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DENSITY ESTIMATES, MICROHABITAT SELECTION AND FORAGING BEHAVIOUR OF THE ENDEMIC BLUE CHAFFINCH *FRINGILLA TEYDEA TEYDEA* ON TENERIFE (CANARY ISLANDS)

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Summary.—*Density estimates, microhabitat selection and foraging behaviour of the endemic Blue Chaffinch* Fringilla teydea teydea *on Tenerife (Canary Islands).*

Aims: The main aim of this study was to present density estimates in good habitat for the Blue Chaffinch on Tenerife. At the same time other ecological aspects were studied, i.e. microhabitat selection and foraging behaviour.

Location: Seven study areas located around the pine forest of Tenerife, Canary Islands.

Methods: Point counts were used for censusing birds. Data were analysed with the DISTANCE software programs using an average detectability function. Microhabitat structure was characterized by measuring 11 variables in a 25m radius at each point. We used Poisson regression models to predict counts for Blue Chaffinch from habitat measurements. Repeated standardised focal samples were used to record the foraging behaviour of Blue Chaffinch (one record per bird). Differences in foraging behaviour were analysed by chi-square tests.

Results: Based on the 370 point counts giving similar densities for the two main pine forest habitats for the species (6.7 birds/ha in the north vs. 6.5 birds/ha in the south). The density of thin pine trees best predicted Blue Chaffinch counts on the whole island. Chaffinch density increased significantly in the north of Tenerife as the shrub cover of *Adenocarpus* sp. increased and as the mean height of the shrub layer increased. Finches were observed foraging mainly for *Myrica faya* seeds during the non-breeding (winter) season and on open cones for their seeds of the Canary Pine trees (*Pinus canariensis*) during nesting (females searching on the needles during this time), at least on the eastern side of the island where the sample protocol was undertaken.

Conclusions: This study justifies a forest management policy of selective clearing of heavily dense areas of pine trees in the north of Tenerife, where no undergrowth is present. Reafforestation campaigns in the south of this island should aim to plant with pine trees those areas which were historically dominated by pine trees.

Key words: Birds, Blue Chaffinch, *Fingilla teydea teydea*, population size, microhabitat selection, foraging behaviour.

Resumen.—*Densidad, selección de microhábitat y comportamiento de alimentación en el Pinzón Azul* Fringilla teydea teydea *en Tenerife (Islas Canarias).*

Objetivos: El objetivo general del trabajo fue el obtener valores de densidad para el Pinzón Azul en Tenerife. A la vez se estudiaron otros aspectos ecológicos, i.e. selección del microhabitat y forrageo.

Localidad: Siete áreas de estudio en el pinar de Tenerife, Islas Canarias.

Métodos: Se censaron a las aves con estaciones de escucha. Los datos se analizaron con el programa DISTANCE usando una función de detectabilidad media. La estructura del microhabitat se caracterizó mi-

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diendo 11 variables visualmente en un radio de 25 m en cada estación de escucha. Usamos modelos de regresión Poisson para predecir la presencia del Pinzón Azul. El método de "repeated standardised focal samples" se usó para las observaciones de forageo del Pinzón Azul (un dato por cada ave observada). Las diferencias en el forrageo fueron analizadas por el test de asociación chi-cuadrado.

Resultados: En 370 estaciones de escucha se obtuvo densidades similares para los dos pinares principales (6,7 aves/ha en el norte vs. 6,5 aves/ha en el sur). La densidad de pinos finos fue la variable que mejor predijo la presencia del Pinzón Azul en toda la isla. La densidad de pinzones aumentó significativamente en el norte de Tenerife al aumentar la cobertura de matorral de *Adenocarpus* sp. y al aumentar la altura media arbustiva. Los pinzones fueron observados principalmente forrajeando y alimentándose de semillas de *Myrica faya* durante el periodo no reproductor y de semillas de piñas abiertas de Pino Canario (*Pinus canariensis*) durante el periodo reproductor (las hembras buscaban en las acículas principalmente durante ese periodo), al menos en la zona oriental muestreada.

Conclusiones: Este estudio justifica una política de manejo forestal de aclarar selectivamente aquellas áreas con mayor densidad de pinos en el norte de Tenerife, donde no exista sotobosque. Las campañas de reforestación en el sur de la isla deben intentar plantar con pinos aquellas zonas dominadas por pinar en el pasado.

Palabras clave: Aves, Pinzón Azul, *Fingilla teydea teydea*, tamaño poblacional, selección del microhabitat, forageo.

