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Song clinal variability in *Passer italiae*, a species of probable hybrid origins

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Abstract - Songs are commonly used to measure the clinal variation in hybrid zones. The Italian sparrow populations are currently considered as stabilised hybrids. Their range is delimited by two contact zones: Alpine area and Sicily island with two parental species, *Passer domesticus* (North European species) and *Passer hispaniolensis* (North African and south Mediterranean islands species) respectively. The Italian sparrows (*Passer italiae*) show intermediate traits according to genotypic and phenotypic clinal variation through the Italian peninsula.
In an analysis of song display in Italian sparrow we have used the male territorial marker song as distinctive display between populations. We have recorded and compared the song of male Italian sparrows with those of the two parental species using spectrogram analysis. By multivariate analysis we have found a clinal variation from *P. hispaniolensis* to peninsular Italian sparrow. This pattern is broken in the Alps where Italian sparrow populations and *P. domesticus* show similar song structure among each other.
This work and other recent studies are concordant to consider *Passer italiae* populations derived from North African sparrow populations.

Introduction

Songbirds use different songs in different situations (Andersson 1994); mate attraction and territory defense are seen as the main functions of song. All the species have a different song that can be recognizable by other members of the same species. Song type is not strictly dependent on the genetic pattern but it is clearly indicative in the evolutionary and phylogenetic problems (Baker 1974, Malacarne 1989); it is even one of the most commonly used measures of clinal variation in hybrid zones (Martens et al. 1994). Birds from the contact zone that sing intermediate or aberrant songs are usually considered hybrids (Mark et al. 1986).
In the genus *Passer* there are several examples of closely-related forms whose taxonomic *status* has been discussed for a long time.
Passer italiae (Vieillot 1817) is endemic in Italy and Corsica island (Thibault 1983). Its range is delimited by two contact zones: Alpine area (with *Passer domesticus*, a typically man-dependent continental species) and Sicily (with *Passer hispaniolensis*, a typically Mediterranean species that occupies more natural environments). Italian sparrow populations (*P. italiae*) are phenotipically different and geographically isolated from the two parental species, and at present it is considered to be a **stabilised hybrid** between the two parapatric species (Meise 1936, Mayr 1963, Johnston 1969), see Massa (1989), for a review. Italian sparrow populations show genotypic and phenotypic clinal variation and intermediate traits between *P. hispaniolensis* and *P. domesticus* ranges (Johnston 1972, Lo Valvo and Lo Verde 1987, Fulgione and Milone 1998).
In this work we try to establish if song traits of Italian sparrow show similarities with the ones of the two parapatric species, and if they change along Italian peninsula according to other phenotypic and genotypic characteristics. Thus, we have analysed clinal variability of song in Italian sparrow populations and compared it with two parental species.

Methods

During 1995-1996, fieldwork was conducted in 11 localities along Italian peninsula: 1) Palermo, Sicilia; 2) Vulcano, Eolie Islands; 3) Cosenza, Calabria; 4) Napoli, Campania; 5) Roma, Lazio; 6) Grosseto, Toscana; 7) Bologna, Emilia Romagna; 8) Ajaccio, Corsica; 9) Cavalese, Trentino; 10) Predazzo, Trentino; 11) Moena, Trentino. *P. domesticus* song was sampled in France (Paris) and *P. hispaniolensis* in Sardinian island (Fig. 1).

