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THE EURASIAN SPARROWHAWK OF MACARONESIA (*ACCIPITER NISUS GRANTI*): NESTING TERRITORIES, PHENOLOGY, AND BREEDING SUCCESS ON MADEIRA ISLAND, PORTUGAL

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Abstract.—The little-known Eurasian Sparrowhawk of Macaronesia (*Accipiter nisus granti*), also named as the Macaronesian sparrowhawk, is endemic to Madeira Island and the Canary Islands (North Atlantic Ocean) and has the smallest area of distribution of the sparrowhawk subspecies. We studied the breeding biology of the Macaronesian sparrowhawk for the first time on Madeira Island, Portugal. Specifically, we described nests, tree nests, nest sites, and nesting territories, and we estimated incubation, hatching and fledging dates. Moreover, we evaluated the influence of altitude on the date of the initiation of breeding and measured the number of fledglings and the factors influencing this parameter. Most nesting territories (88.6%) were located in forest patches where valleys with watercourses were present. Breeding success (73.2% ± 0.1 SE, $n = 18$) and the mean number of young fledged per nest with eggs (2.27 ± 0.04) are lower than the values for the Canary Islands. Altitude influenced the date of the initiation of breeding, with pairs in lowlands (<700 masl) initiating breeding earlier. However, pairs breeding earlier did not have higher reproductive rate than those breeding later. The number of fledglings per nest with eggs in mixed habitats was higher than in exotic and Laurel forests. The main cause of breeding failure was forest cutting. We believe that if the forestry industry does not consider the nesting areas, as well as the breeding phenology of this subspecies, and forest fires are not prevented, then its population in Madeira may be reduced in the near future.

Key Words: *Eurasian Sparrowhawk*; *Macaronesian sparrowhawk*; Accipiter nisus granti; *altitude*; *forestry*; *habitat*; *Laurel forest*; *nest*; *threats.*

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ACCIPITER NISUS GRANTI DE MACARONESIA: TERRITORIOS DE NIDIFICACIÓN, FENOLOGÍA Y ÉXITO REPRODUCTOR EN LA ISLA DE MADEIRA, PORTUGAL

RESUMEN.—La subespecie *Accipiter nisus granti* es endémica de la isla de Madeira y las Islas Canarias (Océano Atlántico Norte), y tiene el área de distribución más pequeña de todas las subespecies de *A. nisus*. Estudiamos la biología reproductiva de esta rapaz por primera vez en Madeira, Portugal. En concreto, describimos los nidos, los árboles donde nidifican, los lugares de nidificación y los territorios de cría, y estimamos las fechas de incubación, de eclosión y de salida de los pollos del nido. Además, evaluamos la influencia de la altitud en la fecha de inicio de la reproducción y examinamos el número de pollos volantones y los factores que influyen en este parámetro. La mayoría de los territorios de cría (88.6%) fueron encontrados en parches de bosque dentro de vaguadas. El éxito reproductor (73.2% ± 0.1 EE, $n=$ 18), así como el número medio de pollos volantones (2.27 ± 0.04) fue inferior a los valores observados en las Islas Canarias. La altitud influyó en la fecha de inicio de la reproducción, iniciando antes la reproducción las parejas nidificantes en territorios situados a altitudes más bajas (<700 m snm). Sin embargo, las parejas que iniciaron antes la reproducción no tuvieron un éxito reproductor mayor que aquellas que lo hicieron más tarde. El número de pollos volantones por nido en hábitats mixtos fue superior al de los que criaron en bosques exóticos y laurisilva. La principal causa del fracaso reproductor fueron las talas forestales. Consideramos que si la gestión de la explotación forestal no tiene en cuenta las áreas de nidificación, así como la fenología reproductiva de esta subespecie, y si no se llevan a cabo medidas eficaces para evitar los incendios forestales, la población de *A. n. granti* podría verse reducida en un futuro próximo.

[Traducción de los autores editada]

The Eurasian Sparrowhawk (*Accipiter nisus*) is a small raptor species closely linked to forest environments (Snow and Perrins 1998). Like many other raptors, it often breeds in the same nesting territories over long periods, and it usually builds a new nest each year near the previous ones (Newton and Marquiss 1982, Newton and Wyllie 1992). Sparrowhawks rarely experience marked year-to-year fluctuations in food supply because they feed on a wide range of small bird species (Zawadzka and Zawadzki 2001, but see Petty et al. 1995).

The Eurasian Sparrowhawk has an extremely large range encompassing most of Europe and Asia. Among its six subspecies, the Macaronesian sparrowhawk (*A. nisus granti*) has the smallest distribution. This endemic subspecies of the Macaronesian region is only found in a few islands of the North Atlantic Ocean, the Canaries (all main islands except Lanzarote and Fuerteventura) and the island of Madeira (del Hoyo et al. 1994, Lorenzo 2007). Short-range endemic taxa, such as the Macaronesian sparrowhawk, are more likely to be threatened by habitat loss, habitat degradation, and climate change, because they are restricted to small patches of suitable habitat in a few insular ecosystems (Harvey 2011, Pellens and Grandcolas 2011).

