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A hypomelanistic common lizard (*Zootoca vivipara*) from the Alps

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Abstract. Here we report on an unusual green-coloured hypomelanistic male common lizard found in the Southern Alps of Italy. The individual displayed a lack of ventral spots and an olive-green dorsal background colouration, and lacked most of the typical dorsal patterning found in other individuals. The individual was in good condition relative to other male common lizards. Hypomelanistic individuals have been reported in other lizard species and locations. Due to their rarity, little is known about their relative fitness compared to the typical colour phenotypes.

Keywords. Altitude, camouflage, colouration, green colouration, hypomelanism, rare phenotype

Introduction

Colour has been shown to play a role in many aspects of the ecology and behaviour of squamates, including predator avoidance through aposematism or crypsis (Valkonen et al., 2011; Allen et al., 2013; Orton et al., 2018), competition for mates or other resources (Amdekar and Thaker, 2019; Moon and Kamath, 2019), and thermoregulation (Clusella Trullas et al., 2007; Geen and Johnston, 2014; Muri et al., 2015). In addition to the striking interspecific diversity seen in this group, many squamate species are polymorphic with respect to colour, containing multiple discrete colour types or "morphs" which are maintained at varying frequencies in wild populations by factors such as predation (Capula et al., 1997), environmental variation (Muri et al., 2015), and frequency-dependent selection (Yewers et al., 2019). Examples of colour morphs in squamates include amelanism (complete absence of the pigment melanin), hypomelanism (significant reduction in melanin), melanism (increased abundance of melanin), axanthism (reduction in red and yellow pteridine pigments), and leucism (almost complete lack of pigmentation) (Bechtel, 1995).

Zootoca vivipara is a small insectivorous lizard from the family Lacertidae, found throughout much of northern Eurasia. Although globally *Z. vivipara* has the largest range of any extant terrestrial reptile (Horreo et al., 2018), in Southern Europe the species is mostly restricted to wet alpine meadows (Speybroeck et al., 2016). Individual lizards may live for 5-7 years, reaching reproductive maturity at age 2, with adult lizards ranging in size from 40-80 mm (snout-vent length) (Horváthová et al., 2013). The species is highly unusual in that it is reproductively bimodal: two oviparous (egg-laying) and four viviparous (live-bearing) lineages are known, with hybridisation and limited gene-flow occurring between populations with differing reproductive modes in some instances (Lindtke et al., 2010; Recknagel, et al., 2018a, 2021; Horreo et al., 2019).

As may be expected for a relatively abundant and widely distributed lizard, *Z. vivipara* displays significant intraspecific colour variation. Adults typically display a cryptic brownish dorsal colouration with dark brown patterns in the form of spots and stripes (Fig. 1). However ventral colour is highly variable in this species, ranging from white, to yellow, to orange in male lizards (Sinervo et al., 2007) and from yellow, to mixed yellow-orange to orange in females (Vercken et al., 2010). Variation in ventral colour in this species has been suggested to play a role in social behaviour and competition for resources, and different colour morphs may be maintained within populations through frequency-dependent selection (Sinervo et al., 2007; Vercken et al., 2010). More unusual morphs have also been reported. Melanic individuals are known to occur throughout the species range, with unusually high frequencies observed in some populations (Iković and

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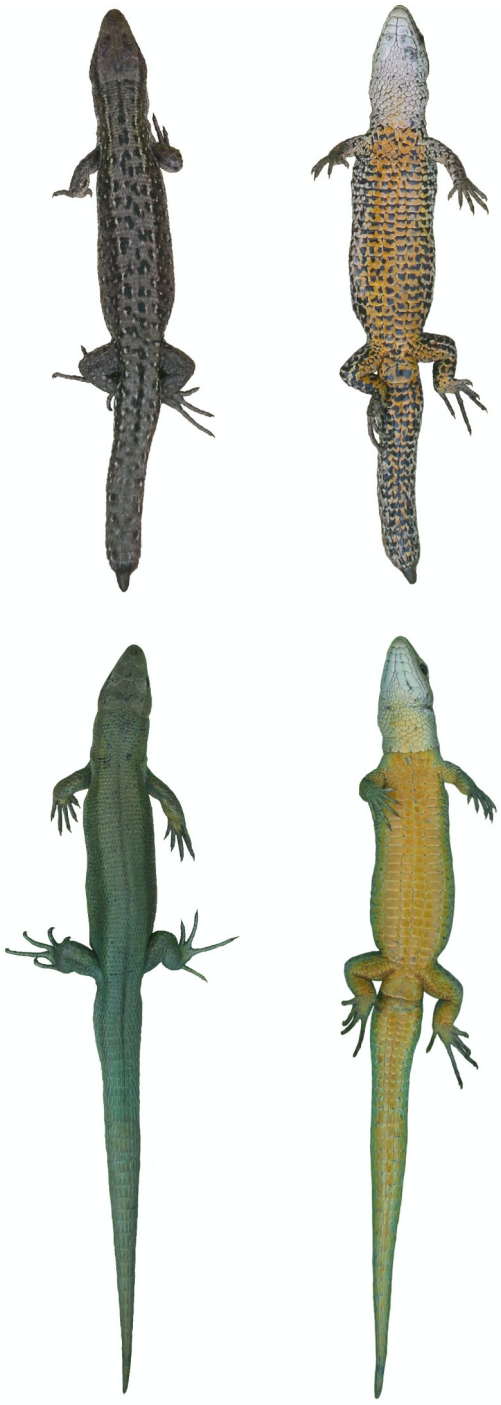