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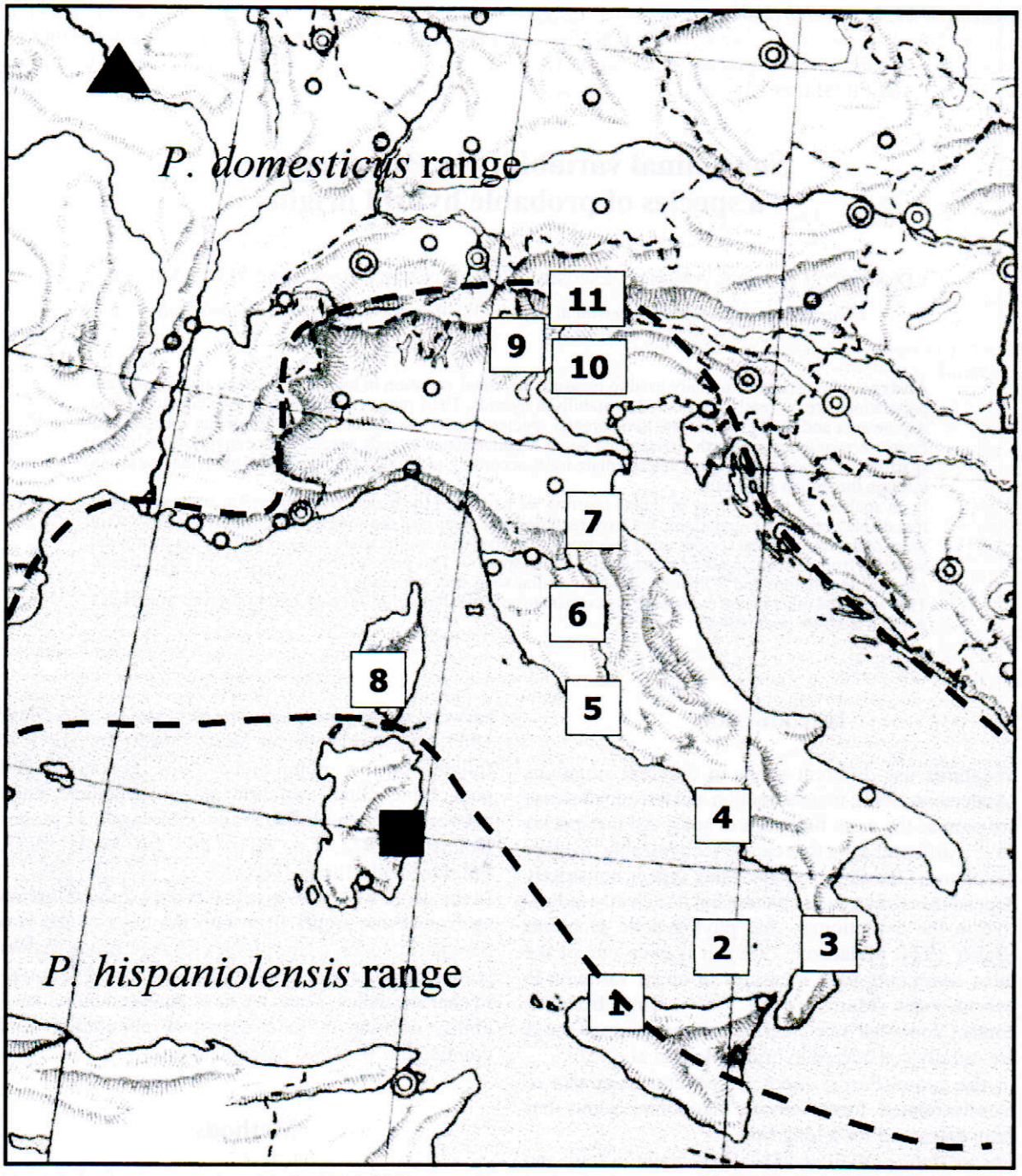

Figure 1. Range of sparrows studied and areas of sampled stations. The numbers represent distribution of populations sampled: 1) Palermo, Sicilia; 2) Vulcano, Eolie Islands; 3) Cosenza, Calabria; 4) Napoli, Campania; 5) Roma, Lazio; 6) Grosseto, Toscana; 7) Bologna, Emilia Romagna; 8) Ajaccio, Corsica; 9) Cavalese, Trentino; 10) Predazzo, Trentino; 11) Moena, Trentino. Square and triangle represent *P. hispaniolensis* and *P. domesticus* populations respectively.

All the populations that we have considered from Italy and hybrid zone as Alpine arc, have been identified as *P. italiae* only if they have typical taxonomic pigmentation: crown brownish and black bib more extensive than *P. domesticus* (Stephan 1986).