The Macaronesian sparrowhawk is also one of the least-known subspecies of *A. nisus*. A few studies have been conducted in the Canary Islands (Delgado 1985, Delgado et al. 1987, Rodríguez and Moreno 1995, Trujillo and Barone 1998) and, to our knowledge, no studies have been done on Madeira. In the Canaries, this subspecies is also linked to forest habitats, and prefers the Macaronesian natural forest (Laurel forest) and mixed pinewoods (both the endemic *Pinus canariensis* and the introduced *P. pinaster* used in reforestation; Barone and Atienza 2004). However, it can also breed in forests composed of tree species that are important to the timber industry, such as eucalyptus (*Eucalyptus* spp.) and Monterey cypress (*Cupressus macrocarpa*; Martin 1987). Due to the reduction of Laurel forest by exploitation, wildfires, and the effect of invasive plants, accidentally or intentionally introduced by humans, on indigenous species, the population of the Macaronesian sparrowhawk declined dramatically in some of the Canary Islands (Bannerman 1912, Quilis et al. 1993, Martín and Lorenzo 2001, Barone and Atienza 2004).

On Madeira, other than the Macaronesian sparrowhawk, there are two diurnal raptor species: the Eurasian Kestrel (*Falco tinnunculus canariensis*) and the Common Buzzard (*Buteo buteo harterti*). Although the kestrel and the buzzard are considered common species, the Macaronesian sparrowhawk is rare on this island (Romano et al. 2010) and current population trends are unknown (BirdLife International 2015). The Macaronesian sparrowhawk is listed in Annex I of the Birds Directive, and also in Appendix II of the Bern Convention (EU Birds

Directive 1979). Studies are therefore needed to ascertain its current conservation status in Madeira.

In this study we report the first data on the Macaronesian sparrowhawk breeding population of Madeira Island, collected at three different altitudes over two consecutive breeding periods (2014 and 2015). We tested whether: (1) breeding phenology varied with altitude of nest sites, (2) pairs breeding earlier had greater reproductive rate than those breeding later, and (3) the number of young fledged per nest with eggs was influenced by nest, nest tree, nest site, and territory-level variables.

Methods

Study Area. The island of Madeira (32°44′N, 17°00′W; 737 km^2) is approximately 630 km off the western coast of Morocco. This mountainous island is dominated by a volcanic landscape, with deep valleys, steep slopes, and scarps. The watercourses are enclosed within cliffs which run roughly perpendicular to the coastline. The maximum altitude is achieved at the top of the eastern mountain range (1861 m at Pico Ruivo). Climatic conditions vary across the island, with the northern part being colder and wetter, and the southern part warmer and drier. The highest annual precipitation (2966.5 mm) occurs at the highest altitudes (>1000 masl) and lower rainfall amounts (about 550 mm) in lowland areas (<700 masl). The average annual temperature also depends on altitude, with values of 17°C at the southern coast and 19°C at the northern coast, falling to 9°C in the highlands.

The Laurel forest occupies 20% of the total area of Madeira, mainly on the northern slopes between 300 and 1300 masl in altitude. Several invasive plant species currently threaten the Madeiran Laurel forest, primarily striated broom (*Cytisus striatus*) and dwarf gorse (*Ulex minor*). Species that are harvested (several pine species [mainly *P. pinaster*], eucalyptus, acacia [*Acacia* spp.], and chestnut [*Castanea sativa*]) prevail mainly in the south of the island between 300 and 800 masl. There are no indigenous pine species in Madeira (Vieira 2002). The reforestation of some areas between 700 and 1200 masl also included species such as Douglas-fir (*Pseudotsuga menziesii*), oak (*Quercus* spp.), and Japanese cedar (*Cryptomeria japonica*). Above 1400 masl, the forest was severely damaged by overgrazing and fire and only a few small woodlots still stand (Capelo et al. 2004).

Monitoring Nests of Macaronesian Sparrowhawk. This subspecies begins mating in February, with egg-laying occurring in April. Young hatch in May, and juveniles eventually leave the nest in July (Delgado et al. 1987). We carried out fieldwork during two successive breeding seasons in 2014 and 2015. In 2014, we surveyed preliminary transects around the island between 24 May and 28 August, using accessible paths and "*levadas*" (walking trails that follow the network of water channels) to search for sparrowhawk nests. However, we detected all nests when the chicks were near fledging age (July and August). During transect surveys, we recorded all Macaronesian sparrowhawks observed and their behavior; we also searched for droppings, plucked prey, and molted feathers as signs of sparrowhawk presence. Breeding females start molting while incubating, so molted primary and secondary feathers can be found near the nest tree (Newton and Marquiss 1982).

In 2015, we conducted 84 1-hr observations with scope and binoculars at high visibility points near forest patches, from 15 February to 31 March (mating and nest-building phases). For some patches, we observed at more than one point in order to cover the whole forest patch area. From the point, we observed courtship flights and then recorded the direction where the pair entered the forest, so that we could later search for their nest. In addition, we performed transect walks to search for nests and other signs of sparrowhawk presence from 1 April to 31 August (incubation, nestling, and fledgling phases). Specifically, we first visited forest patches where courtship flight had been observed in the mating phase; second, we visited forest patches with signs of presence from the 2014 breeding season, and finally, we visited the remaining forest patches around the island. We searched each forest patch from 1–6 d (8hr/d) until the nest was found. We classified nests as either "in use" or old. From the ground, we classified nests as in use if they had freshly broken twigs or flecks of white excreta (during incubation). We classified nests as old if they contained fallen leaves and spider webs (Newton 1976).

