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Botanical composition and structure of hummingbird nests in different habitats from northwestern Patagonia (Argentina)

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Abstract

There are few detailed analyses of the building materials used in bird nests. This study was part of a project on interrelations between northern Patagonian plants and birds. Nests of two hummingbird species distributed in the Andean portion of southern South America: the Green-backed Firecrown *Sephanoides sephanioides* and the White-sided Hillstar *Oreotrochilus leucopleurus*, were collected along a precipitation gradient in northwestern Patagonia (Argentina). Nest morphology, structure, and composition (mostly botanical in origin) were analysed. Plants used as building materials are presented for each nest, arranged by location. The main structural materials were mosses (especially those with falcate leaves) entangled with spider web. Nests were concealed in their environments by the presence of mimetic material on the outer layer (spider cocoons, leprose lichens, feathers, and hairs). Soft material was the main component of the lining (pappi, feathers, spider web, and manufactured cotton). The variety of nesting materials decreased along the precipitation gradient, while the main structural components are generally fixed.

Keywords: *Botanical composition, hummingbirds, mosses, nests, structure*

Introduction

The Neotropical family Trochilidae (hummingbirds) includes a variety of small nectarivorous birds (Schuchmann 1999). Two hummingbird species inhabit the temperate forests region of southern Argentina and Chile, namely the Green-backed Firecrown *Sephanoides sephanioides* (Lesson and Garnot, 1827) and the White-sided Hillstar *Oreotrochilus leucopleurus* (Gould, 1847). Although their ranges partially overlap, they are generally found in different habitats. The Green-backed Firecrown is by far the commonest hummingbird in forested areas and it has the more southerly distribution (Canevari et al. 1991; Couvé and Vidal 2003), ranging from the northern limit of the temperate *Nothofagus* forests to the more southerly areas of South America in Tierra del Fuego. During winter, some populations migrate northerly, reaching Atacama in Chile, and Córdoba and Buenos

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Aires Provinces in Argentina. The White-sided Hillstar, in contrast, is a mountain species. It is the commonest “puna” hummingbird (Johnson 1967), ranging from southern Bolivia to central Chile and Santa Cruz in Argentina (Mazar Barnett 2001). In Argentina, it is common in the northern Patagonian Andes, where it is mostly found between 1200 and 2000 m above sea level (Couvé and Vidal 2003).

Both species show some similarities in nesting habits. They both construct small cup nests, reported in the literature to be made from mosses, lichens, and other soft plant materials (Márquez 2001; Bodrati et al. 2003). They choose, however, different nesting sites (Goodall et al. 1946). Firecrown nests are usually suspended from slender twigs or fern fronds, while Hillstars nest on vertical rock faces, gluing the nest firmly to the rock with a sticky substance said to be obtained from flower nectar, a salivary secretion, or even egg white. These nest descriptions are general, and in the available literature there are no detailed reports on their composition or functional architecture, as is the case for most Neotropical bird species. As far as is known, the only published report for Argentina focusing on plant species composition of nests relates to birds from northeastern areas of the country (Chatellenaz and Ferraro 2000).

Bird nest architecture is generally considered to be species-specific (Hansell 2000). Each type of material used in the nest of a given species has a definite function according to the physical properties of the material (Collias and Collias 1984), and may vary according to nesting site or individual preferences (Hansell 2000). The aim of the present study was to document the building materials and functional architecture of hummingbird nests from Andean Patagonia, and to investigate probable differences in relation to the nesting sites.

Study area

Field observations and nest collections were carried out in northwestern Patagonia (Argentina), between 40°09'–42°23'S and 71°03'–71°49'W (Figure 1). The main orographic system in the area is the Andes mountain range, which stretches north to south. The highest local altitude is 3554 m (Cerro Tronador), and there are numerous glacial lakes in the area, orientated mainly west to east. The Andes mountain range is one of the most important factors influencing the climate in the area, since it produces a precipitation gradient from west to east, which in turn determines the vegetation gradient that decreases in diversity from west to east as the forests are substituted by the arid Patagonian steppe. The mean annual precipitation is ca 3000 mm (maximum 4000 mm) in the most westerly collection sites and 700 mm in the most easterly sites (Barros et al. 1983), with precipitations occurring mainly during winter. The mean annual temperature is ca 8°C and there are frequent, persistent winds from the west (Muñoz and Garay 1985). Phytogeographically, the most westerly area belongs to the Antarctic Region, Subantarctic Dominion, including all forests dominated by *Nothofagus dombeyi* (Valdivian District) (Cabrera 1976). One of the two most easterly collection sites is located in a transition forest dominated by *Austrocedrus chilensis* and considered as part of the Deciduous Forest District, while the other is in a grass steppe area belonging to the Neotropical Region, Patagonian Andes Dominion, Patagonian Province.