Introduction

The Blue Chaffinch (*Fringilla teydea*) is an endemic bird species from the Canary Islands only that occupies the islands of Tenerife (nominate *teydea*, Web, Berthelot & Moquin-Tandon, 1841) and Gran Canaria (subspecies *polatzeki*, Hartert, 1905; (Snow & Perrins, 1998). Although there has been interest in the endangered Gran Canaria subspecies (see Moreno, 1991; Rodriguez & Moreno, 1993), very little is known about the nominate race of Tenerife (see references in Martín & Lorenzo, 2001). The total population of the Gran Canaria race has been estimated at 180-260 individuals (Snow & Perrins, 1998) and has been included in the Canary Islands` Red Data List (Martín *et al.*, 1990).

On the contrary, the Blue Chaffinch is not currently at risk on Tenerife (Blanco & González, 1992) but has been included in the Endangered Species Catalogue of the Canary Islands in the third category as "vulnerable" (Catalogo de Especies Amenazadas de Canarias, Decreto 151/2001 de 23 Julio) but no quantitative data has been presented to support this inclusion.

Although the majority of Blue Chaffinches occur on Tenerife, the total population size is very poorly known (Tucker & Heath, 1994). Carrascal (1987) was the first to present information such as habitat preferences and altitudinal effects, and the first density estimates (based on line transects) for the Blue Chaffinch on Tenerife (i.e. 6.7 birds/10 ha in *Pinus radiata* and 2.5 birds/10ha in *Pinus canariensis*). Tucker and Heath (1994) considered the total population size of this finch in the Canary Islands to be 1000-1500 pairs. However these data should be treated with care (Martín & Lorenzo, 2001). Existing estimates in the Canaries have tended to rely on the assumption that all, or most, of the birds present were detected, and provide no indication of the level of statistical confidence associated with each estimate. In recent years distance sampling has emerged as an efficient, reliable approach to abundance estimation (Buckland *et al.*, 1993; Buckland *et al.*, 2001), performing adequately in dense forest vegetation, where a high proportion of individuals may not be counted (Jones *et al.*, 1995). There is a clear need for density to be estimated with methods that account for detectability.

As well as density estimates, information is also needed about habitat preferences. On both of the islands Blue Chaffinches apparently inhabit the endemic Canary Pine (*Pinus canariensis*) forest, an old relic from an ancient Mediterranean evolutionary centre (Klaus, 1989). This forest is restricted, on Tenerife, from 700 and 2100m above sea level, with special variations according to the orientation. The pine trees can reach 15-25m height but sometimes can even reach 40-60m height, with a diameter greater than 2,5m (Blanco *et al.*, 1989). On Tenerife the Blue Chaffinch also occupies the planted forest of *Pinus radiata* (see Ceballos & Ortuño, 1976; Arco *et al.*, 1992, for the distribution of this forest): Fernandez-Palacios *et al.* (2004) differentiates between the humid pine forest of the north and the dry of the south based on differences in biomass, production and specific composition. Martin *et al.* (1984) were the first to suggest the habitat preferences of the Blue Chaffinch on Tenerife (i.e. the highest numbers are found in areas of pine forest where the undergrowth is dominated by *Chamaecytisus proliferus*, occurring less often in pine woods that are associated with *Myrica faya* and *Erica* sp.). However, the importance of an undergrowth layer for this finch during the breeding season was not supported in a recent study (Garcia-del-Rey, 2002).

The aim of the present work is to present density estimates of the Blue Chaffinch in good areas of habitat on Tenerife. At the same time we aim to test whether the floristic composition of the undergrowth of its pine forest habitat (or a particular plant of this lower stratum) determines Chaffinch abundance. The first quantitative foraging behaviour data are also presented to support the habitat association. Some basic pine forest management actions are then suggested based on the results.

Material and methods

This study was undertaken from 2002 to 2004 on the Canary island of Tenerife (28º20´N-16º20´W). Birds were censused with point counts of 5 minutes each (Bibby *et al.*, 1992; Buckland *et al.*, 1993) at the beginning of the Blue Chaffinch breeding season, between mid May to mid June (Bannerman, 1963; Martin *et al.*, 1984). In 2002 a total of 95 point transects were surveyed (i.e. 65 in the north and 30 in the south) on 3 locations. However, most points were covered during 2003 at 7 different sites (i.e. 125 in the north, 90 in the south). During 2004 another 60 survey points (i.e. 30 in the north and 30 in the south) were done on 2 sites. The total number of point transects was 370 (see Fig. 1) and 224 records of heard and seen Blue Chaffinches were made and their distance to the observer recorded. Distances were estimated in two bands (i.e. 0-25, 25-50, >50 meters). All field work was undertaken by EGDR, in dry, calm conditions, and survey points were located on or near to tracks in the pine forest, at least 300 m apart. Samples were taken from a mean altitude of 1378 ± 20m (range 725 - 1225, n = 224). It is important to note that samples were not randomly located but were restricted to areas of forest with high densities of Chaffinches in the west of the island.