During the 2015 breeding season, all nests in use found prior to egg-laying were visited every 4 d in the incubation, hatching, and fledging periods, in order to estimate the incubation, hatching, and fledging dates of each nest, and number of fledglings. We observed nests from the ground using binoculars and a spotting scope, but did not climb to them.

Variables Measured at Nests, Nest Trees, Nest Sites, and Nesting Territories. For each nest, we measured height aboveground using scaled photographs, and determined nest orientation with respect to the trunk and the orientation of access to the nest used by the birds. We classified the position of the nest in the tree as either near the trunk or on a side branch.

We defined nest tree as the tree in which the nest was placed. We classified the altitude of each nest tree as one of three categories: <700 masl, 700–1000 masl and >1000 masl and measured the distance to the nearest accessible trail or path using a GPS. We also recorded tree species, tree height, and diameter at breast height (dbh); the radius of the top of the tree was measured using scaled photographs.

We defined a nest site as the area within a 10-m radius around each nest tree. Due to the complex and steep topography of Madeira Island, this plot size was the largest accessible area for which nest-site variables could be accurately measured. Within each nest site, we classified the interior watershed (northern or southern). Moreover, we measured slope and assessed the proportion of ground vegetation cover and canopy closure.

We grouped all nests (in use and old) within the same forest patch into the same nesting territory. We identified all dominant tree species, and classified each nesting territory as one of three types of habitat: Laurel, mixed (indigenous and introduced tree species), or exotic forest. We recorded the presence or absence of valleys with watercourses, as well as the presence or absence of open areas (Patrimonio 1984). We also recorded whether the forest patch was in a regeneration process or not, and the causes of this (fire, lumber harvesting, etc.).

Statistical Analyses. We examined the relationship between breeding phenology and altitude of the nest sites using a Pearson's correlation. For this analysis, we used hatching dates because during the visits we could visually confirm the age of the young, whereas the egg-laying dates had to be estimated for some nests. We tested for normality of data using a Shapiro-Wilk test.

We defined breeding success as the percentage of young fledged per egg-laying pair, and reproductive rate as the number of young fledged per egg-laying pair. To evaluate whether pairs breeding earlier had greater reproductive rate than those breeding later, we compared the number of fledglings per nest with eggs with hatching dates using one-way ANOVA. We used the difference (in d) between the mean hatching date and the hatching date of each pair as a categorical variable and transformed the values using natural log. We used chi-square tests to analyze whether the number of fledglings per nest with eggs varied with nest orientation and position, watershed of the nest site, dominant habitat of the nesting territories, and between territories in regeneration or not. We used one-way ANOVAs to test whether the number of fledglings per nest with eggs was influenced by nest height, distance to path, height of nest tree, tree diameter, tree top radius, the slope, vegetation cover, canopy closure of the nest sites, and the number of dominant tree species of nesting territories and the number of territories in regeneration.

RESULTS

Nests, Phenology, and Reproductive Rates of Macaronesian Sparrowhawks. We found 54 different nests on 35 nesting territories between 4–22 August 2014 and from 31 March to 29 August 2015 (Fig. 1; Table 1); 25 of those nests were in use and 29 were classified as old nests. Within the same territory, the average distance between nests (in use and old) was 129.84 m (±26.8 SE, range = 12–230 m) and the mean number of nests was 1.74 (±0.2, 1–7). One nest tree contained two old nests; all others had only one nest. Considering the nest in use as the center of the nesting territory and measuring the distance between nests, we found that the average distance between nests/nesting territories was 4764 m (±238 m, 782–7534 m). In six of the nine nesting territories found in 2014, we confirmed sparrowhawk presence in 2015. In five of these territories, the birds built a new nest near the previous one; in one territory, the breeding pair reused the same nest.

Table 1. Number of nesting territories, nests in use, and old nests found on Madeira Island from 2014 to 2015.

YEAR	NESTING TERRITORIES	NESTS IN USE	OLD NESTS	TOTAL NESTS
2014	9	6	4	10
2015	26[a]	20[a]	25	45[b]
Total	**35**	25	29	**54**

[a] The number of territories in 2015 does not include the territories found in 2014.
[b] One of the nests in use in 2014 was also used in 2015.

The earliest dates of incubation (7 May; mean = 19 May ±1.5 SE; range = 7 May–13 June), hatching (14 June; 27 June ±1.4; 14 June–22 July), and fledging (16 July; 29 July ±1.6; 16 July–25 August) occurred at a lowland nest (234 masl). The latest dates were observed at an upland nest (1538 masl) more than 1 mo later.

Mean breeding success of the Macaronesian sparrowhawk in 2015 was 73.2% ±0.1 SE ($n = 18$). Of five recorded nest failures, four (22.2%) failed due to forest exploitation, by direct cutting or subsequent collapse of the nest due to direct exposure to the wind. At the remaining nest, the cause of failure was unknown. The mean number of fledglings/nest with eggs was 2.27 (± 0.04, 0–3). In 2014, a dead nestling found headless under its nest had an incisor-mark on its right wing. There are two potential predators of Macaronesian sparrowhawk on Madeira, cats (*Felis silvestris catus*) and rats (*Rattus rattus*), and the incisor-mark found on this particular nestling matched the incisor size of cats. Moreover, in three different nests, we recorded one dead nestling each, but the causes of death were unknown.

