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Bruno Massa [a] , Mario Lo Valvo [a] & Adelaide Catalisano [a]
[a] Istituto di Zoologia , Università degli Studi , via Archirafi 18, Palermo, I-90123, Italy
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BRUNO MASSA
MARIO LO VALVO
ADELAIDE CATALISANO
Istituto di Zoologia, Università degli Studi,
via Archirafi 18, I-90123 Palermo (Italy)

ABSTRACT

Mount Etna contains a mosaic of habitats that maintain a rich bird fauna. Between 1981 and 1986 we detected 77 breeding bird species. At the lowest altitudes, the shrubby maquis and the oak woods harbour high populations of Mediterranean species. Above 1000 m dominant conifers (*Pinus laricio*) contain fewer species with lower diversity in even-aged stands, but with higher values in the uneven-aged conifer stands mixed with birch trees (*Betula aetnensis*). Forest edges yield the highest evenness and richness of the bird communities of Etna, while high-altitude scrub contains the fewest number of species. Both forest edges and high altitude scrub harbour the highest number of species restricted to these habitat types. These data could be useful in the management of the Regional Park of Etna.

KEY WORDS: Bird communities; Avifauna of Etna.

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INTRODUCTION

Though many papers deal with the geovulcanology, botany and invertebrate zoology of the highest volcano in the European continent, Etna, its vertebrate fauna is not well known, particularly the avifauna (except for Galvagni, 1839, 1842, 1843). In 1981 we started to study the bird communities of the volcano, chiefly to collect baseline data for the future management of the new Regional Park of Etna. Here we report the results concerning the breeding bird comunities in habitats showing different vegetational structure.

STUDY AREA

Etna, an active volcano of 3350 m, originated in the late Pleistocene and covers an area of 1500 km^2. A large depression of the eastern side (5 × 7 km), called Valle del Bove, makes its conical shape asymmetrical. The climate is Mediterranean, becoming cold-oroxeroteric-type at its highest altitudes. Different microclimates are found along its slopes e.g. the annual rainfall at 600 m is 1250 mm on the east side and 600 mm on the west side. Consequently the distribution of vegetation cover is uneven.

According to Poli *et al.* (1981) its vegetation is characterized by:

1) Basic Mediterranean level (up to 1000 m) with shrubby species of Mediterranean «maquis» such as *Calicotome villosa, Pistacia terebinthus, Rhamnus alaternus, Spartium junceum, Euphorbia dendroides* and different vegetational forms of *Quercus ilex* and *Q. pubescens*. There are also grazing-lands with *Stipa tortilis, Cymbopogon hirtus, Asphodelus microcarpus, Ferula communis* etc.

2) Mid and Mountainous Mediterranean level (1000-1800 m). *Pinus laricio* wood is the most widespread vegetation, and it is the only wood in some places. *Fagus sylvatica* forms small woods and thickets between 1400 and 2000 m, sometimes starting from 600 m, and in some places reaching 2250 m. *Castanea sativa* is a typical species of this level, *Betula aetnensis* forms some pioneer populations associated with *P. laricio* and *F. sylvatica, Q. pubescens* and *Q. cerris*, becoming shrubby at the highest altitudes.

3) The upper Mediterranean level (1800-2950 m), like other Mediterranean mountains, is characterized by summer droughts and low winter temperatures. There are only some sparse thorny bushes such as the xerofitae *Astragalus aetnensis, A. siculus, Berberis aetnensis, Juniperus hemisphaerica*, etc., up to 2450 m. Further up, there are only pioneer species, such as *Rumex aetnensis, Anthemis aetnensis* and *Viola aetnensis*, up to an altitude of 2950 m.

METHODS

Birds breeding in the different habitats were detected with the *Echantillonnages Frequentiels Progressifs* method (EFP: Blondel 1975; Blondel *et al.*, 1981). Between mid May and mid July, from 1981 to 1986, the presence of singing birds was recorded once in 180 point counts of 20 minutes each, randomly selected. Several point-counts were performed in each habitat (Table I) in such a way that the presence/absence of each species in the different point counts could provide a value of occurrence of species. For each point count the vegetation type and relative canopy cover in the different layers were recorded, so that it was possible to assign each point count to one of the following ten habitats: A) sparse thorny and bushy vegetation of Upper Mediterranean level; B) Mediterranean maquis characterized by *E. dendroides* and *C. villosa*; C) *Q. ilex* and *Q. pubescens* thicket; D) *Quercus* spp. mature wood; E) *P. laricio* mature wood mixed with *F. sylvatica*; F) young *P. laricio* wood mixed with *B. aetnensis*; G) unevenly aged *P. laricio* wood with undergrowth; H) unevenly aged *P. laricio* wood mixed with *B. aetnensis*; I) evenly aged *P. laricio* mature wood with scattered bushes; L) edges of woods with bushy and arboreal vegetation.