Microhabitat structure was characterized at each site during 2003 only (i.e. 215 total), by measuring 11 variables visually in a 25m radius at the point transect: PINUS= % of *Pinus canariensis* cover, THIN= Number of pines of 0.1-0.3 m diameter at breast height, THICK= Number of pines greater than 0.3 m diameter at breast height, TMHEIGHT= Tree mean height in meters, MYRICA= % of *Myrica faya* cover, ERICA= % of *Erica* sp. cover, CHAMA= % of *Chamaecytisus proliferus* cover , ADENO= % of *Adenocarpus* sp. cover, SMHEIGHT= Shrub mean height in meters, HERB= % of herbaceous plants cover, CONES= Number of cones on the ground.

A single field technique was used to record the foraging behaviour of Blue Chaffinches, i.e. repeated standard observations (Hartley, 1953) or point sample (Noon & Block,

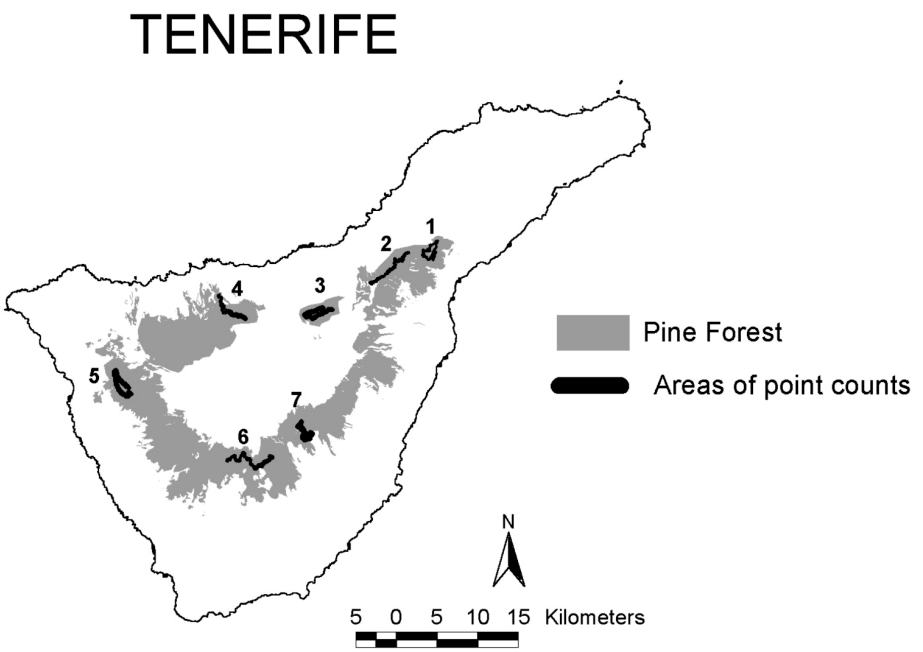

FIG. 1.—Distribution of study areas in the pine forest of Tenerife where point counts were located every 300m: 1= Monte Pinar, 2= Siete Fuentes, 3= Aguamansa, 4= La Guancha, 5= Chío, 6= Agua Agria, 7= Arico.
[Distribución de las areas de estudio en los pinares de Tenerife donde los puntos de muestreo se localizaban cada 300m: 1= Monte Pinar, 2= Siete Fuentes, 3= Aguamansa, 4= La Guancha, 5= Chío, 6= Agua Agria, 7= Arico.]

1990), which is perfectly suitable for this sort of study when compared to other commonly used methods of measuring foraging (Carrascal, 1984). Observations of foraging Chaffinches were made from January 2003 to April 2004 at three locations in the lower pine forest (see 1, 2, 4 in Fig.1) but primarily at location 1 (28º25´N-16º23´E, 1250 m), especially during the winter season. A total of 94 records were obtained during the non breeding season and 69 during the breeding season. Particular attention was paid to not record females searching for nest material during nest building. The division of records into the two groups was straightforward, based on the number of birds seen together at the time of the observation (i.e. small flock or a pair). The study areas were searched systematically, stopping when foraging birds were encountered. Care was taken not to alter the behaviour of the birds or to repeat observations of the same individual. For each bird a 5 second observation was made recording the following parameters: 1) height when first seen above the ground (estimated by eye), 2) Plant species in which it was foraging, 3) Foraging substrate and food items: cone & seeds, myrica seed, arthropod, needles.