Variables Measured at Nests, Nest Trees, Nest Sites and Territories. Nest heights ranged from 4.5–17 m (Table 2). The most frequent position of the nest was on a side branch of the tree. Macaronesian sparrowhawks nested in 11 tree species (Table 3). Although all nests were located <165 m from the nearest accessible path, the number of fledglings/nest with eggs was not influenced by the distance from nest tree to path ($F = 0.250$, $df = 14$, $P = 0.935$). The number of fledglings/nest with eggs was higher for nest sites on the northern side than on the southern side of the island ($\chi^2 = 5.000$, $df = 1$, $P = 0.025$; $n =$ five nests on the northern side and $n = 15$ on the southern). Most territories (88.6%) were located in forest patches where valleys with watercourses were present, and all of them were in close proximity (average 25 m) to open areas. At eleven of the 35 nesting territories (31.4%), the forest was in regeneration, mainly due to fires.

Altitude of the nest tree was positively associated with hatching dates (Fig. 2): Macaronesian sparrow-

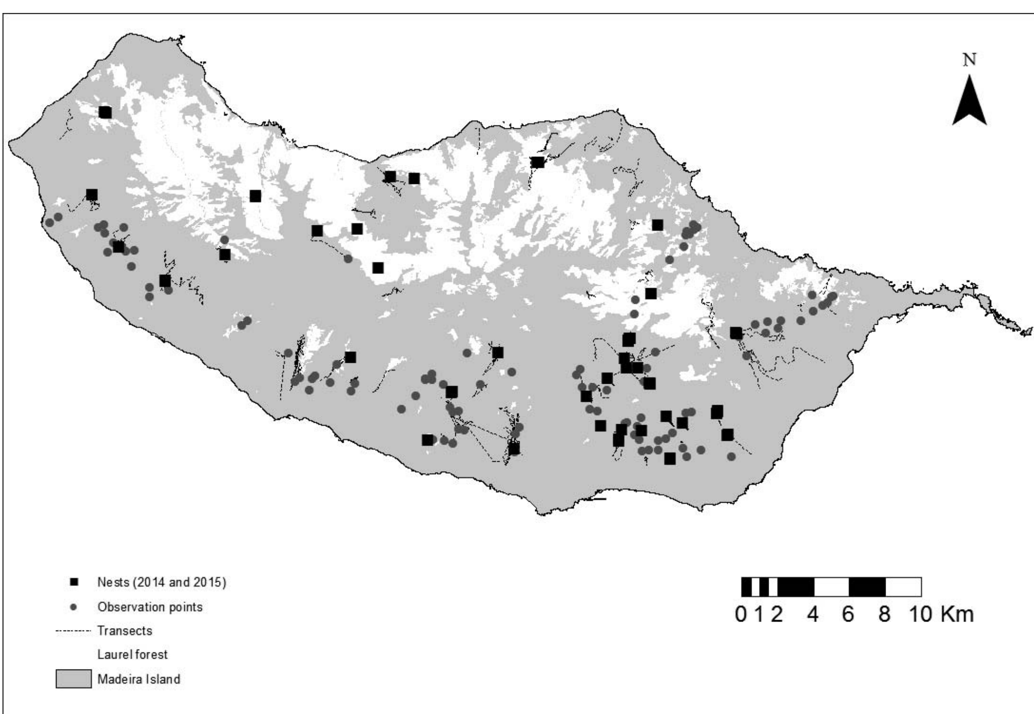

Figure 1. Spatial distribution of the Macaronesian sparrowhawk nests found on Madeira Island from 2014 to 2015.

Table 2. Mean values (SE and ranges) of environmental characteristics of Macaronesian sparrowhawk nesting territories at three different altitudes monitored on Madeira Island from 2014 to 2015. Nest orientation and access orientation are the most common cardinal directions.

