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Quantitative analysis of differences in the vocalizations of the Common Swift *Apus apus* and the Pallid Swift *Apus pallidus*

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Abstract - Multivariate analysis was used to assess acoustic features of the vocalizations of the Common and Pallid Swifts. One set of features, consisting of frequency and temporal patterns, set the two species quite apart. Previous differences based on subjective evaluations have been specified: Pallid Swift calls are on a lower frequency, especially the final part of the vocalization. This difference is discussed considering the features of Swift environment. However, we have no conclusive evidence as to whether these differences play a role in reproductive isolation between the two species.

Key words: *Apus apus*, *Apus pallidus*, multivariate analysis, reproductive isolation,screaming calls

The Pallid Swift *Apus pallidus* is a prevalently Mediterranean species with a marked resemblance to the Common Swift *Apus apus* . Their resemblances is so strong that prolonged views in constant light are needed to appreciate the slight differences in colour and shape. The flight of the Pallid Swift strongly resembles that of the Common Swift, although the wing action is often slower (Cramp 1985). In areas where the two overlap such as in Italy, France or Spain, the same building may house both species. Examples of this are encountered in both urban and rural areas in Piemonte (Northern Italy) such as Torino, Saluzzo, Moncalieri and Carmagnola (Boano 1979, Cucco and Malacarne 1987). Around their colonies the two species mix while performing evening and morning communal screaming displays (Finlayson 1983 fide Cramp 1985, pers. obs.). There are no observations of hybridization, nor of any mixed pairs, it is therefore likely that effective reproductive isolation mechanisms are at work. One of these mechanisms may be the calls: the screaming call is the principal vocalization of the swifts during displays around their colonies and also of the breeding pairs at the nest in duet (Lack & Lack 1952). The Pallid Swift's calls have been described as similar to Common Swift but "deeper and less shrill", sometimes at least disyllabic (Cramp 1985). A subjective and qualitative description of the differences in vocalization reported for swifts and other birds is however an unsatisfactory method, relying frequently on ambiguous terms. Quantitative methods have provided to be useful to better specify differences between individuals, populations or species. Multivariate analysis represent a recent development (Mundinger 1982). Sparling and Williams (1978) discussed "pros and cons" of different analysis applied to Laysan and Black footed albatross vocalizations. Lately Martindale (1980) critically reviewed the paper observing for example that discriminant analysis alone is appropriate as tools for sorting sound in preestablished groups.

We have utilized discriminant analysis, considering frequency and time parameters of the two swift species, in order to statistically discriminate the two screaming calls, frequently described as being much alike.

MATERIALS AND METHODS

The study of Pallid and Common Swift calls was carried out in Carmagnola (Torino). The studied colony took residence in Palazzo Sant'Agostino, where yearly roughly 10 pairs of Pallid Swift occupy holes on the South-West facade, and 4 of Common Swift the western side. Nests were accessible from inside the building and recordings (cassette recorder Sony TC D5 pro) were made by placing the microphone (Sony ECM-23F) next to the nest where each bird or pair makes its screaming calls from. Eight Common Swift and 8 Pallid Swift voices have been recorded. Individually marked birds (Malacarne & Griffa 1987) were not sexed and probably we recorded both male and female voices. Recordings were analyzed with a Kay Elemetrics 7800 sonagraph set on wide band (0-8 KHz band frequency, 300 Hz band width). Four frequency parameters (IF = initial frequency; FF = final frequency; MnF = minimum frequency; MF = maximum frequency) and three temporal parameters (D = call lenght; T1 = time from IF to MF; T2 = time from MF to FF) were analyzed (Fig.1). Discriminant analysis was performed by a Systat program (Wilkinson 1986).

RESULTS

Table I summarizes descriptive statistical values of the measurements taken from the swift calls. Coefficients of Variation (CV) were similar for Common and Pallid swifts

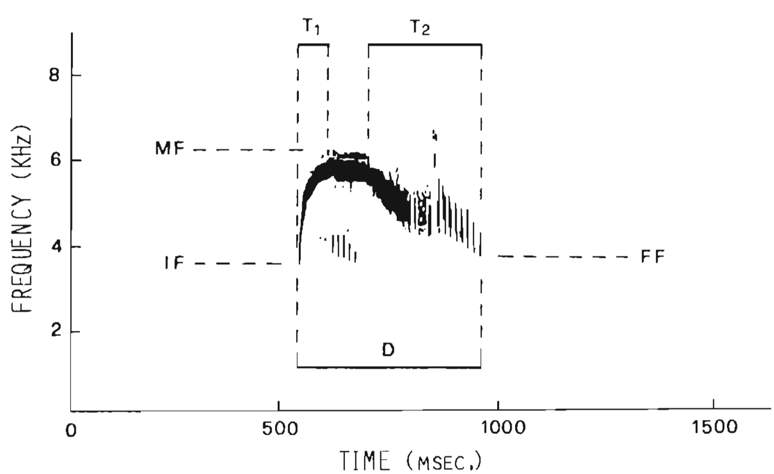

FIGURE 1. Parameters analyzing Swifts screaming calls (IF = Initial Frequency; D = Duration or Call lenght; T1 = Time to frequency peak; MF = Maximum Frequency; T2 = Time from peak to final frequency; FF = Final Frequency).

