5-1-2007

Effects of temperature and illumination on background matching in Mediterranean geckos (Hemidactylus turcicus)

Frederic Zaidan
The University of Texas Rio Grande Valley

Pamela L. Wiebusch

Effects of temperature and illumination on background matching in Mediterranean geckos (Hemidactylus turcicus).

Print

Author: *Zaidan, Frederic, III; Wiebusch, Pamela L.*
Article Type: *Report*
Geographic Code: *1USA*
Date: *May 1, 2007*
Words: *2887*
Publication: *The Texas Journal of Science*
ISSN: *0040-4403*

Abstract. -- The ability to change skin color is a relatively common phenomenon in lizards whose occurrence is often related to crypsis. Field observations suggest that Mediterranean geckos (an often ubiquitous introduced species in many metropolitan areas of the southern United States) have the ability to lighten and darken in response to their background. On light backgrounds, the geckos were typically light pink whereas on dark backgrounds they were typically much darker with a brownish hue to their skin. This study investigated the ability to background match in this species, the main effects of temperature (20, 25, and 30[degrees]C), illumination (total darkness and dim lighting), and their interactions on the lizard's ability to match their skin darkness to four levels of background darkness (black, gray, white, and a combination of the three). Each lizard was measured in a repeated-measures design. While temperature had little effect, illumination strongly influenced the lizard's ability to background contrast match. In the absence of light, 73% of the lizards were light in color. This suggests that lighter skin pigmentation in the dark may be the "default" setting with the melanocytes contracted. In dim lighting, the lizard's skin darkness closely matched background darkness in most cases (81%). These nocturnal lizards are typically associated with human development where low levels of illumination are often present at night. The ability of Mediterranean geckos to accurately background match under conditions of human habitation may have contributed to their success as a colonizing species.

****

Organisms may achieve crypsis by matching their own reflectance, color, pattern, or a combination of the three to those of the background (Endler 1981). The effectiveness of crypsis is dependent on ambient light, the background, body coloration, and the visual sensitivity of the viewer (Hailman 1979; Cooper & Greenberg 1992). Color change in lizards is a common morphologically or physiologically based phenomenon that is species specific and additionally, can represent a selective balance between signaling needs and the need for crypsis (Stuart-Fox et al. 2004). Morphological changes differ from physiological changes in that morphological changes are distinguished by a gradual accumulation of pigment and melanophores over a period of time (Waring 1963). Physiological changes tend to occur much faster, usually within a matter of minutes, and are typically mediated by [alpha]-melanocyte stimulating hormone as the darkening hormone (Sherbrooke et al. 1994; Castrucci et al. 1997; Sherbrooke 1997; Vazquez-Martinez et al. 2001). Physiological changes include changes as an effect of temperature, visual responses (e.g., background color), or non-visual responses such as those invoked by other neural or hormonal stimulation pathways.

Background matching serves to minimize the amount of visual information that a potential predator can receive (Merilaita 2003). Early studies on Gekkonid lizard coloration change show the importance of background color. In Atsatt (1939), color change was measured as paling or darkening of the skin induced by the placement of the white paper either around or away from the lizard's holding dish. Later studies showed that temperature also had an effect on color change in lizards because increases or decreases in temperature could override the background-response to color change (Parker 1948). At low temperatures, lizards that were pale under a white background had a tendency to turn dark, while at high temperatures, dark lizards under a black background had a tendency to turn pale. Color change in some lizards has also been attributed to stress factors. A study on Anolis carolinensis indicated that color is most typically affected by social activities. Color fluctuation was also noted in lizards participating in predation events, whether acting as predator or prey (Greenberg 2002). Such color fluctuations may be linked to hormones associated with physiological stress.

Hemidactylus turcicus (Family Gekkonidae) is an introduced species from the Mediterranean region found scattered throughout the southern United States; the largest continuous range is in the eastern and southern three-quarters of Texas and along the Gulf Coast of Mexico (Conant & Collins 1998). The introduction into Texas occurred slightly over 50 years ago in Brownsville, Cameron County (Conant 1955; Jadin & Coleman 2007). Throughout its introduced range, this nocturnal species is mostly found in urban areas on both abandoned and inhabited buildings and in cracks and crevices of walls (urban equivalents to Middle Eastern and Mediterranean rocky cliffs where they are naturally found; McCoy 1970). This species feeds on insects and therefore is often found near light sources (Davis 1974). Lizards range from a translucent shade of pink (light) to a brownish color (dark) to an intermediate shade and individuals can change between these colors. While mechanisms that cause color change in lizards are well known, most studies focused on the response of diurnal species. Based on field observations, this study investigated some factors that may be important for color matching in a nocturnal species.