TABLE I - *Total number of point-counts performed in each habitat, mean number of bird species (mean richness), total number of species (total richness), expected number at the total frequency of 25 with regards to decreasing frequency of individuals (based on rarefaction method), number of species having frequency more or less than 25%, mean value of the habitat breadth (e^H), number of species restricted only to one habitat, percentage of sedentary species and mean number of vegetational layers observed in the ten habitats examined on Etna. Habitats are arranged according to the decreasing value of the mean richness. Letters in brackets refer to habitats listed under «Methods».*

Habitat	No. of point-counts	Mean richness (s.d.)	Total richness	Expected no. of species	Species having frequency more than 25%	Species having frequency less than 25%	Mean value of habitat breadth (s.d.)	No. species restricted only to one habitat	% of sedentary species	Mean no. of vegetational layers (s.d.)
Uneven aged pine wood mixed with birches (H)	14	12.6 (3.1)	24	16.2	18	6	5.63 (1.7)	0	83.3	3 (0.3)
Edge habitats (L)	30	11.9 (4.8)	43	17.6	19	23	—	0	67.4	4.3 (1.0)
Young pine wood mixed with birches (F)	17	11.4 (3.9)	26	15.9	19	7	5.58 (1.6)	0	73.1	2.6 (0.7)
Quercus mature wood (D)	9	10.7 (0.9)	20	17.5	20	0	5.81 (1.7)	0	75	2.6 (0.9)
Uneven aged pine wood (G)	16	10.2 (4.2)	22	15.5	13	9	5.78 (1.6)	0	86.4	2.8 (0.4)
Quercus thicket (C)	20	10.1 (3.3)	33	15.7	15	17	4.79 (2.1)	1	78.8	4.4 (0.5)
Mature pine wood mixed with beeches (E)	19	10.1 (1.6)	22	14.3	14	8	5.95 (1.4)	0	86.4	3.3 (0.5)
Mediterranean maquis (B)	17	9.5 (2.2)	25	14.4	11	14	4 (2.6)	6	76	3 (0.2)
Even aged mature pine wood (I)	15	7.7 (2)	22	12.5	10	11	5.74 (1.8)	1	81.1	2.4 (0.6)
Thorny and bushy high mountainous habitat (A)	23	5 (1.6)	16	12.7	8	8	2.94 (2.4)	7	56.2	1.7 (0.7)

As the EFP method only allows detection of diurnal singing species (from Columbiformes to Passeriformes), our list excludes aerial feeders, owls, raptors and waterbirbs. Further observations on the avifauna of Etna were carried out in March, April and August to October to complete the list of breeding birds.

We generated the following indices:

1) rarefaction curves; rarefaction of expected number of species E (Sn) with regards to decreasing density of individuals allowed us to build up rarefaction curves (cf. James & Rathbun, 1981). Starting from the fact that (a) frequency obtained from EFP method is highly correlated to the log of abundance, and (b) authors calculate diversity index from the frequency values (Blondel, 1975), we produced the rarefaction curves by the frequential densities achieved in the ten habitats of Etna. To avoid bias due to the different number of point counts performed in each habitat, the number of species in the smallest sample (that is the habitat in which the smallest number of point counts was performed) was taken as the standardized sample size. We related all the censuses in each habitat to the latter, namely the mature oak wood (cf. Hurlbert, 1971; Heck *et al.*, 1975; James & Rathbun, 1981). At the same time, the trend of the rarefaction curves gives information on species-richness, diversity and evenness.

2) Habitat breadth $e^{H'}$, that is the natural exponent of the Shannon diversity (Whittaker, 1972), $H' = -\Sigma\, p(i) \times \ln p(i)$, where p(i) is the frequency of each species in nine of the ten examined habitats (edge habitat was omitted because other habitats are included in it).

3) Frequency curves (avifauna structure) were obtained by correlating the log of the frequency to the species rank (James & Rathbun, 1981).