VARIABLE TYPE	VARIABLE	LOWLANDS (<700 masl)	MIDLANDS (700–1000 masl)	UPLANDS (>1000 masl)
Nest level	*n* nests	19	17[a]	17
	Nest height (m)	7.7 (±0.5, 5–11)	10.3 (±0.6, 5–16)	12.6 (±0.8, 4.5–17)
	Nest orientation	S	N	SW
	Access orientation	SE	NW	W
	Position (*n* trunk/*n* side branch)	4/15	4/13	7/10
Nest-tree level	Distance to path (m)	47.6 (±15.7, 0–164)	11.6 (±3.4, 0–47)	28.9 (±4.1, 7–50)
	Height of nest tree (m)	10.5 (±0.7, 8–16)	13.2 (±0.6, 9–18)	17.1 (±1.2, 5.5–23)
	Tree diameter dbh (cm)	193.8 (±80.6, 114.5–296.5)	173.8 (±91.7, 100.2–239.8)	207.9 (±97.3, 179.7–253.3)
	Tree top radius (m)	3.2 (±0.6, 0.5–5.5)	3.0 (±0.3, 1.5–6.0)	2.8 (±0.2, 0.5–4.0)
Nest-site level	Watershed (*n* north/*n* southern)	5/14	6/11	9/8
	Slope (°)	54.2 (±5.2, 30–80)	66.8 (±3.6, 5–60)	73.2 (±3.3, 5–40)
	Vegetation cover (%)	56.7 (±6.9, 10–100)	42.5 (±6.9, 10–80)	29.4 (±6.2, 05–70)
	Canopy closure (%)	65.3 (±4.4, 25–85)	83.0 (±3.2, 50–95)	85.0 (±2.2, 60–95)
Nesting-territory level	*n* nesting territories	13	12	10
	n dominant tree species	3.3 (±0.2, 2–6)	3.5 (±0.3, 2–5)	2.0 (±0.3, 1–5)
	Dominant habitat	Mixed	Mixed	Exotic
	n in valleys	12	10	9
	n with open areas	13	12	10
	n territories in regeneration	6	4	1

[a] For one nest found between 700 and 1000 m of altitude and with evidence of occupation, we could not measure physical variables because it was found on the ground.

Table 3. The number and percentage of tree species used for nesting by the Macaronesian sparrowhawk, and the territories where these tree species were found, on Madeira Island from 2014 to 2015.

TREE SPECIES	*n* NEST TREE	% NEST TREE	*n* TERRITORIES	% TERRITORIES
Pinaceae	21	38.9%	10	31.3%
Pseudotsuga menziesii[b]	**15**	27.8%	**6**	18.8%
Pinus sp.	6	11.1%	4	12.5%
Myricaceae (*Morella faya*[a])	**8**	14.8%	**5**	15.6%
Lauraceae (*Laurus novocanariensis*[a])	6	11.1%	4	12.5%
Fabaceae (*Acacia sp.*[b])	4	7.4%	2	6.3%
Fagaceae	7	13.0%	5	15.7%
Quercus robur[b]	4	7.4%	2	6.3%
Quercus ilex[b]	2	3.7%	2	6.3%
Castanea sativa[b]	1	1.9%	1	3.1%
Cupressaceae (*Cupressus sp.*)	3	5.6%	2	6.3%
Pittosporaceae (*Pittosporum sp.*[b])	3	5.6%	2	6.3%
Salicaceae (*Salix canariensis*[a b])	2	3.7%	2	6.3%

[a] Native species of Madeira Island.
[b] Species previously undocumented as a nest tree for the Macaronesian sparrowhawk.

hawk pairs breeding in lowland nest trees initiated breeding earlier than those in upland nest trees ($r=0.977$, $P<0.0001$). However, pairs breeding earlier did not have higher reproductive rates than those breeding later ($F=0.186$, $df=2$, $P=0.832$). Mixed forests were the dominant habitat of nesting territories, except in upland territories where exotic forest was prevalent. The number of fledglings/nest with eggs was higher in mixed habitats compared to exotic or Laurel forest ($\chi^2=7.929$, $df=4$, $P=0.040$). None of the remaining variables influenced the number of fledglings/nest with eggs: nest-level variables (nest height $F=0.511$, $df=9$, $P=0.832$; nest orientation $\chi^2=3.333$, $df=7$, $P=0.853$; access orientation $\chi^2=4.222$, $df=7$, $P=0.754$; position $\chi^2=3.556$, $df=1$, $P=0.059$); nest tree-level variables (height of nest tree $F=0.634$, $df=11$, $P=0.755$; tree diameter $F=0.390$, $df=9$, $P=0.905$; tree-top radius $F=2.996$, $df=7$, $P=$

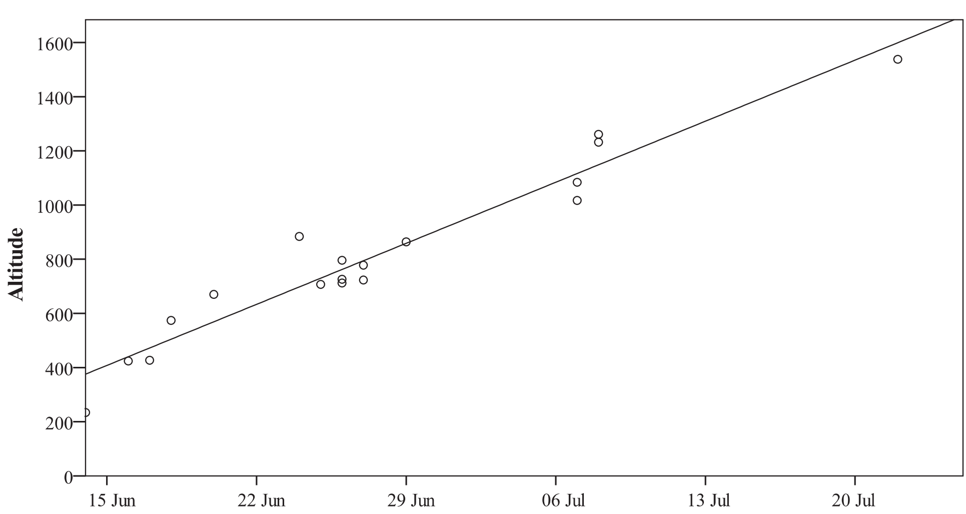

Figure 2. Correlation between altitude (m) of the nest trees and the hatching dates of Macaronesian sparrowhawks for 2015 on Madeira Island ($r=0.977$, $P<0.000$).

