Building evidence for conservation globally

Journal of Threatened Taxa

Open Access

10.11609/jott.2022.14.2.20539-20702
www.threatenedtaxa.org

26 February 2022 (Online & Print)
14(2): 20539-20702
ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

ISSN 0974-7907 (Online); ISSN 0974-7893 (Print)

Publisher
Wildlife Information Liaison Development Society
www.wild.zooreach.org

Host
Zoo Outreach Organization
www.zooreach.org

No. 12, Thiruvannamalai Nagar, Saravanampatti - Kalapatti Road, Saravanampatti,
Coimbatore, Tamil Nadu 641035, India
Ph: +91 9385339863 | www.threatenedtaxa.org
Email: sanjay@threatenedtaxa.org

For Focus, Scope, Aims, and Policies, visit https://threatenedtaxa.org/index.php/JoTT/aims_scope
For Article Submission Guidelines, visit https://threatenedtaxa.org/index.php/JoTT/about/submissions
For Policies against Scientific Misconduct, visit https://threatenedtaxa.org/index.php/JoTT/policies_various

continued on the back inside cover

Cover: *Geodorum laxiflorum* Griff.—inflorescence (Orchidaceae) © Ashish Ravindra Bhoyar.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2022 | 14(2): 20672–20676

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

https://doi.org/10.11609/jott.7558.14.2.20672-20676

#7558 | Received 05 July 2021 | Final received 06 February 2022 | Finally accepted 11 February 2022

OPEN ACCESS

SHORT COMMUNICATION

Lichens and animal camouflage: some observations from central Asian ecoregions

Mahmood Soofi [1], Sandeep Sharma [2], Barbod Safaei-Mahroo [3], Mohammad Sohrabi [4], Moosa Ghorbani Organli [5] & Matthias Waltert [6]

[1,2,6] Department of Conservation Biology, University of Goettingen, Bürgerstr. 50, 37073 Goettingen, Germany.
[1] CSIRO Land and Water, PMB 44, Winnellie, Darwin, 0822, Northern Territory, Australia.
[3] Pars Herpetologists Institute, Corner of third Jahad alley, Arash Str., Jalal-e Ale-Ahmad Boulevard, Tehran, Iran.
[4] Department of Biotechnology, Iranian Research Organization for Science and Technology, Tehran, Iran.
[5] Haj-Asadi alley, 20-Metri-e Jey, Yadegar-e Emam, Dampezeshki Str., Tehran, Iran.
[1] mahmood.soofi@biologie.uni-goettingen.de (corresponding author), [2] sandeeps17@gmail.com, [3] barbodsafaei@gmail.com,
[4] sohrabi.mycolich@gmail.com, [5] ghorbanigeo@gmail.com, [6] mwalter@gwdg.de

Abstract: Camouflage is a fitness-relevant trait that supports survival and fosters evolutionary adaptation by which animals match their body pattern to a background setting. Lichens are among the most common of these backgrounds that several animal species use for camouflage. Lichens are omnipresent and grow in wide arrays of colorations and compositions. Their composition and phenotypic diversity might facilitate cryptic coloration and habitat matching by various animal species. Here, we describe the role of lichens in providing camouflage to various animal species in central Asian and Caucasus mountain ecoregions, which are categorized as global biodiversity hotspots. Despite multiple ecological studies, no information is available on the role of this regions' lichen diversity in providing animal camouflage. Casual field observations of lichen camouflage are reported for four (one mammal and three reptile) species: the Persian Leopard's *Panthera pardus saxicolor* body coat seems to closely match the colors and patterns of saxicolous lichens (*Acarospora* sp. and *Circinaria* sp.) in their habitat. A similar background matching pattern was observed in both morphs of the Caucasian Rock Agama *Paralaudakia caucasia* upon crustose lichens: *Caloplaca* spp., *Circinaria* spp., and the Radde's Rock Lizard *Darevskia raddei* to the crustose lichens *Acarospora* sp. and *Caloplaca* sp. Likewise, the Horny-scaled Agama's *Trapelus ruderatus* grey matches with the color of multiple lichens (*Lecanora* spp., *Circinaria* spp., *Protoparmeliopsis* spp., *Rinodina* spp., and *Anaptychia* spp.). Our observations preliminarily suggest that lichens play an important role for species of different trophic levels, ensuring adaptation and survival through camouflage. We call for more field-based empirical and experimental studies in various terrestrial ecosystems in other parts of the world to test the role of lichens in local adaption and evolutionary plasticity of regional species.

