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MOULT AND AGE DETERMINATION OF EURASIAN SPARROWHAWK *ACCIPITER NISUS* IN SPAIN

PATRÓN DE MUDA Y DETERMINACIÓN DE LA EDAD EN EL GAVILÁN EUROASIÁTICO *ACCIPITER NISUS* EN ESPAÑA

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SUMMARY.—*Moult and age determination of Eurasian sparrowhawks* Accipiter nisus *in Spain*.

The moult sequence of sparrowhawks in Spain and its variations regarding the previously described pattern, and how to use it for on-hand age determination of individuals is described. Eighteen adult sparrowhawks were trapped during the breeding seasons between 2001 and 2007 in Vizcaya and 129 sparrowhawks were examined in Wildlife Rehabilitation Centres between 1999 and 2007, including individuals from Vizcaya and Alava (Northern Spain), Madrid, Guadalajara, Salamanca and Toledo (Central Spain), and Granada and Jaén (Southern Spain). A total of 147 full-grown sparrowhawks were analysed in order to determine the moult sequence. The moult in primaries and their respective primary coverts went in order from the innermost (P1) to the outermost (P10). The moult of secondaries started in four separate moult foci, S5 being normally the first to be shed; afterwards the second focus was located in S11, the third was located in S1 and the fourth in S13. The moult of rectrices usually started in the central pair followed by R4 and R6, while R5 and specially R2 were the last tail feathers moulted. The moult started in June and finished in November. 18.75 % of breeding females and 55.5 % of breeding males had arrested the moult. None of the breeding birds retained flight feathers from the previous season, whilst 32 % of the wintering females and 30 % of wintering males presented retained feathers. Sparrowhawks in Spain follow closely the pattern described by Newton and Marquiss (1982) for Scottish sparrowhawks. However, the effect of wintering birds on the sedentary population and other variables provoke some differences with regard to the Scottish model. These data can be used as a tool to determine the age of Spanish sparrowhawks and could be hypothetically used to distinguish wintering birds from local populations.

Key words: age, Eurasian sparrowhawk, incomplete moult, moult, sequence.

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RESUMEN.—*Patrón de muda y determinación de la edad en el gavilán euroasiático* Accipiter nisus *en España.*

Este trabajo describe el patrón de muda de los gavilanes en España, sus variaciones con respecto a los patrones descritos en la literatura, y cómo utilizar esta información en la determinación de la edad de las aves. Dieciocho gavilanes adultos fueron trampeados en Vizcaya durante las temporadas de cría de 2001 a 2007, y 129 analizados en Centros de Recuperación de Fauna Silvestre (CRFS) de Vizcaya y Álava (norte de España), Madrid, Guadalajara, Salamanca y Toledo (centro de España), y Granada y Jaén (sur de España) entre 1999 y 2007. En total, se registró la secuencia de muda de 147 aves desarrolladas. La muda de las primarias y de sus respectivas cobertoras se inicia en la más interna (P1) y progresa hacia la más externa (P10). La de las secundarias comienza en cuatro puntos diferentes, siendo la S5 la primera en ser mudada, siguiendo la S11, la S1 y la S13. La de las plumas de la cola normalmente comienza en el par central, seguidas por las RR4 y RR6, mientras que las RR5 y especialmente las RR2 eran las últimas en ser mudadas. La muda comenzó en junio y finalizó en noviembre. En los reproductores, el 18,75 % de las hembras y el 55,5 % de los machos habían parado la muda. Ninguna de las aves reproductoras presentó plumas retenidas de una muda previa, mientras que un 32 % de las hembras y un 30 % de los machos invernantes sí presentaron plumas retenidas. Los gavilanes en España ofrecen un patrón de muda similar al descrito por Newton y Marquiss (1982) para los escoceses. Sin embargo, el efecto de las aves invernantes en la población sedentaria y otra serie de variables causan algunas diferencias con respecto al modelo escocés. Los datos expuestos pueden ser empleados para datar la edad de los gavilanes en España y para diferenciar las invernantes de las sedentarias.

Palabras clave: edad, gavilán euroasiático, muda incompleta, retenida, secuencia.