Figure 1. Colour variation in common lizards. On the top row a typically coloured male individual is shown. It exhibits a light/dark brownish dorsal colouration, and a yellow ventral colouration patterned with dark spots. Below the atypical green colour morph is shown, exhibiting an olive/greenish dorsal colouration and no dark spots on its ventral part.

Gvozdenović, 2014; Recknagel et al., 2018b). Green common lizards have also occasionally been observed (Dürigen, 1897; Simms, 1970). Related species of lacertids, such as the sand lizard *Lacerta agilis*, exhibit a wide range of rare colour morphs: the *erythronotus* (red-backed) and *immaculata* or *concolor* (patternless) morphs are known to occur at different frequencies in several populations (Gherghel and Strugariu, 2009; Nekrasova et al., 2018), and hypomelanistic, melanistic, yellow, and even blue sand lizards have also been documented (Blanke and Fearnley, 2015). However the scope and abundance of rare colour morphs are not well reported, and the mechanisms promoting such unusual colouration are not well understood. Here, we report an unusual hypomelanistic or green morph of the Eurasian common lizard, *Zootoca vivipara*, observed in the Piedmont region of Northern Italy.

Materials and Methods

A total of 35 common lizards (*Zootoca vivipara*) were collected non-invasively and non-lethally across the Southern Alps during June 2019 (*Table* 1). On 29 June 2019, four individuals of *Z. vivipara* were captured by hand around Lago di Morasco, in Piedmont, Italy (46.42557°N, 8.40552°E, at 1700 m elevation). The habitat was characterised by a marshy, grass- and moss- dominated vegetation, allowing for ample hiding space.

Images were taken of both the dorsal and ventral side of each lizard using a Canon 70D and a 60 mm fixed lens in a RAW format under standard settings (fixed ISO: 160, aperture: 8, exposure compensation: 0). An X-rite colour checker board was included in each image to standardise colouration between images. RAW images were converted to digital negative (DNG) copies and a colour profile for each image was generated using the X-rite ColorChecker software (version 1.0.1). Images were analysed in Adobe Photoshop CS6. After the colour profile was applied to the image, the white balance was selected for the off-white square on the x-rite colour checker board. The RGB values for the selected square were set to 230 nanometres using the eyedropper tool. Next, the dorsal background colouration of the last 1/3 of each individual was selected using the lasso tool. All scales that were part of patterning were excluded, and colour was then averaged across the selected area. As the final step, RGB values were extracted and the degree of 'greenness' was measured as the ratio of G/R and the formula (2G-R-B)/3 (Huang et al., 2015). No statistical tests were carried out due to the restricted sample size.

Table 1. Overview of sampling locations and number of individuals caught.

Site	Latitude	Longitude	N total	N females	N males	N juveniles
Vallarga-tintal (South Tyrol)	46.72995	11.85608	3	2	0	1
Einhäuserer Alm (South Tyrol)	46.76302	11.81572	2	1	0	1
Hofstatt Alm (South Tyrol)	46.82395	12.09585	8	4	2	2
Bagni di Salomone (South Tyrol)	46.82572	12.09027	1	0	1	0
Lake Antholz (South Tyrol)	46.88958	12.1685	3	0	3	0
Lago di Morasco (Piedmont)	46.42558	8.4054	4	0	2	2
Total			21	7	8	6

For each individual, a spring balance was used to assess body mass, while tail length (TL) and snout-vent length (SVL) were measured using digital callipers to the nearest 0.1 mm before being released at the site of capture. Body condition was calculated for the adults only, using residuals from a linear regression of body mass and SVL (Schulte-Hostedde et al., 2005; Bestion et al., 2014).