4) Similarity between the ten habitats calculated from the species frequencies:

$$\alpha\ jk = 2\ \Sigma p(i)j \times p(i)k/(\Sigma p(i)j^2+\Sigma p(i)k^2),$$

where p(i)j and p(i)k are the frequencies of the species i in the habitats j and k (Horn, 1966). It allowed us to construct a dendrogram of habitat overlap.

RESULTS

Appendix 1 lists the 55 species detected over the ten habitats examined. For each species the maximum altitude at which it was observed and its status (sedentary or migrant breeder) are given. The other 22 species, the breeding of which has been confirmed or supposed (excluded from the point-counts) are listed in Appendix 2. The 77 species found on Etna are about 60% of the species breeding in Sicily as a whole. For 73 of these 77 species breeding on the volcano, Sicily is well within the ranges of their distributions, while for the remaining four (*Sitta europaea, Corvus corone, Aegithalos caudatus* and *Carduelis spinus*) Sicily is at their southern limit. Only the latter two species show a very low frequency, which is typical of marginal zones (Hengeveld & Haeck, 1982).

Table I shows for each habitat the mean number of species or the mean richness, the total number of species or total richness, the number of expected species at the total frequency of 25 (based on rarefaction method), the number of species having a frequency higher than 25% («common species») and less than 25% («scarce species»), the mean value of the habitat breadth, the number of species restricted only to one habitat, the percentage of sedentary species, and the mean number of vegetation layers. The habitats in Table I are arranged according to the decreasing value of the mean richness.

Both bushy high-mountain habitat and edge habitat harbour three species that are restricted to these habitat types. They are probably the most ecologically specialized.

The number of «common species» and the mean richness recovered in the ten habitats shows a parallel trend ($r = 0.46$; $P = 0.09$). The mean richness and the expected number of species at the total frequency of 25 are highly correlated ($r = 0.83$; $P = 0.002$). The highest number of «scarce species» has been observed in the edge habitats, in the Mediterranean maquis, in the oak thicket and in the mature pine wood. Edge habitats and oak thickets had the greatest total richness. The lowest number of sedentary species was observed in the thorny and bushy vegetation of the highest altitude and in the edge habitats, while the highest number has been detected in the mixed mature wood, in the unevenly aged and in the mature pine woods.

Linear regressions of log of the frequency on the species ranks (Table II) were all significant. The steepest slopes are typical of species-poor communities. High frequencies of species of the first ranks occur in ecological models with generally high dominance, e.g. Motomura model (cf. Daget, 1976). A steep slope corresponds to a low evenness, so a high species richness should be opposite to the value of the slope. We found the steepest slopes in the even aged mature pine wood and in the thorny and bushy high mountainous habitat, while the shallowest was obtained in the edge habitats and oak mature wood.

TABLE II - *Linear regression of the log of frequency on the bird species rank in the ten habitats studied on Etna. Habitats are arranged according to the decreasing value of the slope of linear regression. The high values of slopes correspond to low values of evenness. Letters in brackets refer to habitats listed in the methods.*

Even aged mature pine wood (I)	$y = -0.065x + 1.20$	$r = -0.966$
Thorny and bushy high mountainous habitat (A)	$y = -0.063x + 1.23$	$r = -0.964$
Mediterranean maquis (B)	$y = -0.049x + 1.09$	$r = -0.971$
Mature pine wood mixed with beeches (E)	$y = -0.047x + 1.10$	$r = -0.982$
Quercus thicket (C)	$y = -0.041x + 1.03$	$r = -0.989$
Uneven aged pine wood (G)	$y = -0.040x + 1.03$	$r = -0.951$
Young pine wood mixed with birches (F)	$y = -0.036x + 0.99$	$r = -0.968$
Uneven aged pine wood mixed with birches (H)	$y = -0.033x + 0.97$	$r = -0.943$
Quercus mature wood (D)	$y = -0.029x + 0.97$	$r = -0.907$
Edge habitats (L)	$y = -0.029x + 0.86$	$r = -0.986$

Figure 1 shows the estimated species accumulation rates. The relative evenness of groups of bird communities may be compared by means of rarefaction curve trends. We found more sloped curves, corresponding to greater evenness, in the bird communities of oak mature wood (D) and edge habitats (L), and flatter curves in the high mountainous bushy habitat (A) and mature pine wood (I). Communities of the other habitats show intermediate curves. The differences among the communities could reflect a true difference in community organisation.