INTRODUCTION

The ability to identify correctly the age and sex of birds may have important implications for conservation research (eg Newton *et al.*, 1983; Ferrer and Beson, 2003; Penteriani *et al.*, 2003; Zuberogoitia *et al.*, 2008). However, age and gender determination in birds of prey over Europe is normally based on a few original pieces of research (eg Newton and Marquiss, 1982; Hirons *et al.*, 1984; Petty, 1994; Taylor, 1994; Walls and Kenward, 1995; Kenward, 2006), which were carried out in some traditional study areas and then adopted by the remaining European researchers (see Mikkola, 1983; Cramp, 1985; Baker, 1993). Forsman (1999) indicated that it is important to consider that different subspecies, and indeed various populations of the same subspecies, may moult at different times. Since accurate age determination is normally based on moult, and this process may differ among different populations, age determination techniques based on moult should only be applied in those populations whose moult process has been described.

The moult sequence in Eurasian sparrowhawks *Accipiter nisus* from Scotland was described by Newton and Marquiss (1982): (i) Primaries. All birds replaced their primaries in order from the innermost (P1) outwards to P10. Typically, when one feather was partly grown, the next was shed, and so on through the series, so that the bird often had 2 - 3 adjacent feathers growing at once. The primary coverts were replaced at the same time as their equivalent primaries. Some time after the start of primary moult, replacement of the secondary and tail feathers began. (ii) Secondaries. Most of birds had up to three separate moult foci at one time. Each focus had one (occasionally two) feathers in growth at once. One focus usually began at or around feather 5, followed quickly by others around feathers 10 and 1. When the first feather at a focus was partly grown, moult usually spread to a neighbour. In most cases this was the neighbour on the inward side (nearest to the body). From the secondary 10, moult always progressed outwards to the S9 and inwards to the tertials (S11 - 13). (iii) Tail feathers or rectrices. The central feather of the tail (R1) was most often the first to be shed, the outer feather (R6) was most often the second, R3 the third, R4 the fourth, R5 the fifth, and R2 the sixth.

This detailed description of a Scottish population, where the species is sedentary, was widely accepted by different authors in all the European distribution area of the species (see Cramp, 1985; Baker, 1993; Forsman, 1999). However, in raptors, as in many other bird groups, differences in moult patterns among different populations of a single species have been described (i.e. Wheeler, 2003; Zuberogoitia *et al.*, 2005). These differences are generally related to different migratory and breeding habits and, therefore, the application of the moult pattern as an ageing tool of one species from a specific region could not always be reliably applied for ageing birds in a distant region.

If the moult pattern and its phenology are known, it is possible to establish the ages of sparrowhawks at least until the end of the first complete moult, when all juvenile feathers have been replaced by adult-type feathers. However, apart from the description of Newton and Marquiss no further publication has been found on this topic. Hence, our aim is to describe the moult sequence of sparrowhawks and its variations regarding the previously described pattern, and how to use it for on in-hand age determination of individuals.

Material and methods

Eighteen adult sparrowhaws were trapped, ringed and their plumage examined during the breeding season in Vizcaya (Northern Spain). Trapping was conducted using a raptor-specific mist net and an eagle owl *Bubo bubo* as a lure at the nest sites in July, when chicks are fledged, between 2001 and 2007 (see Zuberogoitia *et al.,* 2008). Individuals were sexed according to the presence (females) or absence (males) of a brood patch and from observation of breeding behaviour.

In addition, 91 dead and 38 live sparrowhawks admitted in to Wildlife Rehabilitation Centres (WRC) were examined between 1999 and 2007, including individuals from Vizcaya and Alava (Northern Spain), Madrid, Guadalajara, Salamanca and Toledo (Central Spain) and Granada and Jaén (Southern Spain). We did not consider birds which had been rehabilitating in the WRCs, because moult pattern in captive birds may not follow the same pattern as that of wild birds (authors` unpublished data). Dead birds were sexed by gonad examination, while live birds were sexed extracting a blood sample from the brachial vein for molecular sexing.