For our analysis we have chosen the basic syllable

used by males in song-display at nest to attract females in pair-formation (Cramp and Perrins 1994). This syllable represents the predominant song activity (about 30% of total time) during the nestling period (Metzmacher 1990). This basic call is monosyllabic and it can be strung together to form a song. It is used basically as a nest ownership proclamation call and, as such as, it can also function as an invitation to pairing by an unmated male (Summers-Smith 1988).
Ten adult sparrows were sampled for each population, using an Aiwa tp500 cassette recorder at a speed of 19.5 cm/s with a Sennheiser ME-88 shotgun microphone. Each individual is recorded for a term of 15 seconds in which it string together about 20 time the basic syllable. Spectrograms were made for each type of song recorded from each bird using software Avisoft-SAS Lab for Windows. We have utilized the following setup: time resolution of 1,45 ms depending by an overlap of 93,75%; the FFT-length 256 points, the bandwidth 161 Hz and the part of the FFT-length used for spectrum computation is 100%.
According to Nemeth (1996) we considered an element as a contiguous trace on the spectrogram. If elements are separated by more than 10 milliseconds (ms) they are treated as syllables.
All different songs for each population are recorded, digitized and stored on a specific computer directory. All selected spectrograms are compared one to each other to check the similarities of several populations' songs. Comparison is done by analyzing every spectrograms starting from t_0 to t = 100ms. In this range we measure the frequency every 10 ms (Fig. 2).

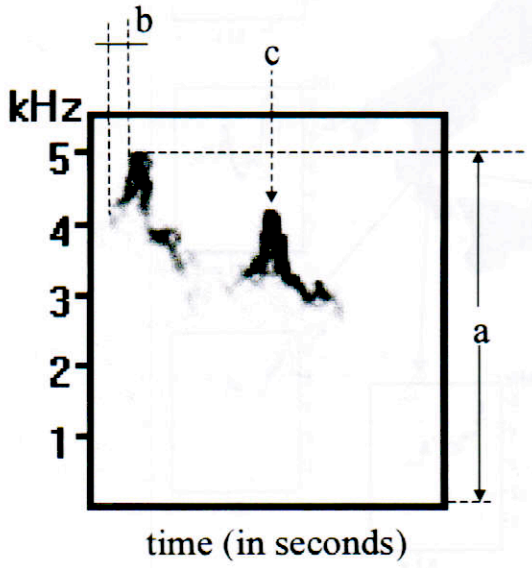

Figure 2. Measurements utilised for syllable analysis; **a**, maximum frequency; **b**, sliding step for scan analysis (10 ms); **c**, third peak in the syllable.

All the frequencies' values are used to build a numeric vector representing each single syllable of a specific population. Every numeric vector is compared by multivariate analysis (Principal Component with specific software SYNTAX IV, Podani 1991) to asses the bidimensional ordination of 13 population.

Results

By spectral analysis we can appreciate the difference in songs between two species *P. hispaniolensis* and *P. domesticus* (Fig. 3a). In fact, North European *P. domesticus* shows a brief song (116 ms) structured by three peaks: the first shrill reaches 4220 Hz (SD = 63.7), the second 3703 Hz (SD = 42.3) and the third 3832 Hz (SD = 51.0). Instead, *P. hispaniolensis'* song is lasts about 130 ms and its structure is differently elaborated: it starts with a shrill (peak at 5426 Hz; SD = 21.1), the second peak is at 4091 Hz (SD = 5.7), the third at 4306 Hz (SD = 2.9) and it finishes with a trill at 3229 Hz (SD = 15.6). There is another trait that can distinguish the general structure of syllable in the two species: in *P. hispaniolensis*, we can note a descendant peak (*b* = - 637.6 in the regression line), while in *P. domesticus* the first and the third peak have a similar frequency (*b* = - 194.0).
The song structure of Italian sparrow populations, recorded from peninsula, shows a high structural variability either in the pattern and in the duration.
Usually in the North populations the pattern of song is like to *P. domesticus'* structure. In fact, their first peak makes round and does not exceed 5000 Hz, furthermore the general pattern of the syllable is structured in three principal high peaks. On the other hand Southern populations show the first peak similar to a shrill that always exceeded the 5000 Hz and the descendent other notes.
Spectrogram of Corsican sparrows is different from *P. hispaniolensis'* song, but it seems similar to the ones of some peninsular populations (Fig. 3b). In fact Corsicans' syllable show a first peak characterised by a distortion absent in *P. hispaniolensis*; moreover the third peak that in *P. hispaniolensis* has the same frequency of the first, than it is in Corsican population much lower. These two traits are present in a lot of peninsular populations like in Tuscany, Campania and Calabria.
We have used the value of scan analysis as variables to multivariate elaboration. The results show that the first two Principal Components account 68.5% of total variance (Tab. 1). The 13 populations examined have be ordered utilising the first