Collection sites

To analyse possible differences in nest composition due to environmental variables, collection sites were selected along the precipitation gradient (3000–700 mm year⁻¹).

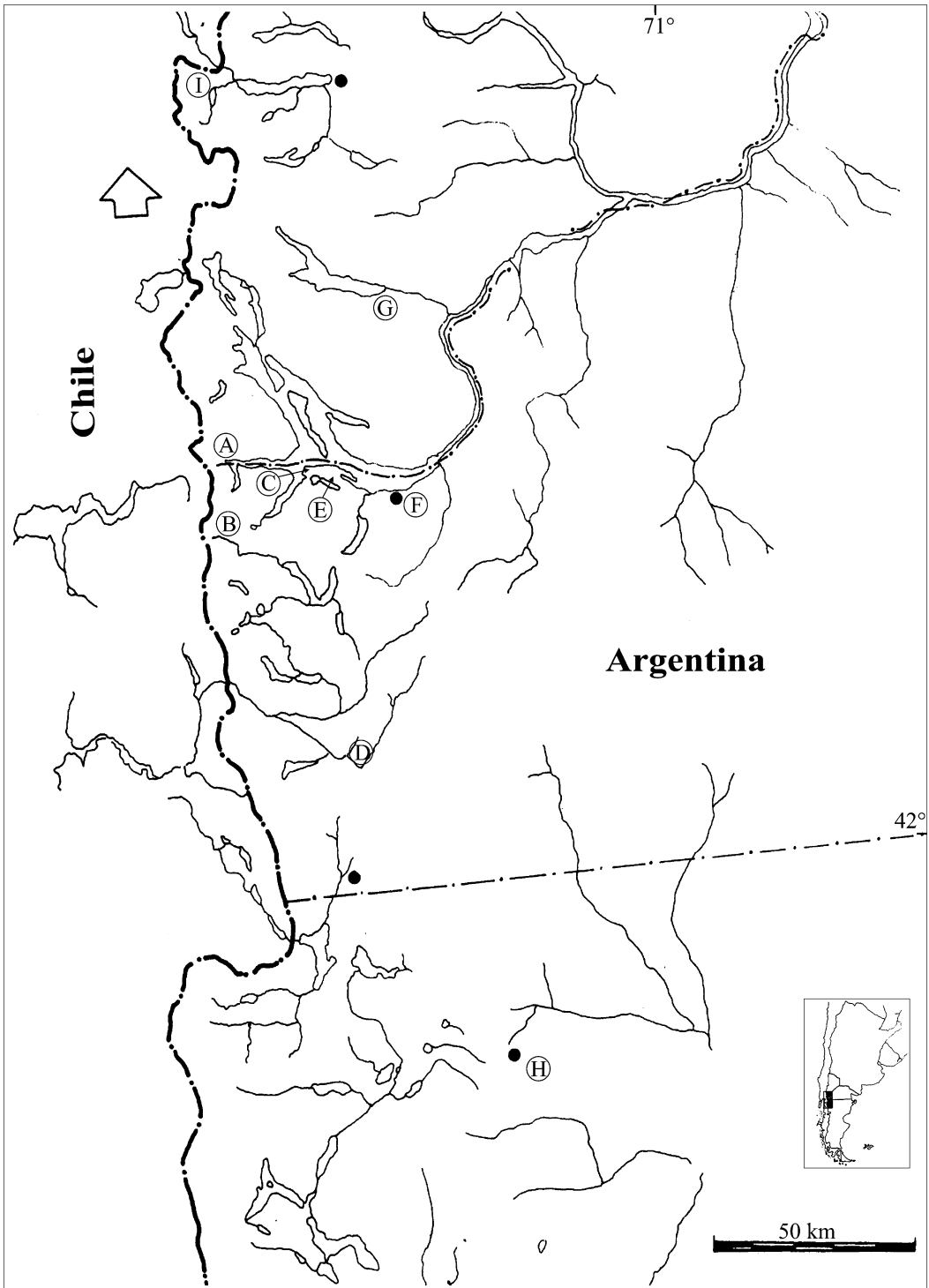


Figure 1. Study area and collections sites. A, Puerto Blest; B, Saltillo las Nalcas; C, Llao-Llao; D, Cascada la Virgen on Route 258; E, northern margin of Lake Moreno; F, downtown Bariloche city; G, Arroyo Verde in Villa Traful; H, Leleque; I, Lake Quení.

Table I. Collection sites. Mean annual precipitation from Barros et al. (1983) and Muñoz and Garay (1985).

Collection site	Latitude S	Longitude W	Altitude (m)	Mean annual precipitation (mm year ⁻¹)
A Puerto Blest	41°02'	71°49'	820	3000
B Saltillo las Nalcas	41°13'	71°47'	830	3000
C Llao-Llao	41°03'	71°37'	800	1800
D Cascada la Virgen	41°34'	71°25'	780	1500
E Lake Moreno	41°06'	71°28'	800	1500
F Bariloche city	41°09'	71°18'	790	1200
G Villa Traful	40°44'	71°13'	780	900
H Leleque	42°23'	71°03'	690	700
I Lake Queñi	40°09'	71°43'	800	3000

Collection site location, altitude, and mean annual precipitation are shown in Table I. The study area has a mean annual temperature of 8.4°C at 800 m altitude (Muñoz and Garay 1985) and it decreases 0.7°C for every 100 m of altitude increment (Gallopín 1978), with local variations due to microhabitat variability. To minimise differences in temperature, the nests were collected at similar altitudes (690–830 m), within a range of 140 m, so that the maximum possible difference in temperature was 1.0°C, and could be disregarded when compared to other major environmental factors, such as the notable precipitation gradient.

Different plant associations were found within the study area. For descriptive purposes, collection sites were grouped according to their mean annual rainfall.