TABLE I. Descriptive and inferential statistic for the measured parameters in the two species.

Parameter		Pallid Swift (Means +/- CV) N = 8	Common Swift (Means +/- CV) N = 8	F value	P
Initial Freq.	(IF)	3843 +/- 12.4	4425 +/- 6.3	8.83	.010
Final Freq.	(FF)	3500 +/- 12.1	4387 +/- 9.3	18.16	.001
Maximum Freq.	(MF)	5740 +/- 10.4	6087 +/- 12.4	1.05	.322
Minimum Freq.	(MnF)	3462 +/- 12.0	4275 +/- 9.8	15.07	.002
Time	(T1)	82.5 +/- 21.8	185 +/- 34.5	19.06	.001
Time	(T2)	282 +/- 20.6	157 +/- 35.0	19.33	.001
Call length	(D)	365 +/- 17.1	343 +/- 14.5	0.638	.438

TABLE II. Discriminant function (canonical correlations between conditional dependent variables and indipendent canonical factor).

Parameter	Canonical loading
IF	0.429
FF	0.615
MF	0.148
MnF	0.560
T1	0.630
T2	-0.634

and T1 and T2 had the greater variance in both species. The univariate analysis of variance (ANOVA) shows significant differences for the parameters IF, FF, MnF, T1 and T2, while MF and D do not differ.

Call duration (D) was not considered in the subsequent multivariate analysis, being so similar in the two species. Discriminant Analysis shows that the two species have statistically different calls (Wilk's lambda = 0.226; $P<0.015$). Therefore, upon examination of the 6 call parameters, the species can be identified with a very small margin of error.

In Table II we observe canonical loadings of the 6 parameters: T2, T1 and FF mainly contribute to the discriminating function, having greater correlation with the canonical factor. Table III shows how acoustic features of the sonograms can predict the call-emitting species ($P<0.005$; Fisher's Exact Probability Test): there was only one case of mis-attribution.

The data show that frequencies are on average 0.5 KHz higher in the Common Swift compared to Pallid Swift and that the former have a longer T1. Moreover, in the Common Swift there is not a marked decrease in frequency during T2, as is present in the Pallid Swift. Therefore the sonographic trace of the Common Swift is bell-shaped (Fig. 2) and that of the Pallid Swift is irregularly concave shaped, with a short T1 and a decrease in frequency following (Fig. 3).

TABLE III. Matrix of the "a priori" predicted cases and the observed groups on the ground of the discriminant analysis.

		Predicted		
		Pallid	Common	Total
	Group 1	8	1	9
Observed	Group 2	0	7	7
	Total	8	8	16

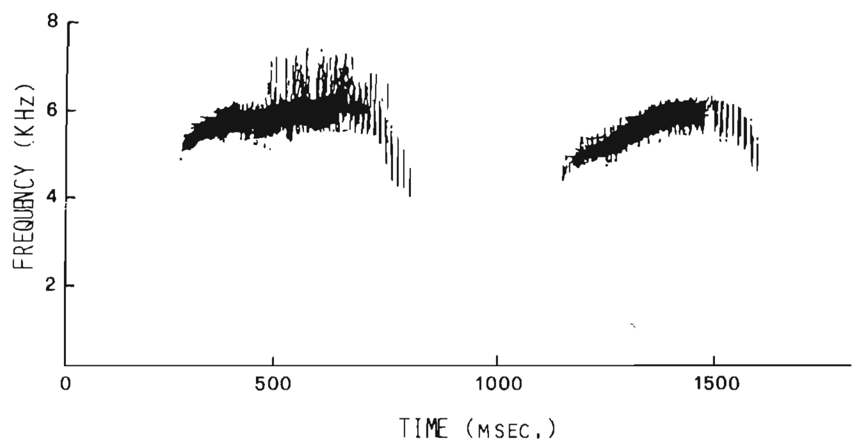

FIGURE 2. Two typical Common Swift calls.