Finally a dendrogram of habitat similarity shows that the thorny and bushy high mountainous habitat (A) is the most distinct type (mean value of overlap with other habitats: 14%) (Fig. 2). Three main groups are recognized: the first includes the Mediterranean maquis (B) and the edge habitats (L); the second the mixed mature wood (E), the mature pine wood (I) and the unevenly aged pine wood (G); the third collates the oak mature forest (D) and the young pine wood mixed with birch trees (F) on the right; the oak thicket (C) and the unevenly aged pine wood mixed with birches (H) on the left.

DISCUSSION

The main results of this research are: a) high mountain thorny scrub is an ecologically isolated habitat; b) edge habitats have the highest bird diversity; c) the highest number of sedentary species inhabits the most mature habitats, and consequently these habitat types seem to be important for their evolution; d) within conifer stands we found the highest species richness in the uneven aged woods and in conifers mixed with broadleaves. We suggest that managers of the Regional Park of Etna should consider these points in projects concerning the volcano.

Species richness

High species richness in edge habitats was reported by Frochot (1979, 1987). The edge between two habitats constitutes a particular habitat with characteristics different from those of the simple sum or combination of the two others (see also Gates & Gysel, 1978). Probably the patches of shrubs among the trees allow light to penetrate more easily, and consequently the greater foliage volume allows for more numerous species of insects and birds. The interspersion of shrubby strips of land colonizing lava beds supports regular relationships between bird communities of the Mediterranean maquis and thorny and bushy high mountainous habitat. Indeed, the increase of «scarce species» characterizes the edge habitats: 53% of bird species living there have a frequency less than 25%. It is interesting to observe that shrubby habitats harbour the lowest percentage of sedentary species (Table I). Sedentariness indeed may be considered a typical parameter of species colonizing and evolving in mature habitats.

The mean richness in pine woods mixed with birch trees, probably depends mainly on the abundance of birches, as conifers support fewer species of birds than broadleaves. Table III shows the number of species having a frequency higher than 25% detected in European forests (from Muller, 1985), in Morocco (from Thévenot, 1979), in Corsica and on Etna (pers. obs.). The number of species living in conifers is always

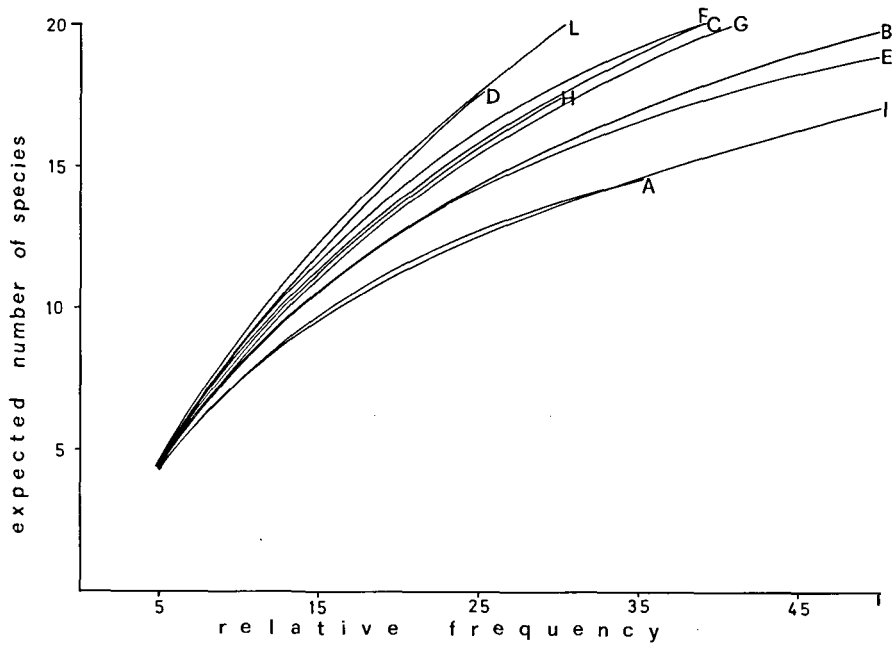

Fig. 1 - Rarefaction curves, i.e. expected number of species with regards to the decreasing frequency of individuals. Letters (A - L) refer to the ten habitats reported under «Methods».