The most westerly collection sites (site A, Puerto Blest; site B, Saltillo las Nalcas) have 3000 mm mean annual precipitation (Barros et al. 1983). Site A is located on the east slopes of the Andes mountain range, near the low-altitude Pérez Rosales pass (978 m). This pass acts as a corridor, enabling species that are typical of the Valdivian Chilean rainforest to grow at site A. The vegetation comprises high, open, evergreen multistratified forest, with two arboreal strata. The dominant tree is *Nothofagus dombeyi* (Mirb.) Oerst., which is associated with *Fitzroya cupressoides* (Molina) I. M. Johnst., *Weinmannia trichosperma* Cav., *Dasyphyllum diacanthoides* (Less.) Cabrera, and *Drymis winteri* J. R. Forst. and G. Forst., among others. There is a dense shrubby understorey, formed mainly by *Fuchsia magellanica* Lam., the bamboo *Chusquea culeou* Desv., ferns such as *Adiantum chilensis* Kaulf., and lianas such as *Hydrangea intergerrima* (Hook. and Arn.) F. Phil. There are also numerous phanerogamic hemiparasitic plants, such as *Misodendrum* spp. and *Tristerix tetrandum* (L.) Kuijt. Lichens and bryophytes (mosses and liverworts) grow profusely in the area, covering tree trunks and branches, rocks and soil, frequently overlapping, forming a continuous cover (Brion et al. 1988; Calabrese 1995; Liberatore et al. 2002). Site B also has 3000 mm mean annual precipitation (Barros et al. 1983), and is also located on the east slope of the Andes mountain range. It differs from site A in that it is located in the area where the Patagonian mountains are at their highest (Cerro Tronador, 3554 m elevation). The typical vegetation is dominated by *Nothofagus dombeyi*, with a dense understorey stratum formed by *Berberis linerifolia* Phil., *Berberis buxifolia* Lam., *Ribes magellanicum* Poir., *Fuchsia magellanica*, and *Chusquea culeou*. The species *Gunnera tinctoria* (Molina) Mierb. and *Adiantum chilensis* often grow in the most humid microhabitats. Surveys of the area show that lichens, liverworts, and mosses, most of which are epiphytic, are very common.