0.064); nest-site-level variables (slope $F = 0.560$, $df = 7$, $P = 0.774$; vegetation cover $F = 0.876$, $df = 10$, $P = 0.586$; canopy closure $F = 1.582$, $df = 6$, $P = 0.235$); nesting territory-level variables (number of dominant tree species $F = 0.620$, $df = 4$, $P = 0.656$; territories in regeneration $\chi^2 = 0.059$, $df = 1$, $P = 0.808$).

DISCUSSION

Reproductive Ecology of the Macaronesian Sparrowhawk. Macaronesian sparrowhawk nests were distributed around the entire island of Madeira (Fig. 1). In this study we identified two nesting territory-level variables that seem to be important in the breeding habitat of this subspecies, and these variables were also identified for *A. nisus wolterstorffi* on Corsica Island (Patrimonio 1984). All nesting territories were near open areas; these were mainly agricultural lands (abandoned or in use), and probably used as hunting areas as sparrowhawks hunt over a wider area than the forest patch containing the nest (Newton et al. 1977). Moreover, most of the territories were in deep valleys where watercourses are numerous. A few territories were found in tiny forest patches (less than 40 m^2), although canopy cover inside these patches was dense; this finding coincided with that observed for *A. nisus wolterstorffi* on Corsica (Patrimonio 1984).

Distances between old nests within a nesting territory in our study area (130 ±27 SE, range = 12–230 m) were shorter than those observed in Britain and Corsica (50–400 m, Newton et al. 1977; >400 m, Patrimonio 1984). This was probably because forest patches on Madeira are frequently interrupted by open meadows and rock ledges. We found fewer old nests per nesting territory (1.74 ±0.2, range = 1–7), compared to those in Britain (15 nests, Newton et al. 1977) and Tenerife (52 nests in 17 nesting territories; Delgado et al. 1987). In the Canaries, the Macaronesian sparrowhawk also shows high fidelity to its nesting territory, and usually builds a new nest each year close to the previous one (Barone and Atienza 2004). The small number of old nests found in the present study on Madeira may indicate that some nesting territories were not consistently occupied for many years, although it is also possible we missed some old nests located farther from the nest in use, due to the steep terrain. On Madeira, the destruction of forest patches by fires and the timber industry may be an important factor in influencing changes in nest site, but other factors such as adverse climatic conditions could also be significant (Martínez et al. 2013). Accurate indices of fidelity to nesting territories would help us understand temporal variation in occupancy.

The two closest nesting territories were 782 m apart; these were located in the same valley, but in different forest patches in the lowlands (<700 masl). However, we did not find a consistent pattern of increasing distance between nesting territories with higher altitude, as reported by Newton et al. (1986).

We found the same number of nesting territories in exotic and Laurel forest (25.7%), and nearly twice as many in mixed habitat (48.6%), composed of indigenous species of the Laurel forest and introduced species (mainly acacia and eucalyptus). In the Canaries, Macaronesian sparrowhawk nests are abundant in Laurel forest, and we believe that more nesting territories than we found in this study should exist in this habitat. However, due to the complex topography of Madeira and the inaccessibility of the Laurel forest, additional research effort is needed.

Nest heights of the Macaronesian sparrowhawk on Madeira (4.5–17 m) were similar to those on Tenerife (5–16 m, $n = 13$ nests; Delgado et al. 1987). Seven of the eleven tree species used for nesting on Madeira (Table 3) are newly reported for this subspecies, whereas the remaining species were reported previously in the Canaries (Delgado 1985, Delgado et al. 1987, Martín and Lorenzo 2001). The three most frequently used tree species were Douglas-fir (very common in exotic habitats), followed by two indigenous species: firetree (*Morella faya*) and laurel (*Laurus novocanariensis*), which are found in the Laurel forest and also in mixed habitats. Although some nests were found in *Pinus* spp., pines do not seem as important in Madeira as in the Canaries (Martín and Lorenzo 2001). This finding may be explained by the decrease of pine populations due to the pinewood nematode (*Bursaphelenchus xylophilus*) introduced on Madeira (Fonseca et al. 2012). Macaronesian sparrowhawks probably adapted to using the large pine plantations for nesting, as they do in the Canaries. However, the lack of previous knowledge on the historical breeding habitat of the Macaronesian sparrowhawk does not allow evaluation of the ecological consequences of the decreasing pine forest on Madeira.

Which Factors Influence Breeding Success and Phenology? The breeding success of the Macaronesian sparrowhawk in Madeira (73.2%) was lower than the value found in the Canaries (81.2%; Delgado et al. 1987). The mean number of fledglings per egg-laying pair (2.3) was also lower than that found in Tenerife (mean = three young, *n* = 15 nests; Delgado et al. 1987). For long-lived raptor species, such as the Macaronesian sparrowhawk, an increase in reproductive success could benefit its population. Because the population of Madeira Island is small (Romano et al. 2010), conservation efforts should be focused on protecting extant nesting territories and improving reproductive rate.

