLife International – Indonesia Programme, Bogor.

Steenis, C. G. G. J. van & Schippers-Lammertse, A. F. (1965): Concise plant-geography of Java. In Backer C. A. & Bakhuizen van der Brink R. C. (eds.): Flora of Java, Vol. 2: 1–72. Groningen.

Taylor, P. D. (1993): Connectivity is a vital element of landscape structure. Oikos 68: 571–572.

Thiollay, J.-M. (1989): Area requirements for the conservation of rainforest raptors and game birds in French Guiana. Conserv. Biol. 3: 128–137.

Thiollay, J.-M. & Meyburg, B.-U. (1988): Forest fragmentation and the conservation of raptors: a survey on the island of Java. Biol. Conserv. 44:229–250.

Whitten, A. J., Soeriaatmadja, R. E. & Afiff, S. A. (1996): The ecology of Java and Bali, the ecology of Indonesia series Vol. II. Singapore.

Widyastuti, Y. E. (1993): Flora-fauna maskot nasional dan propinsi. Jakarta.