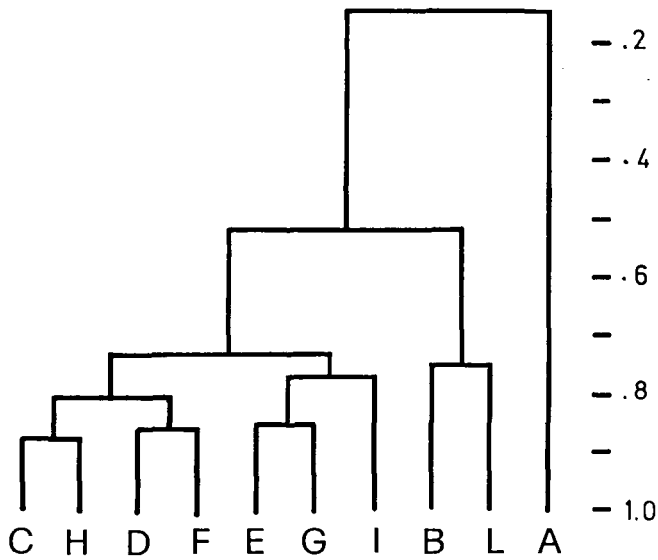

Fig. 2 - Dendrogram constructed from the Horn (1966) overlap index between the ten habitats, calculated on the basis of species frequency. A = Thorny and bushy high mountainous habitat; B = Mediterranean maquis; C = *Quercus* thicket; D = *Quercus* mature wood; E = Mature pine wood mixed with beeches; F = Young pine wood mixed with birches; G = Uneven aged pine wood; H = Uneven aged pine wood mixed with birches; I = Even aged mature pine wood; L = Edge habitats.

TABLE III - *Number of species having a frequency more than 25% in mature woods of Europe (from Muller, 1985), Morocco (Thevenot, 1979), Corsica and Etna. n.a. = data not available.*

	Number of «common species»		
	Broadleaves	Mixed woods	Conifers
Europe	30.5	35	27
Morocco	18-22	n.a.	19
Corsica	20	14	9
Etna	20	14	10

lower than in broadleaves. Conifers are typical woods of northern latitudes and this probably accounts for the lower number of species living in this habitat in Morocco, Corsica and Etna; the insular effect probably causes the particular bird poorness of Corsica and Etna conifers. Therefore, it appears that the increase of mean richness within conifers mixed with birches on Etna depends chiefly on the presence of broadleaves and secondarily on the uneven-age of pines.

The total richness shows a different trend. As reported in Table I, the mean number of canopy layers of the habitats having the highest total richness is greater than in other habitats and consequently the total richness should be an indirect measure of the vegetation structure.

Habitat breadth

In the communities of bird species found living in the shrubby or young habitats, we found a lower mean value of habitat breadth than in the more mature ones (Mann-Whitney U-test; $P < 0.05$). Birds inhabiting woods on Etna have a wider ecological niche, also spreading their distribution into the shrubby habitats. This phenomenon seems to be characteristic of insular mature habitats (cf. Martin, 1982). The mean value of the habitat breadth shows an inverse correlation with the mean richness ($r = -0.69$; $P = 0.018$). According to Fox (1981), this function depends on the interference of species: species that exploit only a few habitats (low breadth value) can coexist with many other species, without interfering with them.

Inter-habitats overlap

It seems that the overlap of bird communities reported in Figure 2 follows (with some exceptions) a gradient of the physiognomy and structure of vegetation, and secondarily altitude and type of vegetation. The close similarity between the oak wood and the pine wood mixed with birches again suggests the importance of bird trees interspersed within the pine woods for the bird communities.

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APPENDIX 1 - *List of terrestrial breeding birds (Columbiformes to Passeriformes), and their frequencies in the ten examined habitats of Etna. Status: s. = sedentary or mainly sedentary species; s.b. = only summer breeding species, not wintering on Etna. Max. altitude = meters above sea level at which the species has been observed on Etna.*