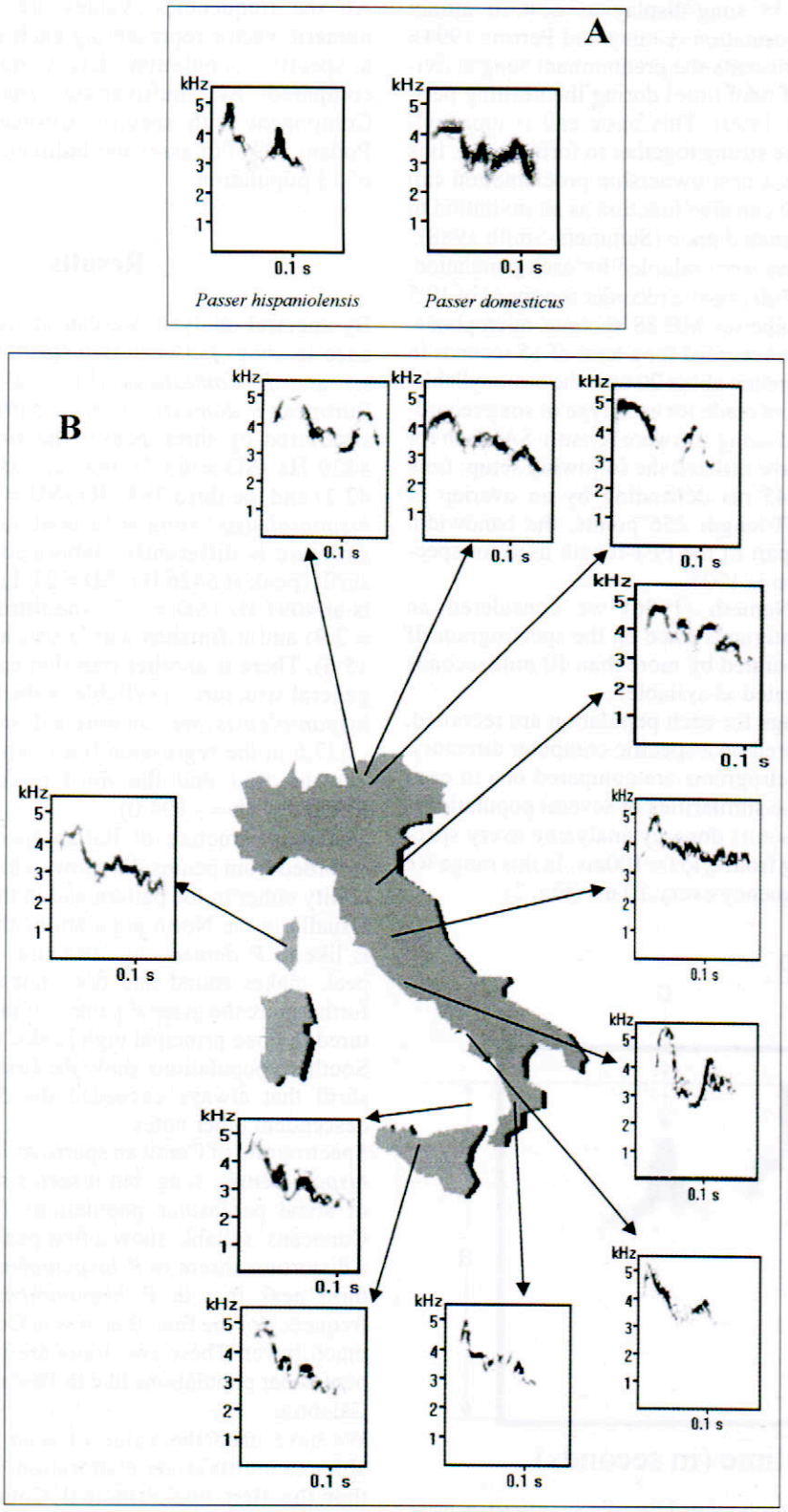

Figure 3. A) Spectrogram of *P. hispaniolensis* and *P. domesticus*, they are referred to Sardinian and French populations respectively. B) Bio-acoustic variability trough Italian peninsula of syllable song in Italian sparrow populations (see figure 1 for their localizations).

Table 1. Eigenvalues of two Principal Component.

Eigenvalues	Eigenvalues as percent	Cumulative percentage of eigenvalues	Square roots of eigenvalues
3.758	41.76	41.76	1.938
2.407	26.74	68.50	1.551

two Principal Components and their latitudinal value (Tab. 2, Fig. 4). The graph shows a general dispersion characterized by clinal variation interposed by *P. domesticus* and *P. hispaniolensis*. The position of Alpine arc populations is affected by *P. domesticus* contact zone (Moena, tr1; Cavalese, tr2; Predazzo, tr3).

Localization of Corsican songs on the graph occupied an intermediate position between the two principal groups, but different from each the songs.

Discussion

The differences found in the song of two species *P. domesticus* and *P. hispaniolensis*, according to other authors (Summers-Smith 1988, Cramp and Perrins 1994), probably reflect respective ecological