Those birds trapped during the breeding season close to their nests and those received in WRCs from May to August were considered as sedentary. All the sparrowhawks examined from September to April were considered birds of “unknown status”. According to ringing recovery data, the first migratory individuals arrive in Spain in the first weeks of September, during the post-breeding migration, and the last birds leave the country in April during the pre-breeding migration (table 1). Some foreign birds were recovered during summer, but we considered them to be anecdotal cases. Within the unknown status group, both local sedentary birds and migratory conspecifics were considered together since it was impossible to set them apart (see de la Hera *et al.*, 2007).

The birds were inspected following a standardized protocol by four researchers (IZ, RA, LP and Ainara Azkona). We recorded a moult card, identifying feather generation by wear, colour, age pattern and growth of the whole flight-feathers (remiges and rectrices), for both wings of each individual. This gave us data for 10 primaries and 13 secondaries for each wing, and 12 rectrices. Primaries (P) and primary coverts (PC) were numbered descendantly (from inside to out-

TABLE 1

Origin of sparrowhawks ringed/recovered in Spain and number of recoveries per month. Source: Ringing Offices of Ministerio Medio Ambiente (ESI) and Aranzadi (ESA).
[Procedencia de los gavilanes que fueron anillados/controlados en España y número de registros por meses. Fuente: Oficinas de anillamiento del Ministerio de Medio Ambiente (ESI) y Aranzadi (ESA).]

Countries *[países]*	**N**	**Month** *[mes]*	**N**
Central Europe		Jan	23
Germany	54	Feb	11
Belgium	17	Mar	9
France	5	Apr	7
Netherlands	22	May	2
Switzerland	9	Jun	2
Scandinavia		Jul	1
Denmark	5	Aug	0
Finland	5	Sep	7
Sweden	6	Oct	15
South-eastern Europe		Nov	39
Czech Republic	5	Dec	26
Italy	2		
North-eastern Europe			
Estonia	2		
Poland	2		
Russia	8		
Total	142		

side), secondaries (S) and great coverts (GC) were numbered ascendantly (from outside to inside), and rectrices (R) were numbered centrifugally (from the centre outwards).

Juvenile feathers (those developed during the nestling period) have a higher proportion of beige or light-brown in the background than adults, while bars are complete and more contrasting, particularly when seen from below (see Baker, 1993; Cieslak and Dul, 2006; Forsman, 1999). The terminal bar from below is narrower in juvenile remiges, leaving a clear narrow tip at the point, broadening when moulted. The juvenile body feathers show the typical buff fringes, normally evident mainly on the head and upperparts, including wing and tail coverts.

In juveniles (Euring age code 3 or 5), all the flight-feathers and body feathers belong to the same generation and show the same wear pattern until the onset of the summer moult. Second winter birds (Euring code 5 or 7) retain some juvenile feathers after the first moult, which are paler and show a significant degree of wear in comparison to the newer adult feathers. Moreover, differences are easily noticed on the upper-parts where the retained juvenile body-feathers, presenting the typical buff fringes, differ from second generation adult type feathers. Adult birds have replaced all juvenile feathers and show one or two different generations of adult feathers (table 2).

RESULTS

Sequence

The moult sequence in primaries and their respective primary coverts went in order from the innermost (P1) to the outermost (P10, fig. 1). Every primary covert was moulted in accordance with its primary, shedding just before. The moult of secondaries started in four separate moult foci, S5 being normally the first to be shed; afterwards the second focus was located in S11, the third was located in S1 and the fourth in S13. When the first feather at a focus was partly-grown, moult usually spread to an adjacent feather. The sequence progressed ascendant from S1 and S5, and descendent from S11 and S13. S4 and S8 were the last secondaries to be moulted. Greater Coverts (GC) did not follow the sequence of the secondaries; the moult started in GC1 just after the first primaries were shed and continued inwards quickly, independent of the flight feather sequence.

The moult of rectrices usually started in the central pair followed by R4 and R6, while R5 and specially R2 were the last tail feathers

TABLE 2

Summary key for ageing sparrowhawks by plumage status. Cy = calendar year.
[Tabla resumen para datar la edad de los gavilanes en función del plumaje. Cy = año de calendario.]