At collection site C (Llao-Llao) mean annual precipitation is lower (1800 mm) (Barros et al. 1983). The typical vegetation here is also dominated by *Nothofagus dombeyi* trees, accompanied by some trees of the species *Austrocedrus chilensis* (D. Don) Pic. Serm. and

Bizzarri, and there is a dense understorey stratum made up of *Berberis buxifolia* Lam., *Ribes magellanicum* Poir., *Fuchsia magellanica*, and *Chusquea culeou*. Surveys of the area show that epiphytic or saxicolous lichens, liverworts, and mosses are very common.

Collection sites D (Cascada la Virgen on Route 258) and E (northern margin of Lake Moreno) are drier than the previous sites, with mean annual precipitation 1400 mm (Barros et al. 1983). The flora corresponds to a forest co-dominated by *N. dombeyi* and *A. chilensis*, with shrubs of *Lomatia hirsuta* (Lam.) Diels, *Schinus patagonicus* (Phil.) I. M. Johnston., *Aristolelia chilensis* (Molina) Stuntz, *Buddleja globosa* Hope, *Ribes magellanicum*, *Maytenus boaria* Molina, *Escallonia rubra* (Ruiz and Pav.) Pers., *Fabiana imbricata* Ruiz and Pav., and *Fuchsia magellanica*; and there are thickets of *Chusquea culeou*. Lichens, mosses, and liverworts, most of which are epiphytic, are common.

Collection site F is located in downtown Bariloche. Bariloche is a tourist centre which has about 100,000 inhabitants. At this collection site, all streets are paved, there are many buildings up to six storeys tall, traffic is heavy, and the area is considered as completely altered. Most gardens and parks are planted with ornamental exotic trees and flowers, and their grounds covered by lawns. Mean annual precipitation is 1400 mm (Barros et al. 1983), but the gardens are artificially watered during summer, increasing microhabitat humidity and enabling mosses, liverworts, and small thalli of epiphytic lichens to grow (Calvelo and Liberatore 2004).

Sites G (Arroyo Verde in Villa Traful) and H (Estancia Leleque) are the most easterly, with 900 and 700 mm mean annual precipitation, respectively (Barros et al. 1983; Muñoz and Garay 1985). Most of the vegetation is transitional between the western *Nothofagus* forests and the eastern steppe. One of the nests (site G) was located on an arid slope, sparsely vegetated with *Austrocedrus chilensis* trees and shrubs of the species *Lomatia hirsuta*, *Schinus patagonicus*, *Balbisia gracilis* (Meyen) A. T. H. Hunziker et L. Ariza, and *Diostea juncea* (Gillies ex Hook.) Miers. The other nest (site H) was located in an area of grass steppe with a few low trees growing along the banks of streams (*Discaria chacaye* (G. Don) Tortosa and *Salix* spp.) and cushion shrubs (*Mulinum spinosum* (Cav.) Pers.). There were a few mosses and poorly developed lichen thalli growing on the ground and rocky cliffs.

Six nests (not available for dissection) were collected at site I, Lake Queñi (40°09'S, 71°43'W), a site that is floristically similar to site A.

Precipitation and mean annual temperatures were taken from specific local climatic publications (Gallopín 1978; Barros et al. 1983; Muñoz and Garay 1985).

Materials and methods

Hummingbird nests are concealed among the forest foliage (Green-backed Firecrown) or inside dark caves (White-sided Hillstar), making them very difficult to find. Nests were located through extensive surveys during the nesting season, and collected after the birds had fledged. For every nest, the following variables were recorded: nest substrate, nest position relative to substrate, and height from nest rim to the ground. One of the Green-backed Firecrown nests was observed during the building process.

In the laboratory, the nests were photographed and processed according to the protocol suggested by Hansell (2000). The dry weight, outer nest diameter (maximum and minimum), nest depth, cup diameter (maximum and minimum), and cup depth were then recorded. Nests were observed under a dissecting microscope, and separated into their component parts to determine building techniques and the proportional contribution of materials to the structure. Three layers were distinguished, namely lining, structural, and

outer layers (after Hansell 2000). All measurements are expressed as a range (mean \pm standard deviation, n). Each nest component was identified by applying techniques according to the type of material. To determine the relative importance of the materials, each one was weighed separately and classified in two categories, as either high or low contribution to the nest composition. Plant components were studied under dissecting microscope, and slides were prepared for observation under light microscope. Identifications were made to the smallest possible taxa, using specific keys and comparison with reference herbaria. Similar procedures were applied to zoological material.