Density estimates were calculated using the DISTANCE software programs (Buckland *et al.,* 1993) for all points using an average detectability function, and for the northern and southern forests separately, using the detection function derived from each area separately. A series of model distributions were compared with the observed distribution using the default settings of DISTANCE. The model that pro-

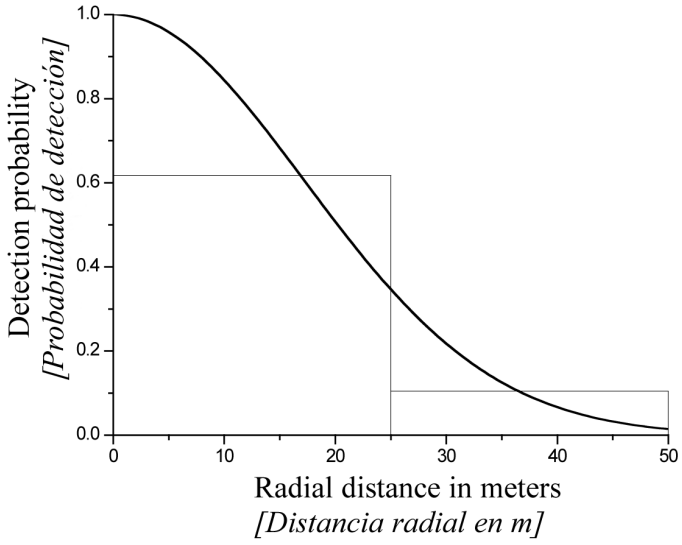

FIG. 2.—Detection probabilities and average detection function with distance from the observer used to estimate densities within DISTANCE. There were 72 records at 0 – 25 m and 152 records at 26 – 50 m from 370 point counts.
[Probabilidades de detección y función de detección promedia con las distancias desde el observador usadas para estimar la densidad (DISTANCE). Hubo 72 registros entre 0 – 25 m y 152 entre 26 – 50 m en 370 puntos de muestreo.]

vided the best overall fit with the fewest parameters was assessed using Akaike's Information Criterion (AIC).The best fit of detection probability plots (Goodness of Fit Test) was used (a half-normal distribution, see Figure 2) and distances were truncated to 50m because nearly all birds were sighted relatively close to the observer (< 50m).

Poisson regression models (procedure Genmod in SAS; SAS, 1996) were used, with a Poisson error distribution corrected for overdispersion) to predict counts for Chaffinch from habitat measurements. After generating a correlation matrix (Spearman's rho) for the habitat variables, the highly inter-correlated variables were excluded from the analysis. The number of thin pines was used as an index of availability of pine trees (No. of thin pines correlated with percentage pine cover $R = 0.42$, $P < 0.001$; no. of thick pine trees $R = -0.26$, $P < 0.001$; and mean height of pine trees $R = -0.18$, $P = 0.008$; $n = 214$ in all cases). Independent variables entered in the model were: location (north or south forest), number of thin pines, percentage cover of *Myrica*, *Erica* sp., *Chamaecytisus proliferus*, *Adenocarpus* sp., and herbaceous plants, shrub height and number of cones. The influence of a range of these potential fixed effect predictors of Chaffinch counts were tested by their stepwise inclusion in a general linear model. Each potential predictor was included in the model in turn and that with the most significant effect (i.e. smallest $P < 0.05$ from a Wald test) was selected for inclusion in the final model. Once the first predictor had been selected, the process was continued by including into the model in turn each of the remaining potential predictor variables in the presence of the first significant predictor. This step-up approach continued until no further predictors accounted for any of the remaining variation in the count data.

TABLE 1

Mean values (± *SE*) of the habitat variables in the northern and southern pine forest. Results and P values of the comparison by Mann-Whitney *U* test.
[Valor medio (± ES*) de las variables de habitat en los pinares del norte y sur de la isla. Se da la comparación de ellos por medio del análisis de la* U *de Mann-Whitney.]*