Keywords: Caucasus, climate change, cryptic coloration, dry ecosystems, Irano-Anatolian, mammals, plasticity, phenotypic traits, reptiles, saxicolous.

Wildlife populations of various taxa are experiencing an unprecedented loss worldwide. The 2020 Global Living Planet Index reported an average 68% decline in the populations of mammals, birds, amphibians, reptiles, and fishes within a period of 46 years (1970–2016). Many of the listed species are subjected to anthropogenic impacts and environmental alterations such as climate change, pollution, disease, invasive species, and land degradation (Kettlewell 1955; Gomulkiewicz & Holt 1995; Gonzalez et al. 2013; Maxwell et al. 2016). Species persistence may also depend on phenotypic plasticity or adaptive evolution (Carlson et al. 2014). The inherent

Editor: Anonymity requested.

Date of publication: 26 February 2022 (online & print)

Citation: Soofi, M., S. Sharma, B. Safaei-Mahroo, M. Sohrabi, M.G. Organli & M. Waltert (2022). Lichens and animal camouflage: some observations from central Asian ecoregions. *Journal of Threatened Taxa* 14(2): 20672–20676. https://doi.org/10.11609/jott.7558.14.2.20672-20676

Funding: See Acknowledgements section.

Competing interests: The authors declare no competing interests.

Acknowledgements: The work leading to this publication was supported by the PRIME programme of the German Academic Exchange Service (DAAD-PRIME, project No. 57436650, 2019-2021) with funds from the German Federal Ministry of Education and Research (BMBF) and Feodor Lynen Fellowship of the Alexander von Humboldt Foundation (award No. DEU 1220304 FLF-P, 2021-2023) provided to M.S. There are no conflicts of interests and all relevant parties involved in the underlying research are either co-authors or listed in here.

genetic variation in a species may help species to adapt towards stressors if these exert strong selection pressure (Gonzalez et al. 2013).

One of the fitness-relevant traits that support survival and foster evolutionary adaptation is camouflage (Pèrez i de Lanuza & Font 2016; Cuthill 2019; Price et al. 2019; Smith & Ruxton 2020). Camouflage is a trait or mechanism by which animals match or tune their body pattern to the background of their habitat, often varying over time and space and across populations (Baling et al. 2019; Cuthill 2019; Smith & Ruxton 2020). Animals employ camouflage in multiple ways to facilitate various strategies including; background matching (i.e., animals resemble the shape of the habitat background) and disruptive coloration (i.e., developing high contrast patches to break up the body's edge). Cryptic coloration and display of specific behaviours may reduce visual detection or recognition by predators (Cuthill 2019). Cryptic coloration can occur seasonally (e.g., as in the form of change of coat colour from brown in summer to white in winter) and may change with patterns and color of habitat, affecting the selection of phenotypic traits for crypsis (Mills et al. 2013). A recent study identified polymorphic regions for some color molting mammal species (e.g., Snowshoe Hare *Lepus americanus*, Arctic Fox *Vulpes lagopus*), suggesting that these regions can function as evolutionary rescue sites in the rapidly changing world due to climate change (Mills et al. 2013).