MATERIALS AND METHODS

Field observations. -- During randomly chosen nights over an 18 month period (April 2004-October 2005), 163 observations of geckos (neonate through adult) were made from residential and commercial areas in Hidalgo County, Texas. All studied areas lie within 80 km of the initial site(s) of introduction in Texas and thus, these gecko populations may represent some of the oldest in the country. Observations are presumed to be unique, as different sites were sampled and each lizard was likely a new observation. Darkness of both the lizard and its background was visually scored as light, intermediate, or dark. Visual assessment of darkness was identical between the two authors and was further corroborated by independent observers. A chi-square analysis was used to test if lizard color was independent of background color. While a quantitative measure of darkness would be preferred, the authors feel that the simplicity and consistency of these measures were more than adequate for a preliminary investigation.

Laboratory observations. -- Fourteen sub-adult to adult (mean mass [+ or -] 1SD = 2.05 g [+ or -] 1.48) Hemidactylus turcicus were captured by hand from residential areas in Edinburg, Hidalgo County, Texas (approximately 26[degrees]18'N, 98[degrees]10'W). Shortly after capture, animals were taken to the laboratory in plastic buckets with ventilation holes in the top. Lizards were identified by physical characteristics and housed communally until tested in a 20 gallon long (75.7 L) aquarium with newspaper substrate and numerous hiding spots. Temperature was maintained at 24[degrees]C with a photoperiod of 12L:12D and water and commercially available crickets were provided ad libitum. Two geckos were placed in one of four 10 gallon (37.9 L) aquaria covered with either black, gray, or white construction paper (with the fourth consisting of all three colors). Aquaria were placed in a Percival incubator (Perry, IA) with a photoperiod of 12L:12D and temperature was dependent on treatment. In the field, geckos were typically active at night-time temperatures above 17[degrees]C, which is available for most o the year (at the very least during early scotophase) in Deep South Texas (Starr, Hidalgo, Cameron, and Willacy counties). Specimens were therefore exposed to field-active temperatures. This study investigated the main effects of temperature (20, 25, and 30[degrees]C), illumination (total darkness and dim lighting), and their interactions on the lizard's ability to match their skin darkness (light, intermediate, and dark; Figure 1) to the levels of background color (white = light, gray = intermediate, and black = dark). The gecko's coloration was observed once during the photophase and once during the scotophase. Observations occurred at least two hours after the onset of photophase or scotophase. To assess the ability to background match, the response was scored as -2 through 2 where a score of 0 indicated a perfect match, -1 or 1 if the gecko was one shade lighter or darker than its immediate background, and -2 or 2 if the gecko was two shades lighter or darker. Each lizard was rotated through all temperatures and all tank backgrounds in a repeated-measures design. After all measurements were taken, geckos were released at their point of capture.

[FIGURE 1 OMITTED]

RESULTS

Early field observations indicated that the lizards change shade in order to closely match the background shade (Table 1 and [chi square] = 82.04, [[chi square].sub.crit (0.05, 4)] = 9.49, P < 0.001). Overall, the lizards correctly matched the background 70% of the time. The lizards were most accurate in their color matching on dark and light backgrounds (84% and 86% correct, respectively). In contrast the lizards were only 14% correct on intermediate backgrounds.

Because the laboratory data failed the assumption of normality, data were analyzed with Friedman's repeated-measures ANOVA (Zar 1984; SAS 1985). Illumination significantly affected the gecko's ability to background match (P < 0.0001). The gecko's body coloration typically matched their background color under dim illumination, but was lighter than their background in the absence of light (Figure 2). No significant effects of temperature (P = 0.2539) or interaction of temperature and lighting (P = 0.4563) were detected.

DISCUSSION

Field observations showed that the geckos closely matched their background in terms of reducing their contrast. Previous studies showed that lizards often match their reflectance or hue without an exact color match (Norris & Lowe 1964; Gibbons & Lilywhite 1981). Any inconsistencies were due to either classification error by the observers, differential discrimination between the lizard versus human eye (as with the case of intermediate backgrounds), or background matching prior to observation. Most of the observations during this study occurred in residential areas, where background heterogeneity is typically considerable. On several occasions, lizards were observed to lighten or darken when moving to new areas and the change typically took several minutes. A light background was often adjacent to a dark one and a mismatch may have been due to movement before observation.