Variable	North (*n*=125)	South (*n*=90)	U	P	North/South (*n*=215)
Pinus canariensis cover (%) *[Cobertura de* P. canariensis *(%)]*	24.7 ± 2.0	10.7 ± 0.9	3509.0	<0.001	18.85 ± 1.28
Number of thin pines (0.1-0.3 m) *[Nº de pinos finos (0.1-0.3 m)]*	26.0 ± 1.7	22.2 ± 2.2	4673.0	0.034	24.40 ± 1.34
Number of thick pines (>0.3 m) *[Nº de pinos gruesos (>0.3 m)]*	2.7 ± 0.3	1.1 ± 0.2	3979.5	<0.001	2.04 ± 0.21
Tree mean height (m) *[Altura media de los árboles (m)]*	10.3 ± 0.3	7.5 ± 0.3	2398.5	<0.001	9.20 ± 0.25
Myrica faya cover (%) *[Cobertura de* Myrica faya *(%)]*	1.6 ± 0.4	0.1 ± 0.1	3810.5	<0.001	0.98 ± 0.23
Erica sp. Cover (%) *[Cobertura de* Erica *sp (%)]*	11.0 ± 1.7	0	1080.0	<0.001	6.41 ± 1.04
Chamaecytisus proliferus cover (%) *[Cobertura de* Chamaecytisus proliferus *(%)]*	3.3 ± 1.3	1.3 ± 0.2	4451.0	0.001	2.47 ± 0.76
Adenocarpus sp. cover (%) *[Cobertura de* Adenocarpus *sp. (%)]*	4.0 ± 0.8	0.2 ± 0.1	3046.0	<0.001	2.41 ± 0.46
Shrub mean height (m) *[Altura media de los arbustos (m)]*	1.5 ± 0.2	0.5 ± 0.1	2479.5	<0.001	1.09 ± 0.11
Herbaceous plants cover (%) *[Cobertura de herbáceas (%)]*	3.3 ± 1.1	7.5 ± 2.2	4896.5	0.04	5.05 ± 1.11
Number of cones on the ground *[Nº de piñas en el suelo]*	20.2 ± 3.2	58.7 ± 6.2	2592.0	<0.001	36.31 ± 3.45

RESULTS

There were clear differences in the vegetation between the northern and southern forests (Table 1), with pine density and height, and shrub species cover being much greater in the northern forests and southern forests having a higher percentage cover of herbs and a higher cone density.

The average density of Blue Chaffinches in areas of apparently the best habitat in the northern forest was 6.7 (5.7 - 8.0 95% CL) birds per hectare, and in the southern forest was 6.5 (5.3 - 8.0 95% CL) birds per hectare. The overall density was 6.6 (5.8 - 7.6 95% CL) birds per hectare. Note that this density is relatively high for any passerine species (see discussion) and is a reflection probably of the maximum density that can be reached by the Blue Chaffinch as areas of the best habitat were preferentially sampled.

The density of thin pine trees best predicted Chaffinch counts; as pine sampling density increased so did Chaffinch count (Table 2). Note that this effect is the opposite that would be predicted if count was affected by tree density through decreases in detectability. Chaffinch count also increased significantly as the percentage ground cover of *Adenocarpus* sp. increased and as the mean height of

TABLE 2

Results of a General Linear Model to explain Chaffinch counts from habitat variables.
[Resultados del Modelo General Lineal para explicar la presencia de Pinzones en relación a las variables del hábitat.]

Variables in model *[Variables en el modelo]*	df	Type III Chi square	P	Parameter	Type I Deviance
Number of thin pines (0.1-0.3 m) *[Nº de pinos finos (0.1-0.3 m)]*	1,210	16.4	< 0.0001	0.02	236.7
Adenocarpus sp. cover (%) *[Cobertura de* Adenocarpus *sp. (%)]*	1,210	6.8	0.0093	0.03	229.9
Shrub mean height (m) *[Altura media de los arbustos (m)]*	1,210	4.3	0.038	0.1	225.3
Overall model deviance: 225.3					
Variables excluded from model *[Variables excluidas en el modelo]*					
Location *[Localidad]*	1,201	0.4	0.53		
Myrica faya cover (%) *[Cobertura de* Myrica faya *(%)]*	1,201	0.5	0.48		
Erica sp. cover (%) *[Cobertura de* Erica *sp (%)]*	1,201	0.2	0.69		
Chamaecytisus cover (%) *[Cobertura de* Chamaecytisus *(%)]*	1,201	1.9	0.17		
Herbaceous plants cover (%) *[Cobertura de herbáceas (%)]*	1,201	0.5	0.46		
Number of cones on the ground *[Nº de piñas en el suelo]*	1,201	0.1	0.81		
Latitude *[Latitud]*	1,201	0.6	0.43		
Longitude *[Longitud]*	1,201	0.5	0.50		
Altitude *[Altitud]*	1,201	1.3	0.25		

There were no significant non-linear effects of latitude or longitude *[No hay efectos no lineales de la latitude y longitud]*

the shrub layer increased (Table 2). The effect of thin pine tree density on Chaffinch counts was the same in the northern and southern forests (interaction term THIN * Location, $\chi^2_{1,208} = 0.3$, $P = 0.60$; location $\chi^2_{1,208} = 0.2$, $P = 0.67$ added to the model in Table 2). The percentage cover of *Adenocarpus* sp. and the mean shrub height was very frequently zero in the southern forests so the analysis of any interaction of these variables with location was not possible. Despite what has been found in a recent study (*e.g.* Carrascal, 2005), there were no significant non-linear effects of latitude, longitude or altitude in this study.