The most quoted classic example of rapid plasticity in response to anthropogenic climate change affecting the effectiveness of camouflage is that of the Peppered Moth *Biston betularia* (Grant & Howlett 1988; Majerus et al. 2000; Cuthill 2019). During the industrial revolution (ca. 1760–1840), the Silver Birch Trees' *Betula pendula* bark became darker due to pollution (Grant & Howlett 1988). As a result, the melanic forms of the Peppered Moth (dark) in polluted regions had low predation pressure over lichen-like individuals (pale speckled), which were easily spotted by their avian predators due to contrasting dark background. When pollution levels in these regions declined, and the lichens grew back on the trees, the pale speckled morphs regained abundance (Kettlewell 1955; Grant & Howlett 1988). In an experimental study Walton & Stevens (2018) showed that the pale-speckled form of the Peppered Moth closely resembles the crustose lichen found on tree barks, making them less vulnerable to predation by birds, compared to melanic forms. This example provides striking evidence about the importance of the rapid evolutionary response of animals to environmental alterations under the influence of strong selection pressure. It also emphasizes the role of lichens in sustaining populations by providing important ecosystem services such as camouflage that helped reversing population decline (Walton & Stevens 2018).

There are several other examples reported from various parts of the world, where lichens were employed by various species not only as habitat and food source, but also for camouflage (Zedda & Rambold 2011). The larvae of insect species such as Lacewing (Neuroptera: Chrysopidae) and Bagworm (Lepidoptera: Psychidae) use lichens as food and camouflage to escape from predators (Skorepa & Sharp 1971; Cannon 2010). Another interesting case of lichen camouflage is reported in the nymph of the katydid *Lichenodraculus matti* that mimics epiphytic lichens. A species of beetle *Gymnopholus lichenifer* and a land snail species *Napaeus barquini* use lichens as food and cover their body with live lichen to actively carry the camouflage with them (Gressit 1977; Allgaier 2007). The Lichen Huntsman Spider *Pandercetes gracilis* hides among lichens for predation (Botsford-Comstock 1986; Mukherjee et al. 2010). There are several other species of frogs and lizards that use tree and rock lichens for camouflage (Braun et al. 1997; Hocking & Semlitsch 2007; Zedda & Rambold 2011; Sumotha et al. 2012).

Lichens and animal camouflage in central Asian mountain ecoregion

Lichens are a symbiotic group of organisms that occur in terrestrial ecosystems. They cover approximately 8% of the global land surface (Nash 2008), and grow in wide arrays of colorations, compositions and patterns on substrates such as rocks, trees or shrubs' bark, and even anthropogenic material such as concrete (Nash 2008). They are specifically more diverse and abundant in dry high altitude grasslands and tundra ecosystems (Asplund & Wardle 2017). Lichens are sensitive to a wide range of pollutants and climatic alterations and thus serve as indicators of ecosystem health (Munzi et al. 2014; Root et al. 2015). For instance, the depletion of lichens also indicates population decline of Caribou in the arctic ecosystem (Joly et al. 2009).

Here, we describe the importance of lichens in providing camouflage to various animal species of central Asian mountain ecoregion. The Irano-Anatolian, Caucasus, and central Asian mountains ecoregions are mainly characterized by vast dry scrublands, grasslands and steppic mountainous landscapes and are categorized amongst the global biodiversity hotspots (Olson & Dinerstein 2008; Marchese 2015). These ecoregions are vulnerable to climate change as well as intense human

use (Stone 2015). Despite several long-term ecological studies on many species from this region, no information is available on the role of regional lichen species in providing animal camouflage. We here present examples from four animal species (one mammal and three reptilian) that represent and occupy different trophic levels in the Irano-Anatolian, Caucasus, and central Asian mountains ecoregions.

The Persian Leopard *Panthera pardus saxicolor*, synonym: *P. p. tulliana* was described by R.I. Pocock in 1927. The etymological meaning of '*saxicolor*' in its scientific name is 'stone-grey' or 'stone-color' (Pocock 1927). Persian Leopard has a grey and yellowish-buff coat interspersed with black rosette patterns (Pocock 1927) that seem to closely match and merge with the colors and patterns of regional saxicolous lichen species such as *Acarospora* sp. (Ascosporaceae) and *Circinaria* sp. (Megasporaceae) (Image 1), and other families of lichens including Candelariaceae, Collemataceae, Lecanoraceae, Lecideaceae, Lichinaceae, Megasporaceae, Parmeliaceae, Physciaceae, Rhizocarpaceae, Teloschistaceae, Umbilicariaceae, and Verrucariaceae that are also found in their habitat in these ecoregions. The Persian Leopard is an apex predator of these ecoregions, that inhabits rocky mountainous habitats in western and central Asia (Jacobson et al. 2016). Their arid and rocky habitat is covered by saxicolous lichens that help them in camouflage, which is often useful in their ambush hunting technique. It reduces their chances of visual detection by their prey species and might improve their ambush predation success.