To analyse the relationship between nest composition variables and the mean annual precipitation at each nesting site, Spearman's rank correlations were performed (Zar 1996). The variables used were: total number of plant species, total number of moss species, total number of liverworts, and total number of materials employed.

Results

Nest descriptions

Sephanoides sephaniodes. Fourteen Green-backed Firecrown nests were collected. All these nests were open cups, circular to oval in shape, some of them vertically elongated (Figures 2, 3a, b). Nests measured (in cm): outer nest diameter (maximum): 5.4–10.3 (7.4 ± 1.4 , 13); outer nest diameter (minimum): 5.1–9.5 (6.4 ± 1.3 , 13); nest depth: 2.9–9.8 (5.7 ± 2.4 , 13); cup diameter (maximum): 1.8–5.7 (3.4 ± 1.2 , 13); cup diameter (minimum): 1.8–4.8 (3.0 ± 1.0 , 13); cup depth 1.2–4.6 (2.7 ± 1.0 , 10). Dry weight (in g) 2.83–10.53 (6.19 ± 2.50 , 12). There were no significant differences (t tests $P > 0.05$) among nests from different sites for these variables.

According to the classification in Hansell (2000), all nests were constructed using the "velcro" interlocking technique, which involves entangled plant material among sticky threads of silk (mostly spider silk either from webs or cocoons). All nests consisted of a structural layer formed mainly by mosses (up to 91% of total nest dry weight) and spider silk, and a soft lining mainly composed of pappi was present in 85% of the nests, representing up to 32% of total nest dry weight. Other materials, such as mosses, down feathers, spider web, and commercial cotton fibres (in the nest from the urban site) were also found in the lining. An outer layer was recognisable in eight nests. Common materials forming the outer layer were *Chusquea* leaves, leprose lichens, pappi, and/or large pieces of white spider cocoon silk (Figure 1c). The nest from the urban site also contained commercial cotton fibres in the outer layer (Figure 3b).

The Green-backed Firecrown used different plants as nesting substrates: *Chusquea culeou* (four), *Berberis darwinii* (one), *Schinus patagonicus* (one), *Fuchsia magellanica* (three), *Escallonia rubra* (one), and *Blechnum hastatum* Kaulf. (one). The nests were often built between two parallel twigs. Interestingly, the nest built in the urban area was attached to two parallel electricity wires. The nests were fastened firmly to substrates either basally (three cases) or laterally (nine cases; Figure 2c). Height of nest above ground was 0.7–2.3 m (1.8 ± 1.1 m, 10). Two nests showed signs of having been constructed on the remains of old nests (Figure 2d).

The complete construction of a nest at site C took ca 13 days. It was detected on 15 October, as a mass of moss and spider silk attached to a hanging bamboo branch. Five days later, a cup-like structure could be seen, and it was enlarged with additional material during the following days. During all observations, considerably large white patches of spider



Figure 2. Nests of the Green-backed Firecrown *Sephanoides sephaniodes*. (a) Incubating female sitting in a nest camouflaged in a dense bamboo thicket; (b) upper view of an active nest; (c) nest showing lateral attachment to substrate, and pieces of bamboo leaves in the outer layer; (d) bulky nest built on a pre-existent cup. Photographs: (a, b) L. Sympson; (c, d) the authors.



Figure 3. (a, b) Nests of the Green-backed Firecrown *Sephanoides sephaniodes*: (a) inner cup showing pappi as lining material; (b) nest collected from an urban site, with manufactured cotton in the outer layer. (c, d) Nest of White-sided Hillstar *Oreotrochilus leucopleurus*: (c) lateral view of nest covered by sheep's wool and feathers (reference in cm); (d) upper view, the cup opening is hardly noticeable due to soft materials present. Photographs: the authors.

cocoon silk could be seen on the outer layer. Nevertheless, when the nest was collected 3 months later, these white patches were not obvious, possibly due to dehydration. Therefore, we consider that the presence of spider cocoon silk could have been underestimated for some nests.