The results on the foraging behaviour suggest that Blue Chaffinches forage mainly on very low heights during the non-breeding season (overall mean height was 0.61 m for males and 0.73 m for females) and higher during breeding (overall mean height was 1.37 for males and 3.98 for females) (Mann-Whitney U test for both sexes combined: $U = 2342.0$, $P < 0.001$). *Myrica faya* was the preferred plant during the non breeding (winter) season with

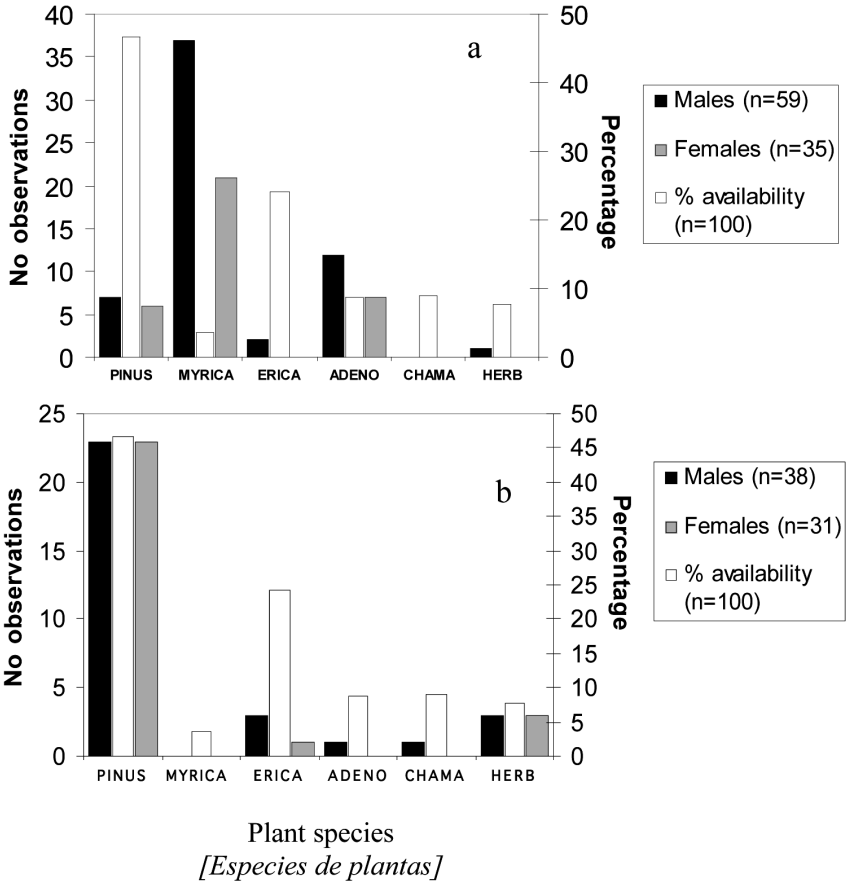

FIG. 3.—(a) Number of observations of foraging Blue Chaffinches (by sex) on (a) the different plant species during the non breeding season (a) and during the breeding season (b), and mean percentage cover available for each plant species. Sample size in brackets.
[Número de observaciones de Pinzones Azules (por sexo) alimentándose en las diferentes plantas durante la época no reproductora (a) y durante la época reproductora (b), así como el porcentaje medio de cobertura disponible para cada especie de planta. Los tamaños maestrales se dan entre paréntesis.]

a total of 61% of observations, yet only a 4% availability ($\chi_1^2 = 782.4$, $P < 0.001$) and *Pinus canariensis* during the breeding season with a total of 66% of observations, yet only 47% availability ($\chi_1^2 = 6.4$, $P < 0.05$; see Fig 3a and 3b). Blue Chaffinches searched for *Myrica faya* seeds during the non breeding season and took pine seeds from the cones during breeding (overall differences between the two periods; $\chi_3^2 = 66.15$, $P < 0.0001$; see Fig. 4a and 4b). Foraging among the needles was particularly important for the females while nesting (overall between sexes differences; $\chi_1^2 = 9.9$, $P < 0.01$; see Fig 4b).