Autumn	**Spring**	
1cy	2cy	Homogeneous juvenile pattern. *[Patrón juvenil homogéneo.]*
2cy	3cy	Retained juvenile flight feathers and juvenile body feathers in upper wing surface, strongly contrasting with the remaining adult feathers. *[Plumas de vuelo y cobertoras de la parte superior del ala de patrón juvenil retenidas que contrastan fuertemente con el resto, adultas.]*
2cy+	3cy+	Adult pattern, not distinguishing between generations (very rare cases). *[Patrón adulto, no se distinguen generaciones (casos contados).]*
3cy+	4cy+	Retained feathers from the previous moult contrasting a little with the rest, from the last moult. *[Plumas retenidas de la muda anterior que contrastan ligeramente con las cambiadas en la última muda.]*

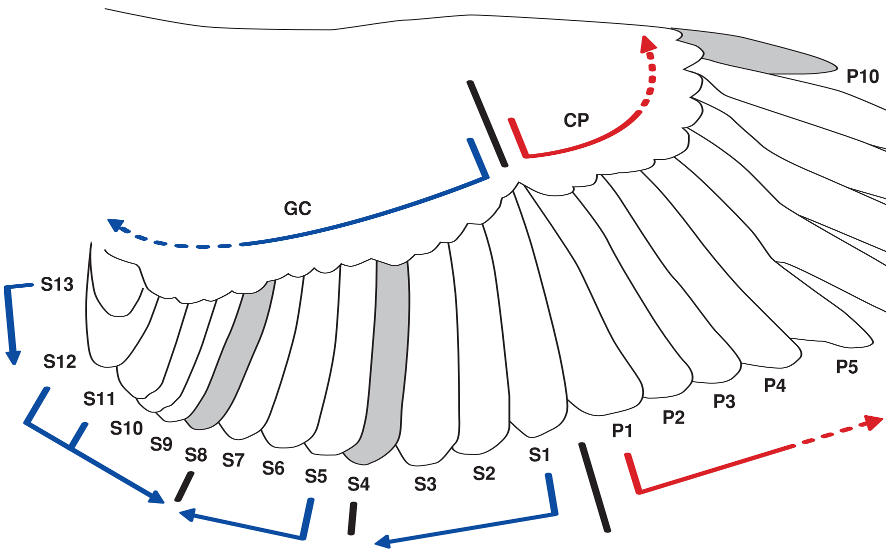

FIG. 1.—Moult sequence in the Eurasian sparrowhawk *Accipiter nissus* in Spain. Arrows show each moulting centre and indicates the progression of the moult-front. Shaded P10, S4 and S8 are the last feathers to be moulted.
[Secuencia de muda del gavilán euroasiático Accipiter nissus *en España. Las flechas indican los centros y la progresión de la muda. Las plumas sombreadas P10, S4 y S8 corresponden a las últimas plumas en ser mudadas.]*