Species	status	Max altitude	Thorny and bushy high mountainous habitat	Mediterranean maquis	*Quercus* thicket	*Quercus* mature wood	Mature pine wood mixed with beeches	Young pine wood mixed with birches	Uneven aged pine wood	Uneven aged pine wood mixed with birches	Even aged mature pine wood	Edge habitats
Columba palumbus	s.	1800			29	67		11	80	40		
Streptopelia turtur	s.b.	1100		20	14	33						
Cuculus canorus	s.b.	1800	11	10	48	33	30	33	20	60	7	40
Upupa epops	s.b.	1800		10	19			33	20	80	7	20
Jynx torquilla	s.b.	1700			9			11		20		10
Picoides major	s.	1800			33	67	60	55	80	60	73	15
Galerida cristata	s.	1000		10								10
Lullula arborea	s.	1800	44		5	33		11	20	40		15
Alauda arvensis	s.	2300	44									
Anthus campestris	s.b.	2300	22									
Motacilla alba	s.	1800										5
Troglodytes troglodytes	s.	2300	22	20	76	67	60	77	40	60	13	80
Erithacus rubecula	s.	1800			71	67	80	44	40	80	60	15
Luscinia megarhynchos	s.b.	1200		100	19	67		44				55
Phoenicurus ochruros	s.	1800	33				30	33	20		13	15
Phoenicurus phoenicurus	s.b.	1800										5
Saxicola torquata	s.	2000	33	20								40
Oenanthe oenanthe	s.b.	2000	55									25
Oenanthe hispanica	s.b.	1850	11									
Monticola saxatilis	s.b.	1800	11									10
Monticola solitarius	s.	1500	11	50								15
Turdus merula	s.	2000		50	71	100	40	77	40	80	13	35
Turdus viscivorus	s.	1700			9					20		
Cettia cetti	s.	850		10								
Cisticola juncidis	s.	1400	11	10								
Sylvia conspicillata	s.b.	2200	67									25
Sylvia cantillans	s.b.	1800		90	19	67	20	89		20		65
Sylvia melanocephala	s.	1300		90								20
Sylvia communis	s.b.	1760										5
Sylvia atricapilla	s.	1800		80	86	100	100	100	60	80	60	60
Phylloscopus collybita	s.	1800			38	33	80	22	100	60	7	10
Regulus ignicapillus	s.	1800			14				20			
Aegithalos caudatus	s.	1800			9							
Parus ater	s.	1800			71	67	100	77	80	60	100	55
Parus caeruleus	s.	1800			43		10	33		80	27	15
Parus major	s.	1800		70	38		20	33	20	60	60	60
Sitta europaea	s.	1600			9				20	40		
Certhia brachydactyla	s.	1800			29		40	22	100	100	100	30
Oriolus oriolus	s.b.	1500			9	33						
Lanius senator	s.b.	1800		10								5
Garrulus glandarius	s.	1700			43	33	10	44		40	27	25
Pica pica	s.	1800			19			22	20		27	10
Corvus corone	s.	1800			5		20	11			13	15
Passer hispaniolensis	s.	1900		60	9							60
Passer montanus	s.	1800		10								15
Petronia petronia	s.	1800	11									5
Fringilla coelebs	s.	1800		20	81	67	100	67	100	80	100	45
Serinus serinus	s.	1800		50	19	33	20	67	40	60	13	65
Carduelis chloris	s.	1850		10	33	33	30	33	20	20	13	30
Carduelis carduelis	s.	1800		40	5		20				13	40
Carduelis cannabina	s.	2200	67	20	5	33	50		40	20		25
Loxia curvirostra	s.	1800									7	5
Emberiza cirlus	s.	1800		60	19	33	20	55				65
Emberiza cia	s.	1800	44				70	33	40	20		10
Miliaria calandra	s.	1600		20								15

APPENDIX 2 - *Birds breeding on Etna detected apart from the point count method. c = confirmed breeding; pr = probable breeding; ps = possible breeding according to the bird Atlas criteria.*

Species	
Accipiter nisus	pr.
Buteo buteo	c.
Aquila chrysaetus	ps. (Dimarca, Sarà, *pers. comm.*)
Falco tinnunculus	c.
Falco peregrinus	pr.
Alectoris graeca	c.
Coturnix coturnix	c.
Columba livia	c.
Tyto alba	c.
Otus scops	c.
Strix aluco	c.
Asio otus	pr. (Ciaccio & Siracusa, 1985)
Caprimulgus europaeus	pr. (Sarà, *pers. comm.*)
Apus apus	c.
Calandrella brachydactyla	c.
Ptyonoprogne rupestris	pr.
Delichon urbica	c.
Motacilla cinerea	c.
Corvus monedula	c.
Corvus corax	c.
Sturnus unicolor	c.
Carduelis spinus	pr. (1984), c (1985)

Note

Picus viridis: one individual observed on 22 Nov 1981 near Bronte (F. Tassi, *pers. comm.*) and possibly another on May 1982 (A. Priolo, *pers. comm.*); as this species has became extinct in Sicily, according to bird Atlas criteria, the possibility of breeding cannot be considered; its presence on Etna could be attributed to an immigration attempt from the continent.