DISCUSSION

Density

The present study revealed that Blue Chaffinch maximum density estimates between

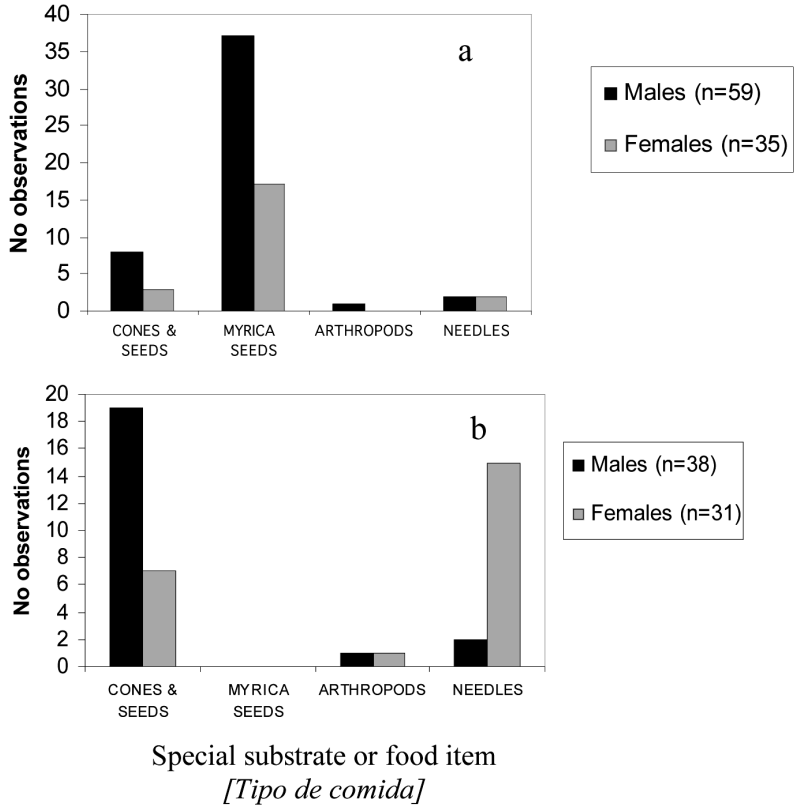

FIG. 4.—Number of observations of blue chaffinches, by the two sexes, exploiting different food sources during the non breeding season (a) and during the breeding season. Sample size in brackets. *[Número de observaciones de Pinzones Azules (por sexo) explotando distintos recursos alimenticios durante la época no reproductora (a) y durante la reproductora (b). Los tamaños maestrales se dan entre paréntesis.]*

two very different pine forests (north vs. south) (Fernandez-Palacios *et al.*, 2004 and Table 1) were very similar (6.7 vs. 6.5 birds per hectare). This supports the generalist aspect of the Blue Chaffinch suggested by Carrascal (1987) in the past, and the heterogeneous pine forest of monotonous undergrowth associations and intensive alteration by human actions and forest fires (Ceballos & Ortuño, 1951; Ceballos & Ortuño, 1976). However, a recent study (Carrascal, 2005) has shown that longitude (being more important than latitude) played a relevant role determining the spatial variation in Blue Chaffinch density (i.e. more abundant in the eastern half of the island [Long>346] and above 1594 m of altitude with trees higher than 13.5 m), but this was not found on this study. Carrascal (2005) also found that Blue Chaffinches were more abundant in the northern pine forests when trees are higher than 13.5 m and situated below 1594 m altitude.

Previous density estimates were much lower (Carrascal, 1987). It is likely that some of the differences in density between Carrascal's study and our own are due to differences in methodology: Carrascal (1987) did not account for detectability. But, assuming the highest value of Carrascal (1987) to be correct for

the entire pine forest (i.e. 0.67 birds/ha) and not correcting our data for detectability (71 observations in 370 25 m point counts, an area of 72.6 ha = 0.97 birds/ha), the results are more similar. Therefore, although the past counts were probably too low because they did not account for detectability it seems likely that the population has increased since, possibly as the outcome of the intensive reafforestation campaigns on the island (ICONA, 1979), which are still continuing at the present time (*pers. obs.*). Nevertheless it is important to re-emphasize that the density estimates we present here represent possible maximum densities in the best habitat, rather than average densities for the island as a whole, because point counts were not randomly sited.

Microhabitat selection

Results on microhabitat selection agree with Garcia-del-Rey (2002) in that the density of thin pine trees best predicts Blue Chaffinch counts for both the northern and southern pine forest. However, the results of this study differ in that they identify the importance of the *Adenocarpus* sp. and the mean height of the shrub layer found for the northern pine forest in the present study. Although *Adenocarpus* was a significant predictor of counts it is not an essential habitat element for the Blue Chaffinches as they were common in the south where there was no *Adenocarpus*. The number of thin pines was used in the present study as an index of availability of pine trees. A high density of pine trees in the territory increases foraging sites during the critical nesting period and increases the probability of having a good number of pine cones with seeds on the ground later in the season because the pine tree flowers in March or April and the pine cone matures in spring every two years [seeds are dispersed in the summer approximately 24-30 months after flowering (Ceballos & Ortuño, 1976; Blanco *et al.*, 1989), when adults are still feeding their young (*pers. obs.*). Cones were possibly not a predictor (see Table 2) because their numbers were difficult to estimate accurately. At the present time it is not clear why the other predictors (percentage ground cover of *Adenocarpus* sp. and the mean height of the shrub layer) are important for the Blue Chaffinch - they may be an index for the occurrence of some other unmeasured resource or provide a resource which is as yet unappreciated.