Results

Of the 21 collected individuals, 15 were adults (total proportion = 71%), which included 7 females (proportion = 47% of the adults) and 8 males (proportion = 53% of the adults) (Table 1); only the adult males are examined in this study because of sexual dichromatism (Vercken et al., 2007). One of the adult males displayed a body colouration remarkably different to the typical *Z. vivipara* of this and other Alpine sites (Recknagel et al., 2018b). Dorsal background colouration was predominantly olive green, with some paler blue shades on the tail region (Fig. 1; Table 2). The difference was apparent from both measures of the degree of greenness (hypomelanistic individual: G/R = 1.09, 'greenness' = 55; typical individuals: G/R = 0.88 (0.82-0.98), 'greenness' = 11.9 (-1-26)). Lighter and darker dots and stripes constituting the typical pattern for this species were almost absent on both the dorsal and ventral sides. Finally, this individual presented a yellow-orange belly colouration lacking any melanic spots which would usually be characteristic of male individuals (Fig. 1).

SVL of the hypomelanistic individual was 66.5 mm, while the tail measured 49.7 mm. Out of the nine males caught, it exhibited the second largest body condition (range for typically-coloured males = -0.789 – 0.744, mean = -0.153; hypomelanistic male: 0.309).

Discussion

We report on the discovery of a male common lizard with an unusual colouration: it had green dorsal colouration and lacked dark spots on the venter (Fig. 1; Table 2). To our knowledge, this is the first report of a green *Z. vivipara* in Italy. There are a handful of accounts of green *Z. vivipara* in the literature: a survey of *Z. vivipara* populations in England and Wales carried out in the 1960's reported several locations where green lizards were observed, occurring at frequencies as high as 30% at some sites (Simms, 1970). However, the author does not give a full description of their

Table 2. Red/Green/Blue digital colour measures of all males sampled. Level of greenness was measured as G/R and as 2G-R-B. Range of observed values and average including standard deviation in brackets displayed.

		range (min-max)		average	
colour morph	N	G/R	greenness	G/R	greenness
typical colour	6	0.82-0.98	-1-26	0.88 (0.05)	11.9 (9.3)
hypomelanistic	1	1.09	55	1.09	55.0

appearance. A more detailed account of a green variety of *Z. vivipara* in Germany, dating from the late 19th century, differs substantially from the individual found at Lago di Morasco, describing a lizard with dark spots and greyish head colouration (Dürigen, 1897). These two accounts may or may not describe the same colouration observed here. It seems likely that a spectrum of variance exists including normally coloured brown lizards, lizards with fully green dorsal colouration (such as the Lago di Morasco individual), and lizards with partial greenish colouration retaining some degree of the typical brownish pattern, with melanic lizards perhaps representing the opposite extreme. Usually these colour descriptions have not been quantitative and are therefore difficult to compare.

Given that most distinctive features of this individual can be attributed to the reduction or absence of typical brown and black dorsal and ventral patterning, it seems likely that the Lago di Morasco individual represents an example of hypomelanism. Hypomelanism in squamates is a well-established phenomenon (Bechtel, 1995), with examples from species closely related to *Z. vivipara* such as *Lacerta agilis* (e.g. Gvoždík, 1999b). Hypomelanistic individuals have reduced numbers of melanophores, cells containing the pigment melanin which gives reptiles their brown and black colouration. The reverse condition, melanism, is well attested in *Z. vivipara*, with melanistic individuals documented from numerous wild populations across the species' range (San-Jose et al., 2008; Nekrasova, 2018; Recknagel et al., 2018b), occurring at frequencies as high as 8% in some cases (Gvoždík, 1999a).

Here, we found that the hypomelanistic individual was in good body condition, better than all except one other male measured (Table 1). This suggests that this lizard was not at a disadvantage in food acquisition. Statistical analyses are not possible on these small sample sizes but we note that the hypomelanistic individual can be compared to the mean and distribution of the more typical colour variants at the sites. Given that melanic ventral patterning in *Z. vivipara* has been suggested to play a role in intraspecific signalling and mate choice, in addition to the presumed function of dorsal patterning in terms of crypsis and predator avoidance, hypomelanism in this species may carry significant penalties in terms of individual survival and reproductive success (Vervust et al., 2013). This perhaps explains the apparent scarcity of hypomelanistic individuals in the wild. Future discoveries of hypomelanistic common lizards may yield insights into the true prevalence and ecological significance of this striking instance of colour polymorphism.

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