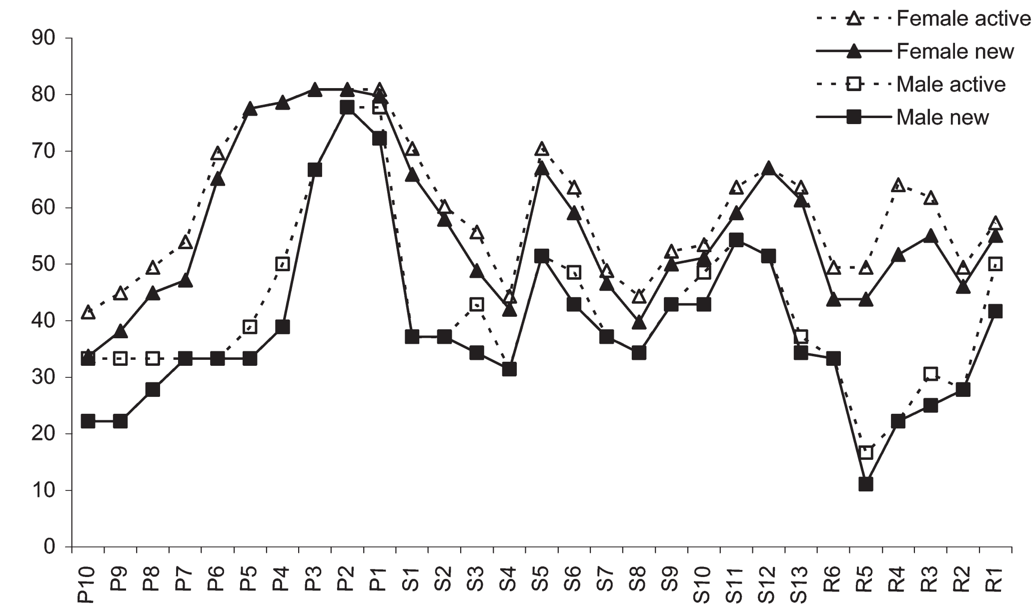

FIG. 2.—Percentage of moulted (bald figures) and active moulting (empty figures) flight-feathers considering 15 male (squares) and 43 female (triangle) sparrowhawks analysed over the study period.
[Porcentaje de plumas de vuelo mudadas (figuras negras) y en muda activa (figuras huecas) de 15 gavilanes macho (cuadrados) y 43 hembras (triángulos) analizados durante el periodo de estudio.]

moulted (fig. 2), although the moult pattern of rectrices varied among individuals and sex.

Duration and timing

There was no evidence of moult in 66 juvenile sparrowhawks analysed between the fledgling season and spring the following year. The moult of body feathers started in June and the first remiges (PP1) were shed later, during the first weeks of June, although a high variability among individuals and between sexes was observed (fig. 3).

Five breeding females trapped during the first 10 days of July had moulted on average 57 % of the primaries whilst four breeding males had moulted 23 %. Afterwards, the moult continued progressively (fig. 3). There were significant differences in the number of moulted feathers between sexes during the breeding period (Man-Withney U test, U = 10.50, $P = 0.050$).

The moult continued until November. P9 and P10 were the last moulted primaries, although in November and even in December, it was possible to find secondaries and rectrices still growing in some birds. In fact, a female examined on 3rd November presented a complete moult but for SS8, which was still growing. The most extreme case was a 2nd calendar year female, on 2nd December, which had just shed the second tail feather.

Arrested moult

During the breeding season, in July, when the chicks are fledgling, 18.75 % of the females (n = 16) and 55.5 % of the males (n = 9) had arrested the moult. Those females which had arrested the moult were raising 4.6 chicks (SD =

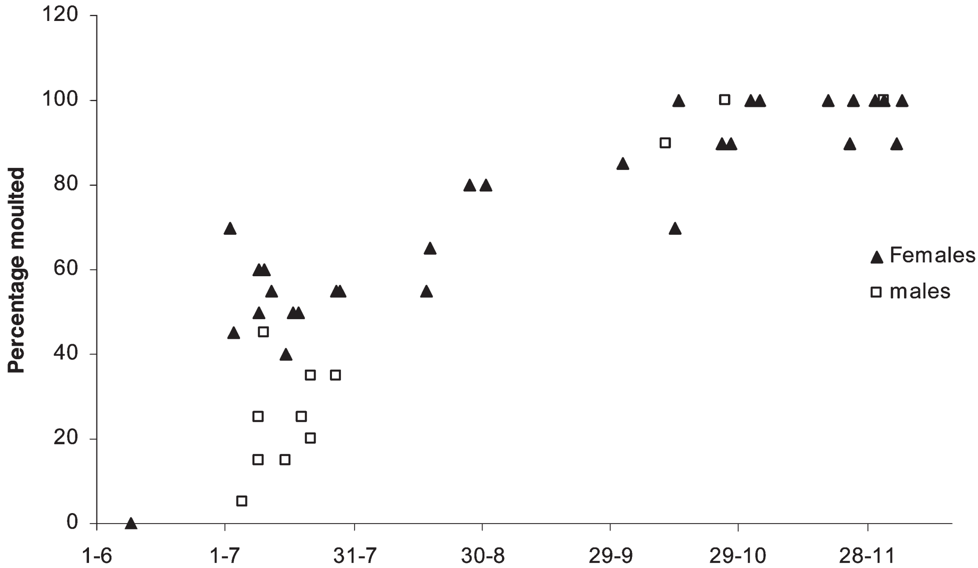

FIG. 3.—Percentage (%) of primaries (considering both wings) moulted in sparrowhawks in relation to date; years and age groups combined. Squares = male, triangles = female.
[Porcentaje de primarias (considerando las dos alas) mudadas en los gavilanes en función de las fechas; se unificaron los años de estudio y los grupos de edad. Cuadrados = machos, triángulos = hembras.]