The influence of altitude on breeding phenology was first reported here for this subspecies, although this pattern has been observed in *A. melanoleucus* of Africa (Sebele 2012) and is not unexpected. Although birds aim to breed when environmental conditions favor breeding success (Newton 1979), ideal breeding conditions in Madeira seem to occur at different times according to altitude. The influence of this factor on breeding phenology may be related to an increase of rainfall and decrease in temperature with altitude. Moreover, the Macaronesian sparrowhawk, in order to successfully breed, may have to shift the timing of breeding to match reproduction with peak food availability, which likely also varies with altitude (Wright et al. 2009). Future studies on the variables influencing breeding phenology are needed to evaluate other potential factors, such as breeders' experience and mate choice (see Newton and Marquiss 1982), and to consider their overall effect.

Threats Potentially Limiting the Population of Macaronesian Sparrowhawk on Madeira. Our study revealed that the principal cause of breeding failure of Macaronesian sparrowhawk was forest cutting. Currently, forest exploitation is one of the most important economic activities on the island; however, this activity seems to be destroying recent breeding areas of the Macaronesian sparrowhawk. We found evidence of the effect of the forestry industry on Macaronesian sparrowhawk breeding success. To avoid a population decline of this short-range subspecies, forest management practices should consider species' requirements by: (1) determining the location of nests before harvesting; (2) conserving a minimum number of suitable nesting and hunting areas in regions subject to major logging; (3) postponing logging during the breeding season; and (4) purchasing mature plots of suitable nesting habitat for the species.

We found 31.4% of nesting territories in forest patches that had been burned. In recent years (especially 2010 and 2012), fires had devastating effects on Madeira Island, and they have been responsible for the destruction of many hectares of forest (Fontinha et al. 2014). In some forest patches, fires have created a heterogeneous mosaic of areas with varying degrees of damage, and areas with unburnt trees that were occupied by the Macaronesian sparrowhawk as nest sites. Once an area has been destroyed by fire, it loses potential not only as a nesting site, but also as a hunting site, and it takes many years for the habitat to recover (Haslem et al. 2011). The restoration of burned areas on Madeira is urgently needed to prevent soil erosion, expansion of invasive species, and loss of indigenous species (Fontinha et al. 2014). Fires have also devastated large forest areas used by the Macaronesian sparrowhawk on some of the Canary Islands (Barone and Atienza 2004). Therefore, accurate knowledge about the Macaronesian sparrowhawk's response to fire is needed in order to meet the goals of the Birds Directive for this short-range taxa.

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Literature Cited

Bannerman, D.A. 1912. The birds of Gran Canaria. *Ibis* 9:557–627.

Barone, R. and J.C. Atienza. 2004. Busardo Ratonero *Buteo buteo insularum.* Pages 143–145 *in* A. Madroño, C. González and J. Atienza [Eds.], Libro Rojo de las aves de España. Dirección General de Conservación de la Naturaleza-SEO/BirdLife, Madrid, Spain.

BirdLife International. 2015. European Red List of Birds. Office for Official Publications of the European Communities, Luxembourg.

Capelo, J., M. Menezes de Sequeira, R. Jardim, and J. Costa. 2004. Guia da excursão geobotânica dos V Encontros ALFA 2004 à ilha da Madeira. *Quercetea* 6:5–45.

DEL HOYO, J., A. ELLIOTT, AND J. SARGATAL. 1994. Handbook of the birds of the world. Vol. 2. New world vultures to guineafowl. Lynx Edicions, Barcelona, Spain.

DELGADO, G. 1985. Presencia y nidificación del gavilán (*Accipiter nisus granti* Sharpe, 1890) en la isla de El Hierro. *Doñana, Acta Vertebrata* 12:172–173.

———— AND A. MARTÍN, K. EEMMERSON, AND V. QUILIS. 1987. Biologie de la reproduction de l'épervier (*Accipiter nisus*) à Ténérife (Iles Canaries). *Alauda* 55:116–121.

EU BIRDS DIRECTIVE. 1979. Council Directive of 2 April 1979 on the conservation of wild birds (79/409/EEC). Official Journal of the European Communities No. L103.

FONSECA, L., J. CARDOSO, A. LOPES, M. PESTANA, F. ABREU, N. NUNES, M. MOTA, AND I. ABRANTES. 2012. The pinewood nematode, *Bursaphelenchus xylophilus*, in Madeira Island. *Helminthologia* 49:96–103.

FONTINHA, S., D. HENRIQUES, H. NÓBREGA, D. TEIXEIRA, A. FERRO, AND M.A. DE CARVALHO. 2014. Vegetation recovery after a large forest fire in the Ecological Park of Funchal (Madeira Island, Portugal). *Silva Lusitana* 22:207–229.

HARVEY, M.S., M.G. RIX, V.W. FRAMENAU, Z.R. HAMILTON, M.S. JOHNSON, R.J. TEALE, G. HUMPHREYS, AND W.F. HUMPHREYS. 2011. Protecting the innocent: studying short–range endemic taxa enhances conservation outcomes. *Invertebrate Systematics* 25:1–10.