segregation. *P. hispaniolensis* lives in natural environments where it uses a more elaborated song, with "laborious" shrill and trilling; *P. domesticus* is a more urbanized species that shows a simple song without strong notes, useless in this "troubled" environment. The differences between the two parental species allow to measure the geographical introgression that affects Italian sparrow populations and allow to establish

Table 2. Loading of two Principal Components and Latitude value of 13 populations exanimate. **P. hispaniolensis'* latitudinal value was assumed southern of Sicilian population according to his ranges in the Mediterranean basin.

	PC1	*PC2*	*Latitude value*
P. hispaniolensis	-0,50	1,82	37°06'*
P. italiae (Sicilia)	1,00	1,60	38°07'
P. italiae (Isole Eolie)	2,52	1,57	38°23'
P. italiae (Calabria)	1,26	1,06	39°17'
P. italiae (Campania)	0,01	0,65	40°50'
P. italiae (Lazio)	-1,70	0,30	41°53'
P. italiae (Toscana)	-2,43	0,41	42°46'
P. italiae (Emilia Romagna)	-2,19	0,65	44°30'
P. italiae (Trentino-Moena)	-3,17	-0,41	46°22'
P. italiae (Trentino-Cavalese)	-0,30	-1,63	46°17'
P. italiae (Trentino-Predazzo)	-0,20	-1,30	46°18'
P. italiae (Corsica)	1,70	0,00	41°55'
Passer domesticus	1,09	-3,14	48°51'