1.5) on average whereas moulting females were raising 4 chicks (SD = 1.5) on average. There were no statistical differences between these two groups (Man-Withney U test, U = 8.5, $P = 0.43$). Regarding males, those whose moult was arrested were raising on average 3.25 chicks (SD = 1.9) and the only male in active moult whose status was known, was raising 3 chicks.

During winter, among the birds of "unknown status" it was common to find evidence of arrested moult, showing clear signs of wear in the primaries moulted in the previous moult season, and an evident wear separation between groups, those arrested and those moulted in the current year.

Incomplete moult

Considering breeding birds, none of the examined birds (18) had retained flight-feathers from the previous season, whilst considering wintering birds, eight out of 25 females (32 %) and three out of 10 males (30 %) which had already undertaken at least one previous complete moult, presented retained feathers (table 3). The most commonly retained flying feathers were S8, R5 and R4 in females and S4, R5, R4 and R3 in males.

The retention of a few isolated body feathers on the upper wing was usual, however, in both breeding and wintering birds.

DISCUSSION

The moult pattern follows the same established pattern in all the Accipitridae species, however our knowledge and understanding of the different sources of variation (timing of the moult in the annual cycle and the sequence in which feathers are replaced) is still far from complete (Ginn and Melville, 2000). Edelstam (2001) summarized the sequence as a rule, the

TABLE 3

Feathers retained after the moult and percentage (%) of occurrence in eight female and three male sparrowhawks.
[Plumas retenidas tras la muda y la frecuencia de ocurrencia en ocho gavilanes hembra y tres machos.]

	P10	**P4**	**S3**	**S4**	**S6**	**S7**	**S8**	**S9**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**
Females	6.25	6.25		25		37.5	62.5	21.25	12.5	37.5	12.5	43.75	50	12.5
Males			16.7	50	16.7	16.7				33.3	50	50	66.7	

primary moult series, continuing the primaries from the innermost outwards, starts with the fourth primary (p4) in the family Falconidae, but with p1 in all other diurnal raptors and concludes with p10. The moult of secondaries and rectrices is also normally accomplished within the same period, although occasionally an inner secondary may be shed first, and a middle secondary last (one of s4 or s7 - 9, counting inwards).

The moult sequence of sparrowhawks in Spain described here follows the previous description by Newton and Marquiss (1982) for sparrowhawks in Scotland, at least regarding primaries and primary coverts, which goes in order from the innermost (P1) to the outermost (P10). Our results also agree with theirs on the multi-foci of secondaries, although the third focus is displaced to the S11 or 12 instead of S10 and a fourth focus was found in S13. Concerning the tail feathers (rectrices, the moult starts in the central pair, as Newton and Marquiss (1982) found, but afterwards there is high variability among individuals and it is difficult to establish a common pattern. Regarding primary coverts, they are replaced at the same time as their correspondent primaries. Greater Coverts, however, follow the same pattern as with passerine birds (Svensson, 1992).

