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CORRELATED SEASONAL VARIATIONS OF COLOUR  
AND CHEMICAL SIGNALS SUPPORT THE OCCURRENCE  
OF A MULTI-CHANNEL SYSTEM OF COMMUNICATION  
IN THE ITALIAN WALL LIZARDS *PODARCIS SICULUS*

SUMMARY

The signals animals use in intraspecific communication are usually extremely conspicuous because they serve to convey honest information about their quality in order to maximize their mating success. Precisely because they are flashy, communication signals tend to increase the possibility of being detected by predators, leading to a reduction of individual fitness. There are different evolutionary solutions to solve this trade-off between the opposing requirements of camouflage and communication, including multi-channel signal systems, in which information is encoded in more than one type of signal. In the March-October 2019 period we characterized the dorsal colouration and the structure of the proteins of the femoral secretions in a sample of 228 male Italian wall lizards captured at the Certosa di Calci (Pi). The results of the analyses support the hypothesis that color and secretions may be part of a multi-channel communication system.

*Key words.* Intraspecific communication, visual signals, chemical signals, seasonal variation.

RIASSUNTO

*Le variazioni correlate stagionali di colore e segnale chimico supportano la presenza di un sistema di comunicazione multicanale nella Lucertola campestre Podarcis siculus.* I segnali che gli animali utilizzano nella comunicazione intraspecifica sono estremamente appariscenti perché servono per trasmettere informazioni oneste sulla propria qualità al fine di massimizzare il proprio successo di accoppiamento. Proprio perché appariscenti, i segnali comunicativi tendono ad aumentare la possibilità di essere rilevati dai predatori con una conseguente riduzione della fitness. Le soluzioni evolutive per risolvere questo trade-off tra le opposte esigenze di mimetizzazione e comunicazione sono diverse e comprendono anche i sistemi di segnale multicanale. Nel periodo marzo-ottobre 2019 abbiamo caratterizzato la colorazione dorsale e la struttura delle proteine delle secrezioni femorali in un campione di 228 maschi di lucertola campestre catturati presso la Certosa di Calci (Pi). I risul-

tati delle analisi supportano l'ipotesi che colore e secreti possano essere parte di un sistema di comunicazione multicanale.

*Parole chiave.* Comunicazione intraspecifica, segnali visivi, segnali chimici, variazioni stagionali.

## INTRODUZIONE

Research on animal signals has been carried out intensively in recent decades and is now a rapidly-growing interdisciplinary branch of zoology that involves a wide variety of biological sectors including genetics, developmental biology, reproductive biology and feeding ecology. The evolution of intra-specific signals is most often the result of the interaction between contrasting pressures rather than the outcome of one single factor (ENDLER, 1981). Indeed, individual signals involved in intraspecific communication are normally extremely conspicuous in order to convey honest information on the quality of the sender and serve both to fight off competing males and to attract mating partners. In contrast, conspicuous signals tend to increase the chance of being detected by predators, causing fitness reduction. Evolutionary solutions for reconciling the competing requirements of camouflage and communication include signal partitioning, signal resolution, signalling behaviour, or seasonal variation in signalling. A further solution is offered by multi-channel signal systems, in which information is coded in more than one type of signal (e.g., visual and chemical signals) in order to optimize the probability the receiver would be able to detect the information given the costs associated with each communication channel. Reptiles, notably lizards, offer an ideal model to check multi-channel signalling, as both visual and chemical signals are contemporaneously used for intraspecific communication in most species. A recent study (PELLITTERI-ROSA *et al.*, 2020) described seasonal variation in dorsal colouration of the Italian wall Lizards *Podarcis siculus* and related it to the background colour of vegetation, supporting the hypothesis that the green dorsal colouration in this species has a primary role in camouflage. However, a second study on the same species (STORNILO *et al.*, 2021) clearly demonstrated that the green colouration in males is more saturated and brilliant than in females, and the intensity of colouration peaks during the breeding season, supporting the hypothesis that green colouration in males plays a primary role in intra- and intersexual communication. In this study we compared the seasonal patterns of dorsal colouration and chemical signals of femoral pores in order to understand if colour and chemicals might be part of a multi-channel system of communication in this species.

## MATERIALS & METHODS

Data were collected from March to October 2019 in Calci (Tuscany, 43°43' N, 10°31' E), and 228 males were captured by noosing (Aut. PNM 0004217/2017), measured (SVL) and photographed adjacent to a Gretag-MacBeth Mini ColorChecker chart (24 colour references, 5.7cm × 8.25cm) in a 44 × 44 cm lightbox illuminated with two daylight 22 W circular neon tubes (Reporter 55100 Studio-kit). Each digital image was processed according to SACCHI *et al.* (2013). Femoral pore secretions were collected from individuals each month and analysed for protein composition following MANGIACOTTI *et al.* (2019).

### *Analyses*

Both colour and chemical data were summarized using a Principal Component analysis (PCA) and the scores of the first PCs were used as the dependent variable in statistical models. Seasonal variation was analysed through random intercept linear mixed models (LMM) including a single component cosinor function to model the effect of season. LMMs were fit in a Bayesian analytical framework available in the package JAGS 4.3.0 (<http://mcmc-jags.sourceforge.net/>), using flat priors for coefficients and intercept ( $\mu = 0$  and  $\sigma = 0.001$ ), and uninformative half-Cauchy priors ( $x_0 = 0$ ,  $\gamma = 25$ ) for both error and random effect.

## RESULTS

Results confirmed the seasonal pattern of variation of hue saturation and brightness observed in previous studies, with a peak between mid-February and late March. The analyses of the protein showed that the ensemble of protein clusters remained constant throughout the season, while changing its relative expression. Notably, the central region (29-50 KDa) decreased expression and the low-molecular weight region (< 29 KDa) and the region around 60 KDa did not vary, whereas two distinct bands in the high-molecular weight region (> 65 KDa) were expressed maximally later in the season.

## DISCUSSION

Our data show the occurrence of a clear correlation between seasonal pattern of expression of the green dorsal colouration and pore secretions in male Italian wall lizards, and support the hypothesis that colouration and chemical

secretions could be part of a multi-channel system of communication in this species.

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