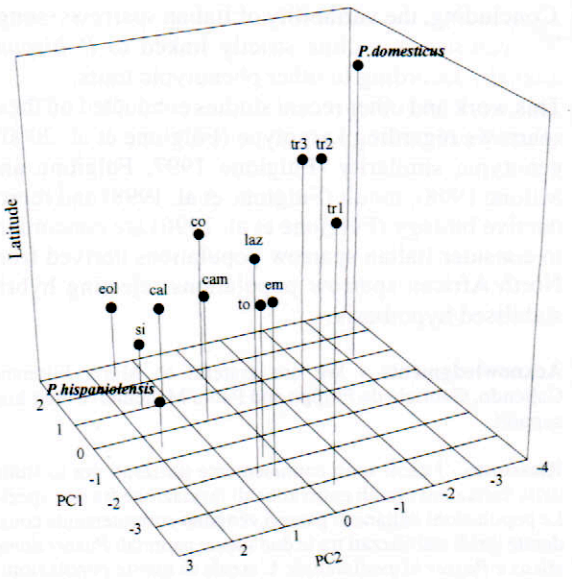

Figure 4. Cross relation between latitudinal value of examined populations, and Principal Component Analysis, using correlations, of 10 characteristic frequencies (variables) of the 13 syllables examined (objects). In the graph: **si**, Sicilia; **cal**, Calabria; **eol**, Eolie; **cam**, Campania; **co**, Corsica; **laz**, Lazio; **em**, Emilia Romagna; **to**, Toscana; **tr1**, Moena; **tr2**, Cavalese; **tr3**, Predazzo.

patterns of variation of this characteristic along the peninsula.

In previous works (Robbins et al. 1986, Martens 1996) about hybrid zones' song, syllables were strictly intermediate and the entire contact zone sample was distributed unimodaly along an intermediate mean. Italian sparrow's song shows an high level of diversification between all examined populations. However, the Italian sparrows' syllables show a general similarity to those of *P. hispaniolensis* more than to *P. domesticus*. In fact, for example, all syllables recorded in Italy and in its neighbor islands (Eolie) show a first shrill note like *P. hispaniolensis*. Only the Alpine sparrow, (morphologically like-Italian sparrows) breaks this pattern showing the first note to make round like in *P. domesticus*.

By multivariate analysis it is possible to note that the diversification showed by peninsular sparrows is distributed according to geographical cline.

It is very interesting to note that Corsican populations confirm to be different from Sardinian populations: in fact, the multivariate analysis shows that the structure of the syllable is located in an intermediate position between two groups even if it is different in range from that of other peninsular populations. This results accord to Thibault (1983) who considered Corsican population part of Italian sparrow populations and not of the closest Sardinians'.

Concluding, the variability of Italian sparrows' songs is organised as a cline strictly linked to *P. hispaniolensis*, according to other phenotypic traits.
This work and other recent studies conducted on these sparrows regarding karyotype (Fulgione et al. 2000), genotypic similarity (Fulgione 1997, Fulgione and Milone 1998), moult (Fulgione et al. 1998) and reproductive biology (Fulgione et al. 1996) are concordant to consider Italian sparrow populations derived from North African sparrow populations rejecting hybrid stabilised hypothesis.

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Riassunto - I canti sono comunemente utilizzati per lo studio delle variazioni clinali entro zone di ibridazione fra due specie. Le popolazioni italiane di passeri vengono correntemente considerate ibridi stabilizzati tra le due specie parentali *Passer domesticus* e *Passer hispaniolensis*. L'areale di queste popolazioni è compreso fra due zone di contatto: le Alpi a nord e la Sicilia a sud. Diversi tratti fenotipici e genotipici dei passeri italiani evidenziano una variazione clinale lungo la penisola.
In questo studio abbiamo utilizzato il canto territoriale del maschio come variabile distintiva delle popolazioni italiane e delle due specie parentali. Attraverso lo studio dei sonogrammi e l'elaborazione di alcune frequenze mediante analisi multivariata è stata individuata una variazione clinale fortemente influenzata dalla zona di contatto con *P. hispaniolensis*. Questa variazione viene interrotta a livello dell'arco alpino dove le popolazioni evidenziano una struttura delle sillabe molto simile a *P. domesticus*.
Tali prove ed altre provenienti da recenti lavori suggerirebbero una derivazione delle popolazioni di *Passer italiae* da popolazioni Nord Africane.

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