Results in the laboratory setting closely reflected background matching observed in field results. Temperature did not affect the success of the background matching. Previous studies showed the importance of body temperature to color change in several species of predominantly diurnal lizards (e.g., Urosaurus ornatus, Phrynosoma cornutum, and Sceloporus jarrovii) as a consequence of thermoregulatory issues (Sherbrooke et al. 1994; Castrucci et al. 1997; Sherbrooke 1997). Dark coloration enhances absorption of solar radiation and speeds an increase in body temperature (Porter & Gates 1969). In a nocturnal lizard, such as Hemidactylus turcicus, solar radiation is not important for thermoregulation (other than its avoidance and during brief periods of crepuscular activity; Carman et al. 2000) and body coloration can be used strictly for crypsis.

[FIGURE 2 OMITTED]

While temperature had no effect, illumination strongly influenced a lizard's ability to match background color. In the absence of light, 73% of the lizards were light in color. In dim lighting, the lizard's skin darkness closely matched the background darkness in most cases (81%). These results suggest that: (a) lighter skin pigmentation in the dark may be the "default" setting with the melanocytes contracted and (b) some light is required for the geckos to assess their immediate background. These nocturnal lizards are typically associated with human development where low levels of illumination are often present at night, thus light will usually be available for the geckos to visualize their background.

Fifty years after its introduction to the southern tip of Texas, published records of Mediterranean geckos can currently be found for almost 90 counties (Dixon 2000; Jadin & Coleman 2007) and many more unpublished county records likely exist. Their primary mode of dispersal appears to be jump, rather than diffusion, dispersal (Locey & Stone 2006). This species typically does well in areas with vertical surfaces that support their nocturnal and insectivorous habits (Saenz 1996; Punzo 2001). Ecological attributes driving their success include low interspecific competition, high survivorship, egg characteristics, and low predation pressure (Rose & Barbour 1968; Selcer 1986). The ability to change their color to closely match the background may allow H. turcicus avoid the few visual predators (e.g., cats and skunks; Locey & Stone 2006) that it would encounter during its active period. Accurate background matching may serve to further lower low predation pressure previously reported and contribute to its colonization success in urban areas. This project examined background matching on a coarse scale; further work using quantitative measures (e.g., digital analyses) will clarify the accuracy and precision of background matching on a fine scale and serve to strengthen the relationship with predator avoidance.

ACKNOWLEDGEMENTS

We wish to thank J. Ortega for the photographs and for other contributions. We would also like to thank L. Zaidan, C. Little, M. Persans, and the Wiebusch family for assisting in various aspects of the study. The animals were collected under Texas Parks and Wildlife's Scientific Collecting Permit (SPR-1003-325) to F. Zaidan and the studies were approved by the University of Texas-Pan American's Institutional Animal Care and Use Committee. This is publication number CSS 2007-03 of the UTPA Center for Subtropical Studies.

LITERATURE CITED

Atsatt, S. R. 1939. Color changes as controlled by temperature and light in the lizards of the desert regions of Southern California. Publ. University of California at Los Angeles Biol. Sci., 1:237-276.

Carman, E. N., G. W. Ferguson, W. H. Gehrmann, C. C. Tai & M. F. Holick. 2000. Photobiosynthetic opportunity and ability for UV-B generated vitamin D synthesis in free-living House Geckos (Hemidactylus turcicus) and Texas

Spiny Lizards (Sceloporus olivaceus). Copeia, 2000:245-250.

Castrucci, A. M. de L., W. C. Sherbrooke & N. Zucker. 1997. Regulation of physiological color change in dorsal skin of male tree lizards, Urosaurus ornatus. Herpetologica, 53:405-410.

Conant, R. 1955. Notes on three Texas reptiles including an addition to the fauna of the state. Amer. Mus. Nov., 1726:1-6.

Conant, R. & J. T. Collins. 1998. A Field Guide to Reptiles and Amphibians of Eastern and Central North America. Third Edition Expanded, Houghton Mifflin Co., New York. xviii+616 pp.

Cooper, W. E. & N. Greenberg. 1992. Reptilian coloration and behavior. Pp. 298-422 in Biology of the Reptilia 18, Physiology E: Hormones, Brain, and Behavior (C. Gans & D. Crews, Eds.). The University of Chicago Press, Chicago, Illinois. xiv+564 pp.

Davis, J. R. 1974. The Mediterranean gecko, Hemidactylus turcicus in Texas. J. Herpetol., 8:77-80.