Oreotrochilus leucopleurus. The two White-sided Hillstar nests (Figure 3c, d) were found at sites G and H. They were glued laterally to the rocky roof of a cave. The cementing substance could not be identified, although it lacked structure when observed under magnification (e.g. as it would in the case of animal silk). They were cup-shaped. Measurements were (in cm): nest diameter (maximum) 4.8–6.9; nest diameter (minimum) 4.6–6.3; nest depth 6.0–9.7; cup diameter (maximum) 2.1–2.2; cup diameter (minimum) 1.8–2.1; and cup depth 3.2–4.4. Dry weight (in g) was 3.50–10.15. We did not attempt to test for differences between nests, because of the small sample size.

These nests were also constructed using the “velcro” interlocking technique. They had an outer layer of sheep’s wool, grey feathers, or unidentified brown hair (see detail in Figure 3d), which made them almost indistinguishable from the grey surface of the cave walls to which they were attached. The structural layer consisted of feathers and a matrix of mosses entangled with sheep’s hair. Mosses constituted up to 55% of total nest dry weight. The lining was made of feathers and/or hairs.

One of the nests showed signs of having been constructed on the remains of an old nest.

Nest composition

Table II shows the building materials of all nests, indicating the major components. Mosses were by far the material most commonly employed by both the Green-backed Firecrown and the White-sided Hillstar, not only regarding the diversity of species used, but also because, in most cases, they represented the major component of the nests: up to 91% of total materials employed by Firecrowns and 55% by Hillstars. Liverworts were second in importance only in Firecrown nests, especially in the more humid habitats.

Vascular plants were mostly represented by Gramineae leaves and pappi. Only small fragments of lichens were present, making it almost impossible to identify them to species level.

Positive significant correlations ($P < 0.01$) were found for each variable considered related to precipitation (Table III). The number of plant species, mosses, liverworts, and total materials used decreased from the most humid sites to the drier ones. Liverworts were not present in nest structures in drier sites.

With regard to mosses, only three of the species identified have falcate (scythe-like) leaves, namely *Raphidorrhynchium callidum*, *Hypnum skottsbergii*, and *Dicranoloma capillare*. It is interesting to note that *Raphidorrhynchium callidum* is the only species present in all nests, and a major component in 70% of the nests. *Hypnum skottsbergii* is present in 70% of the nests, and is a major component in 62% of them. *Dicranoloma capillare* is present in 31% and is a major component in 15% of nests. Moreover, at least one of the two most frequently used species is a major component of all nests.

Pappi were an important component of most nests, giving them a very soft texture (Figure 3a). In some nests, pappi were finely cut into small pieces of up to 1 mm. Gramineae leaves were present in all nests but one (Figure 2c). *Chusquea culeou* leaves were used whenever the species was present in the habitat, but were replaced by leaves of

Table II. Building materials of all analysed nests (presence is indicated with an X; bold indicates high proportion).