Sparrowhawks start moulting in June, although we cannot ascertain the precise date because we did not trap adults during the incubation or chick- hatching period (see Zuberogoitia *et al.*, 2008), however a strong variation is expected among individuals in accordance with the stage of their breeding cycle. Newton and Marquiss (1982) estimated that among females, dates of moult strongly correlated with the onset of egg laying: birds which laid clutches late in the season also moulted late. Our results show that there was an evident delay in males with respect to females. Males may delay moult because of the constraints/demands of hunting to provide for nestlings, whereas females are mostly incubating or brooding during the early chick stages (Zuberogoitia *et al.*, 2005). In fact, the high energy demand of feeding chicks and providing food for the females may be the reason why 55.5 % of males arrested the moult, whilst only 18.75 % of females did. However, Newton and Marquiss (1982) obtained just the opposite result, 59 % of the females and 34 % of the males had arrested the moult. The period in which some individuals were found to have stopped moulting coincided with the peak of food demand by nestlings (pre-fledging period). Thus different food availability in the study areas of Spain and Scotland may be the factor explaining such differences in the proportion of birds showing arrested moult. However, breeding success, fitness and the age at which both adults start the breeding period, the richness and abundance of prey species in the territories, weather conditions during the breeding process and other variables must be considered together in order to explain differences between sexes and among individuals (Newton and Marquiss, 1982, Hirons *et al.*, 1984; Petty, 1994; Wiggins *et al.*, 1998; Martínez *et al.*, 2002; Hinsley *et al.*, 2003; Zuberogoitia *et al.*, 2005).

Although sparrowhawks replace all the flight and tail feathers at each moult, in contrast to other *Accipitrid* raptors which follow a wave moult in more than one year (Ginn and Melville, 2000; Clark, 2004), some individuals do not complete the moult in a single year. Newton and Marquiss (1982) occasionally caught individuals which had retained one or two secondary feathers or (less often) tail feathers. In our case, there was a high percentage of uncompleted moults in wintering birds, whilst all the sedentary, breeding birds, had completed the moult. The sedentary birds, therefore, would do a complete moult whilst migrant raptors were seemingly forced to trade-off the moult process versus migration (see Forsman, 1999). Nevertheless, it is known that responses to photoperiod in birds differ with latitude and that more northerly breeders tend to moult faster (Silverin *et al.*, 1993; Hinsley *et al.*, 2003). In accordance with these authors, Zuberogoitia *et al.* (2005) reported that the moult strategies in common buzzards *Buteo buteo* seem appear to differ between regions within Europe, and are likely to depend on factors such as prey availability and migratory status. However, all the sparrowhawks examined during the autumn migration period (September-November) presented active moult. Based on our results, the moult of northern birds would be delayed relative to sedentary (Spanish or Scottish) birds and although they still continue moulting in wintering areas, as late as November, the natural difficulties of winter conditions in a foreign area and after a migratory event would be decisive in the retention of some feathers. This may explain the difference of about two months in the end of the moult between Spanish (November-December) and Scottish (September-October) sparrowhawks. Moreover, we must consider different moulting behaviour with regard to the origin of the migratory and wintering birds, since most (75 %) came from Central Europe, but others came from Northern countries, including Russia (table 1).

The retained feathers, flight-feathers and body feathers located in the upper-wing, allow determination of age in sparrowhawks (table 2). A bird showing a combination of a variable extent of new adult feathers and retained juvenile feathers would be 2nd / 3rd cy, while a bird showing two different generations of adult feathers would be 3rd / 4th cy or older bird. Moreover, observing the moulting sequence, we could hypothetically differentiate between a sparrowhawk from Spain or from a northern country, although it should be tested using ringed birds. Some sedentary birds could suffer diseases or traumatic events which cause weakness and a subsequent delay in the moult process and the retention of some feathers, since moulting is an energetically demanding process (Hemford and Lundberg, 1998). In fact, the only sparrowhawk observed moulting in January presented both P10 growing and eight secondaries and six tail feathers retained. This 3rd cy female was very weak and presented a high level of infection by capilarias.

In conclusion, Spanish sparrowhawks follow approximately the pattern described by Newton and Marquiss (1982) for Scottish sparrowhawks. However, the effect of wintering birds on our sedentary population and obvious differences in food availability, daylight duration, weather and others, provoke some differences with regard to the Scottish model. These data can be used as a tool to determine the age of Spanish sparrowhawks and could be hypothetically used to distinguish wintering birds from local populations. The increasing importance of research projects involving in-depth knowledge of individuals demands guidelines to determine age, gender and possible origin, among others. Moreover, the improvement in knowledge can be used in wildlife rehabilitation centres to manage resources and develop adequate mechanisms for the recovery of sparrowhawks according to their origin.

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