Endler, J. A. 1981. A predator's view of animal color patterns. Evol. Biol., 11:319-364.

Gibbons, J. R. H. & H. B. Lillywhite. 1981. Ecological segregation, color matching, and speciation in lizards of the Amphibolurus decresii species complex (Lacertilia: Agamidae). Ecology, 62:1573-1584.

Greenberg, N. 2002. Ethological aspects of stress in a model lizard, Anolis carolinensis. Int. Comp. Biol., 42:526-40.

Hailman, J. P. 1979. Environmental light and conspicuous colors. Pp. 289-358, in The Behavioral Significance of Color (E.H. Burtt, Jr., Ed.). Garland STPM Press, New York. xiv+456 pp.

Jadin, R. C. & J. L. Coleman. 2007. New county records of the Mediterranean gecko (Hemidactylus turcicus) in northeastern Texas, with comments on range expansion. Appl. Herpetol., 4:90-94.

Locey, K. J. & P. A. Stone. 2006. Factors affecting range expansion in the introduced Mediterranean gecko, Hemidactylus turcicus. J. Herpetol., 40:526-530.

McCoy, C. J. 1970. Hemidactylus turcicus (Linneaus), Mediterranean gecko. Catalogue of American Amphibians and Reptiles, 87.1-87.2.

Merilaita, S. 2003. Visual background complexity facilitates the evolution of camouflage. Evol., 57:1248-1254.

Norris, K. S. & C. H. Lowe. 1964. An analysis of background color-matching in amphibians and reptiles. Ecology, 45:565-580.

Parker, G. H. 1948. Animal colour changes and their neurohumours: A survey of investigations, 1910-1943. Cambridge University Press. x+377 pp.

Porter, W. P. & D. M. Gates. 1969. Thermodynamic equilibria of animals with the environment. Ecol. Mono., 39:227-244.

Punzo, F. 2001. The Mediterranean gecko, Hemidactylus turcicus: Life in an urban landscape. Florida Scientist, 65:56-66.

Rose, F. L. & C. D. Barbour. 1968. Ecology and reproductive cycles of the introduced gecko, Hemidactylus turcicus, in the Southern United States. Am. Midl. Nat., 79:159-168.

SAS Institute. 1985. SAS Users Guide: Statistics, Version 5. SAS Institute, Inc., Cary, North Carolina. 956 pp.

Saenz, D. 1996. Dietary overview of Hemidactylus turcicus with possible implications of food partitioning. J. Herpetol., 30:461-466.

Selcer, K. W. 1986. Life history of a successful colonizer: The Mediterranean gecko Hemidactylus turcicus in southern Texas USA. Copeia, 1986:956-962.

Sherbrooke, W. C. 1997. Physiological (rapid) change of color in horned lizards (Phrynosoma) of arid habits. Hormonal regulation, effects of temperature, and role in nature. Amphibia-Reptilia, 18:155-175.

Sherbrooke, W. C., A. M.de L. Castrucci & M. E. Hadley. 1994. Temperature effects on in vitro skin darkening in the mountain spiny lizard, Sceloporus jarrovii: A thermoregulatory adaptation? Physiol. Zool., 67:659-672.

Stuart-Fox, D. M., A. Moussalli, G. R. Johnston & I. P. F Owens. 2004. Evolution of color variation in dragon lizards: Quantitative tests of the role of crypsis and local adaptation. Evol., 58:1549-1559.

Vazquez-Martinez, R., J. R. Peinado, J. L. Gonzalez de Aguilar, L. Desrues, M. C. Tonon, H. Vaudry, F. Gracia-Navarro & M. M. Malagon. 2001. Melanotrope cell plasticity: A key mechanism for the physiological adaptation to background color changes. Endocrinol., 142:3060-3067.

Waring, H. 1963. Color Change Mechanisms of Cold-Blooded Vertebrates. Academic Press, New York. 266 pp.

Zar, J. H. 1984. Biostatistical Analysis, Second Edition. Prentice Hall, Englewood Cliffs, New Jersey. xiv+718 pp.

FZ at: fzaidan@utpa.edu

Frederic Zaidan III and Pamela L. Wiebusch

Department of Biology and Center for Subtropical Studies University of Texas--Pan American

Edinburg, Texas 78539

Table 1. Counts of lizard shades and background shades from field observations conducted between April 2004-October 2005 during scotophase.

	Dark background	Intermediate background	Light background
Dark gecko	53	17	9
Intermediate gecko	1	5	0
Light gecko	9	13	56