DISCUSSION

Cramp (1985) give an onomatopoeic description of the differences between the two species which are better specified by our research. The Pallid Swift has a lower and less shrill call, because of the lower frequency and the decrease in frequency during T2. Burges description (fide Cramp 1985) of the occasional disyllabic call in the Pallid Swift is not confirmed.

Miller (1982) described the evolution of the characteristics of sound signals among related species, in relation with categories of habitat and/or behavioural traits. We can observe that:

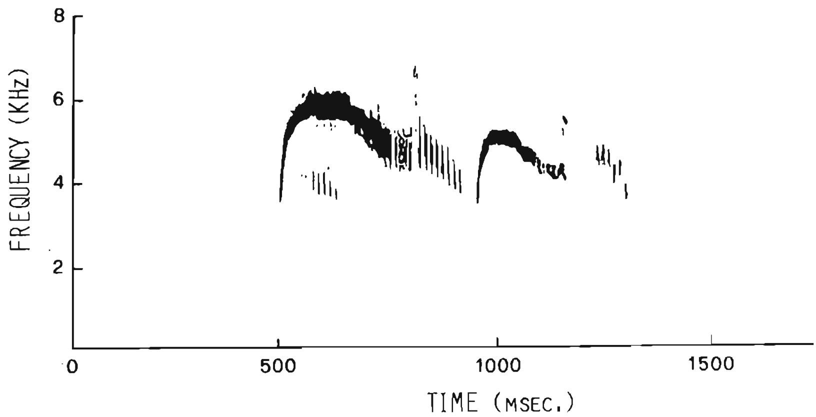

FIGURE 3. Two typical Pallid Swift calls.

a) the two species we studied belong to the category of birds (living in fairly simple and constant environments) that Miller (1982) identified as having characters and variance shifts in voice with occurred more frequently. Shifts should be especially pronounced in sounds used in mate attraction and territorial advertisement. Both functions, particularly the latter, seem true for the screaming calls produced by swifts around and within the colony.

b) Miller (1982) suggests that when a species exhibits shifts in acoustic signals, temporal features and time varying characteristic of frequencies are liked to change first; major change in the frequency spectra of sounds should be harder to evolve. In our opinion this prediction is supported by the differences between Common and Pallid Swift calls, wich vary mainly in their time frequency characteristics.

A still unsolved problem is if shift in acoustic signals is most liked to occur among related species for reasons related to hybridization. Some authors (e.g. Miller 1982) believe that this is not the case and argue that this phenomenon is probably less common and important than generally thought.

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RIASSUNTO

Analisi quantitativa delle differenze nelle vocalizzazioni di Rondone comune *Apus apus* e Rondone pallido *Apus pallidus*

- In alcune città e paesi mediterranei (Italia, Francia, Spagna) rondone comune e rondone pallido nidificano negli stessi palazzi, formando gruppi misti nei caroselli mattutini e serali intorno alla colonia. Per verificare l'eventuale ruolo delle vocalizzazioni nell'isolamento riproduttivo delle due specie, si sono analizzate quantitativamente le differenze spettrali e temporali delle grida delle due specie mediante analisti statistiche multivariate.
- Una componente, che tiene conto dei parametri di frequenza e dei tempi di ascesa alla frequenza massima e discesa da essa alla frequenza finale, discrimina nettamente le due specie.
- Vengono approfondite le differenze indicate in precedente letteratura, basate su rilevazioni soggettive, secondo cui le vocalizzazioni del rondone pallido sono più gravi e con spettro in calando più accentuato.
- Si discute sul significato di questa differenza alla luce delle caratteristiche ambientali in cui i rondoni vivono. Non è ancora chiaro se le differenze bioacustiche possono giocare un ruolo nell'isolamento riproduttivo delle due specie.

FIG. 1. Parametri utilizzati nell'analisi delle vocalizzazioni dei rondoni IF = Frequenza Iniziale, D = Durata, T1 = Tempo necessario per raggiungere la Frequenza Massima, MF = Frequenza Massima, T2 = Tempo intercorrente tra la Frequenza Massima e la Frequenza Finale, FF = Frequenza Finale.
FIG. 2. Due vocalizzazioni caratteristiche di rondone comune.
FIG. 3. Due vocalizzazioni caratteristiche di rondone pallido.
TAB. I. Statistica descrittiva ed inferenziale per i parametri considerati nelle due specie.
TAB. II. Funzione Discriminante: correlazioni canoniche tra variabili condizionali dipendenti e fattori dipendenti canonici.
TAB. III. Matrice dei casi predetti "a priori" e dei gruppi osservati sulla base dell'Analisi Discriminante.

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