Nest ^a	SS III	SS IV	SS V	SS VI	SS IX	SS X	SS XI	SS I	SS VIII	SS II	SS VII	OL I	OL II
Collection site ^b	A	A	B	B	B	B	B	C	D	E	F	G	H
Mean annual rainfall (mm year ⁻¹)	3000	3000	3000	3000	3000	3000	3000	1800	1500	1500	1200	900	700
Musci													
<i>Acrocladium auriculatum</i> (Mont.) Mitt.			X	X	X	X							
<i>Ancistrodes genuflexa</i> (Müll. Hal.) Crosby	X	X			X			X					
<i>Bartramia halleriana</i> Hedw.	X		X		X	X	X						
<i>Ceratodon purpureus</i> (Hedw.) Brid.			X		X	X	X						
<i>Dicranoloma capillare</i> (Dusén) Broth.	X	X			X	X							
<i>Dicranoloma robustum</i> (Hook. f. et Wilson)	X		X	X	X	X		X					
Paris													
<i>Hypnum skottsbergii</i> Ando		X	X	X	X	X		X	X	X		X	
<i>Leptostomus menziesii</i> R. Br. bis	X	X	X										
<i>Lepyrodon hexastichus</i> (Müll. Hal.) Wijk et	X	X		X	X	X	X		X				
Margad.													
<i>Pohlia cruda</i> (Hedw.) Lindb.			X		X	X		X					
<i>Polytrichadelphus magellanicus</i> (Hedw.)					X								
Mitt.													
<i>Rhaphidorrhynchium callidum</i> (Mont.)	X	X	X	X	X	X	X	X	X	X	X	X	X
Broth.													
<i>Rigodium brachypodium</i> (Müll. Hal.) Paris	X	X	X	X	X	X							
<i>Sphagnum magellanicum</i> Brid.	X	X			X			X					
<i>Vittia pachyloma</i> (Mont.) Ochyra					X	X							
<i>Weymouthia mollis</i> (Hedw.) Broth.	X								X				
Liverworts													
<i>Frullania</i> sp.	X	X	X				X	X	X	X			
<i>Lepicolea ochroleuca</i> (Spreng.) Spruce	X												
Metzgeriales sp.	X	X		X			X		X				
<i>Metzgeria</i> sp.	X	X		X	X	X	X		X				
<i>Plagiochila</i> sp.	X	X		X	X	X	X						
<i>Pseudolepicolea</i> sp.	X	X											
Lichens													
<i>Colemataceae</i>	X												
<i>Leptogium cyanescens</i> (Rabenh.) Koerb.							X		X				

Table II. (continued.)

Nest ^a	SS III	SS IV	SS V	SS VI	SS IX	SS X	SS XI	SS I	SS VIII	SS II	SS VII	OL I	OL II
Collection site ^b	A	A	B	B	B	B	B	C	D	E	F	G	H
Mean annual rainfall (mm year ⁻¹)	3000	3000	3000	3000	3000	3000	3000	1800	1500	1500	1200	900	700
<i>Leptogium</i> sp.						X	X						
<i>Nephroma antarcticum</i> (Jacq.) Nyl.	X												
<i>Protousnea magellanica</i> (Mont.) Krog		X											
<i>Sphaerophorus</i> sp.	X												
Leprose lichen	X	X	X	X	X	X	X		X	X		X	
Algae													
<i>Chaetophora</i> sp.		X											
Vascular plants													
<i>Adiantum chilense</i> Kaulf. (leaves)			X		X	X							
<i>Balbisia gracilis</i> (Meyen) A. T. H. Hunziker et L. Ariza												X	
<i>Chusquea</i> (cut leaves)	X		X	X	X	X	X	X	X	X			
<i>Fuchsia magellanica</i> Lam. (scales of outer cortex)								X		X			
<i>Escalonia rubra</i> (R. et P.) Pers. (leaves)									X				
<i>Misodendrum punctulatum</i> Manks ex DC. (seeds)								X	X				
Gramineae (cut leaves)						X				X	X	X	X
Pappus	X	X	X		X	X	X	X	X	X	X	X	X
Small piece of roots, up to 1.2 mm diameter		X				X							
Small wood branches, up to 1–1.5 mm diameter			X						X				X
Various													
Spider web	X	X	X	X	X	X	X	X	X	X	X	X	
Hairs												X	X
Feathers		X	X	X	X							X	
Cotton, very thin threads											X		
Cotton or nylon threads									X		X		
Small stones, up to 0.5 mm diameter												X	X

Table II. (continued.)

Nest ^a	SS III	SS IV	SS V	SS VI	SS IX	SS X	SS XI	SS I	SS VIII	SS II	SS VII	OL I	OL II
Collection site ^b	A	A	B	B	B	B	B	C	D	E	F	G	H
Mean annual rainfall (mm year ⁻¹)	3000	3000	3000	3000	3000	3000	3000	1800	1500	1500	1200	900	700
Total number of plant species	21	16	13	11	20	18	11	10	12	5	1	4	1
Total number of mosses employed	10	8	9	6	14	11	4	6	4	2	1	2	1
Total number of liverworts employed	6	5	1	3	2	3	4	1	3	0	0	0	0
Total number of materials employed	23	20	17	13	23	22	13	12	16	8	6	10	5

^aSS, *Sephanoides sephanioides*; OL, *Oreotrochilus leucopleurus*. ^bCollection sites are arranged from left (most humid) to right (least humid): A, Puerto Blest; B, Saltillo de las Nalcas; C, Llao-Llao; D, Cascada la Virgen; E, East Lake Moreno; F, urban area, Bariloche; G, Villa Traful; H, Estancia Leleque.