A Canary Pine can live 250 to 300 years but some reach up to 600 years. After their 15th year they start to grow in thickness and by 30 years old they can reach heights of 15-20m (Ceballos & Ortuño, 1976) if the trees are well spaced from other (P. Gil-Muñoz, *pers. comm.*). The finding that Blue Chaffinch density increases with increasing the number of thin pine trees can then explain the increased density of Chaffinches recently because of the intensive and poorly planned reafforestation campaign in Tenerife (ICONA, 1979). The number of pine trees in a natural pine forest varies from 42-75 trees/ha whereas in reafforested areas more than 1000 trees/ha have been documented (these of 5-12 m height and 0.18-0.40 m diameter; Delgado & Naranjo, 2000).

Foraging behaviour

During the breeding period the significant importance of the pine trees for foraging Blue Chaffinches is supported by the results of the present study (Fig. 3b). Both sexes exploited the opened cones of *Pinus canariensis* for their seeds (Fig. 4b) on the ground (65% for males and 30% for females). The Blue Chaffinch can pick up pine seeds loose on the ground or extract them from open cones and dehusks them (Godman, 1872). However, females foraged intensively on the needles (see Fig. 4b), possibly for arthropods, which are rich in proteins and water (Godman, 1872). *Chamaecytisus proliferus,* suggested as an important shrub for the Tenerife Blue Chaffinch

during breeding (Martin *et al.,* 1984), was not selected by the Gran Canaria race (Rodriguez-Luengo *et al.,* 2003) and was not chosen in this study. However, this shrub has recently been found to be a reliable source of caterpillars for Tenerife Blue Tit nestlings (Garcia-del-Rey, 2003), breeding much earlier than the Blue Chaffinches (Martin *et al.,* 1984).

Myrica faya is mainly a monteverde tree (occurring right below the pine forest) but occupies the lower strata in some areas of pine forest (i.e. transition of monteverde-pinar), especially in the north (900-1250 m). During the non-breeding period finches were observed exploiting their seeds (Fig 3a and 4a). Preference for this shrub may be less than measured because detecting any bird feeding on pure pine forest was extremely hard (*pers. obs.*). Myricacea, commonly named as Canary Islands Wax-Myrtle, flowers in spring and produces crops of small, waxy, black berries (Bramwell, 1998) every year around late summer (L. Sanchez-Pinto, *pers. comm.*), making them readily available for the finches during the winter. Hence, and at least on the eastern side of the island, birds do exploit other sources of food during the winter than just pine seeds. However, an altitudinal movement during the winter to lower areas to exploit these resources cannot yet be inferred due to the sample protocol undertaken on this study.

Conservation

The present study has shown that Blue Chaffinch density increased significantly as the percentage ground cover of *Adenocarpus* sp. and the mean height of the shrub layer increases in the north of Tenerife. This justifies a basic forest management policy, in northern Tenerife, of selective clearing of pine trees in those patches where the density of trees is so thick that no undergrowth has been able to develop. These are also very poor areas for Blue Chaffinches because no pine cones are produced by these trees (P. Gil-Muñoz, *pers. comm.*). However, the effects of pine tree clearing were not explicitly established by the present study. More detailed ecological studies are also necessary in order to explain why *Adenocarpus* sp. is important for this endemic finch. But clearly, planting more pine trees in the south of Tenerife, especially where it was cleared in the past, will benefit the Blue Chaffinch by increasing foraging sites and enlarging their historical distributional area.

Hunting and habitat destruction have been considered as the two major threats for this species in the past (Martin, 1979) and the pine forests have suffered intensive clearing of the undergrowth (Lack & Southern, 1949; Volsøe, 1951). The Blue Chaffinch and its habitat are currently protected by national and local laws, and have been included in the Annex I of the European Union Wild Birds Directive (Tucker & Heath, 1994). At the present time serious attention should be paid to conserve those areas of pine forest where *Myrica faya* dominates the undergrowth by preventing summer forest fires which have affected 64,000 hectares since 1969 (Delgado & Naranjo, 2000). Despite the adaptability of this pine forest to fires (Ceballos & Ortuño, 1976) how these affect the endemic Blue Chaffinch is not known.

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