HASLEM, A., L.T. KELLY, D.G. NIMMO, S.J. WATSON, S.A. KENNY, R.S. TAYLOR, S.C. AVITABILE, K.E. CALLISTER, L.M. SPENCE-BAILEY, M.F. CLARKE, AND A.F. BENNETT. 2011. Habitat or fuel? Implications of long-term, post-fire dynamics for the development of key resources for fauna and fire. *Journal of Applied Ecology* 48:247–256.

LORENZO, J.A. 2007. Atlas de las aves nidificantes en el archipiélago canario: 1997–2003. Dirección General para la Conservación de la Naturaleza y SEO/BirdLife, Madrid, Spain.

MARTÍN, A. AND J.A. LORENZO. 2001. Aves del Archipiélago Canario. Francisco Lemus, La Laguna, Santa Cruz de Tenerife, Spain.

MARTÍNEZ, J.E., M.V. JIMÉNEZ-FRANCO, I. ZUBEROGOITIA, M. LEÓN-ORTEGA, AND J.F. CALVO. 2013. Assessing the short-term effects of an extreme storm on Mediterranean forest raptors. *Acta Oecologica* 48:47–53.

NEWTON, I. 1976. Breeding of sparrowhawks (*Accipiter nisus*) in different environments. *Journal of Animal Ecology* 45: 831–849.

————. 1979. Population ecology of raptors. T. and A.D. Poyser Ltd., Calton, Hertfordshire, U.K.

———— AND M. MARQUISS. 1982. Fidelity to breeding area and mate in sparrowhawks *Accipiter nisus*. *Journal of Animal Ecology* 51:327–341.

————, ————, D. WEIR, AND D. MOSS. 1977. Spacing of sparrowhawk nesting territories. *Journal of Animal Ecology* 46:425–441.

———— AND I. WYLLIE. 1992. Fidelity to nesting territory among European Sparrowhawks in three areas. *Journal of Raptor Research* 26:108–114.

————, ————, AND R. MEARNS. 1986. Spacing of sparrowhawks in relation to food supply. *Journal of Animal Ecology* 55:361–370.

PATRIMONIO, O. 1984. La reproduction de l'épervier (*Accipiter nisus*) en Corse: comparaison avec des régions continentales. *Faculté des Sciences et Techniques du Languedoc,* Université de Montpellier, Montpellier, France.

PELLENS, R. AND P. GRANDCOLAS. 2011. Conservation and management of the biodiversity in a hotspot characterized by short range endemism and rarity: the challenge of New Caledonia. *Environmental Research Journal* 5:563–575.

PETTY, S.J., I.J. PATTERSON, D.I.K. ANDERSON, B. LITTLE, AND M. DAVISON. 1995. Numbers, breeding performance and diet of the sparrowhawk *Accipiter nisus* and Merlin *Falco columbarius* in relation to cone crops and coniferous seed-eating finches. *Forest Ecology and Management* 79:133–146.

QUILIS, V., G. DELGADO, J. CARRILLO, M. NOGALES, AND O. TRUJILLO. 1993. Status y distribución del ratonero común (*Buteo buteo* L.) y el gavilán (*Accipiter nisus* L.) en las Islas Canarias. *Vieraea* 22:89–96.

RODRÍGUEZ, G. AND M. MORENO. 1995. Nidificación del Gavilán (*Accipiter nisus granti* Sharpe 1890) en la isla de Gran Canaria (Aves: Accipitridae). *Vieraea* 24:193–194.

ROMANO, H., C. CORREIA-FAGUNDES, F.J. ZINO, AND M.BISCOITO. 2010. Birds of the archipelagos of Madeira and the Selvagens II. New records and checklist update (1995–2010). *Boletim do Museu Municipal do Funchal* 60:5–44.

SEBELE, L. 2012. Factors influencing the timing of breeding in a range expanding raptor at two spatial scales. M.S. thesis. Percy FitzPatrick Institute of African Ornithology, University of Cape Town, Rondebosch, Africa.

SNOW, D. AND C. PERRINS. 1998. The birds of the western Palearctic. Vol. 2. Passerines. Oxford, U.K.

TRUJILLO, D. AND R. BARONE. 1998. Nidification de l'epervier d'Europe *Accipiter nisus* dans des cultures d'avocats (îles Canaries). *Alauda* 66:69.

VIEIRA, R.M.S. 2002. Flora da Madeira: plantas vasculares naturalizadas no arquipélago da Madeira. Suplemento No. 8. Museu Municipal do Funchal, História Natural, Departamento de Ciência da Câmara Municipal do Funchal Funchal, Madeira, Portugal.

WRIGHT, L.J., R.A. HOBLYN, R.E. GREEN, C.G. BOWDEN, J.W. MALLORD, W.J. SUTHERLAND, AND P.M. DOLMAN. 2009. Importance of climatic and environmental change in the demography of a multi-brooded passerine, the woodlark *Lullula arborea*. *Journal of Animal Ecology* 78:1191–1202.

ZAWADZKA, D. AND J. ZAWADZKI. 2001. Breeding populations and diets of the Sparrowhawk *Accipiter nisus* and the Hobby *Falco subbuteo* in the Wigry National Park (NE Poland). *Acta Ornithologica* 36:25–31.

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