Table III. Spearman's rank correlations between mean annual rainfall at collection sites and nest composition materials.

Correlations	Total nests	Firecrown nests
Precipitation versus total number of species	$\rho=0.834$	$\rho=0.730$
Precipitation versus total number of mosses	$\rho=0.851$	$\rho=0.772$
Precipitation versus total number of liverworts	$\rho=0.781$	$\rho=0.651$
Precipitation versus total number of materials	$\rho=0.805$	$\rho=0.705$

All correlations are significant ($P < 0.01$).

herbaceous Gramineae when bamboos were not available at the nesting site. Both types of leaves were cut longitudinally into slender strips that were delicately interwoven with the rest of the materials. They were very important in giving the nest a circular shape.

Regarding the morphology, there were no significant differences between the nests of both species (t tests $P > 0.05$).

Discussion and conclusions

In all the nests studied, the main components were mosses, seemingly an irreplaceable material in the structural layer. The moss flora is well known only for one of the collection sites, namely Puerto Blest. Only three species with falcate leaves are recorded for this area (Calabrese 1995), so it is remarkable that these three species are used by the birds as nesting material. We assume that the leaf arrangement of mosses and the falcate form of the leaves of the most frequently used mosses provide the necessary hooks to bind the silk together, making the "velcro" building technique effective. The fact that hooked plant material is necessary for this technique has been discussed previously by Hansell (2000).

Other nest materials may be substituted by different materials having similar functional characteristics, when they are present at the nesting site. In the lining, a variety of materials was used. Pappi were predominant, but alternatively hairs, feathers (especially down), spider web, and manufactured cotton fibres were also employed. Any of these elements surely provide the nest with the required softness and thermal conditions for the adequate care and development of eggs and nestlings.

The function of the outer layer seems to be to camouflage the nest against its surroundings. White spider cocoon and white leprose lichen spots work well to conceal the nests hanging among the foliage in the sunshine, as hypothesised by Hansell (1996). Other mimetic materials are grey feathers and brown hairs in the case of the White-sided Hillstar. However, the lack of an outer layer in some nests may be due to the dehydration of the material, as was observed when we followed the building process of one Green-backed Firecrown nest.

An association between *Rhaphidorrhynchium callidum* and *Hypnum skottsbergii* growing in the field has been reported (Calabrese 1995), and they are widely distributed in Patagonia from ca 37° to 55°S (Matteri 2003) and locally abundant (G. M. Calabrese, personal communication). The diversity of the moss species used decreased along the gradient from the most humid to the driest habitats, but not the amount of material employed. *A priori*, and based on our own observations, the number of mosses in the field also decreases along this gradient, but there are no ecological studies regarding the diversity of mosses in the study area. The Green-backed Firecrown also used liverworts in the most humid habitats,

but they were never a major nest component. The diversity of liverwort species used also decreased along the gradient from the most humid to the driest habitats.

Spider silk fulfilled two functions: structural and mimetic. It was found as part of the structural layer in the form of threads interwoven with mosses or as an adhesive material, and in the outer layer, in the form of cocoon silk as mimetic material.

In spite of the relative abundance of lichens at almost all sites (Calvelo and Liberatore 2002), they were a minor component of nests, and in most cases, only leprose lichens were found as a component of the outer layer, apparently with mimetic functions. Even though lichens are often mentioned in literature as components of hummingbirds' nests (Schuchmann 1999), this was not the case for the two local species, according to our findings. Fungi, another material known to be used by many birds, including some hummingbirds, (Hedger 1990) were not found at all in Patagonian hummingbird nests.

A special mention should be made of the nest from the urban site, which was built in the covered balcony of an apartment. It employed the least variety of material, and lacked spider silk, which was replaced by very thin cotton threads and synthetic fibres.

As final conclusions, the diversity of nesting materials undoubtedly decreased along the precipitation gradient, while the main structural components were invariable. Therefore, the hummingbirds appear to actively seek mosses having a particular morphology for the construction of their nests and select nest materials, especially those involved in the structure.

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