To further illustrate the importance of lichens in

Image 1. a—Persian Leopard (*Panthera pardus tulliana*, synonym *P.p. saxicolor*) resting on the calcareous rocks in Golestan National Park, Iran. Its coat colors and patterns closely resemble the crustose lichens: *Acarospora* sp. and *Circinaria* sp. (© J. Hasanzadeh) | b—represents the background matching of Radde's Rock Lizard (*Darevskia raddei*) on the volcanic rocks in Arasbaran National Park, the lesser Caucasus ecoregion in Iran (© B. Safaei-Mahroo) and the crustose lichens *Acarospora* sp. and *Caloplaca* sp. | c—shows Caucasian Rock Agama (*Paralaudakia caucasia*) in an alert position on the calcareous rock, in Iran-Turkey border (Sero). The background matching is enhanced by several crustose lichens: *Circinaria* sp. and *Protoparmeliopsis* sp. and *Rinodina* sp. (© B. Safaei-Mahroo) | d—represents the Caucasian Rock Agama in an alert position, its dorsal coloration resembling the crustose lichens *Caloplaca* sp. and *Circinaria* sp. (© J. Hasanzadeh).

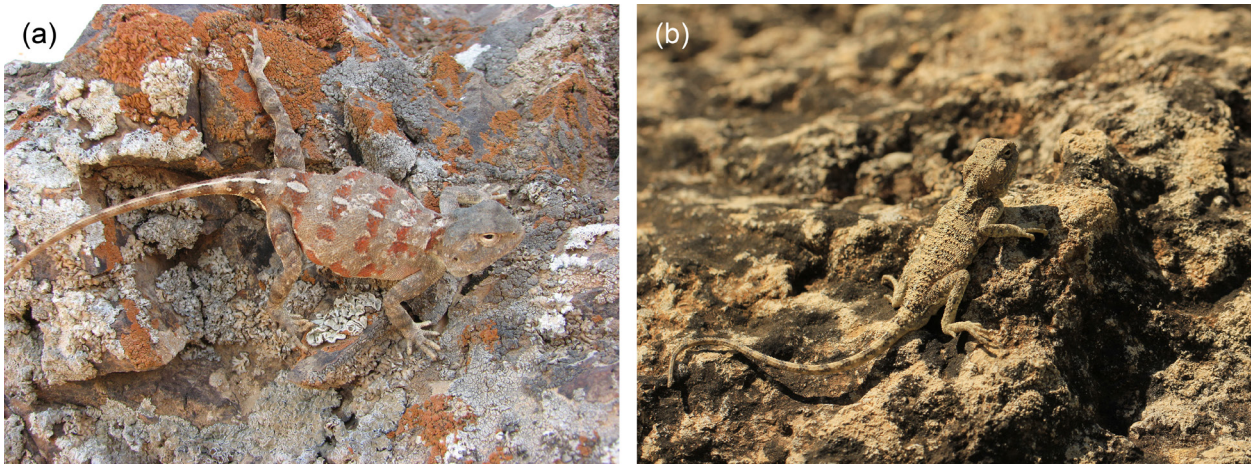

Image 2. a—illustrates a summer morph of the Horny-scaled Ground Agama (*Trapelus ruderatus*), Zagros mountains, Iran. Its body scales closely match with lichens covered rocks: fire-dot lichen *Caloplaca* sp., lim lichen *Lecanora* sp., sunken disk lichen *Circinaria* sp., *Protoparmeliopsis* sp., *Rinodina* sp., and *Anaptychia* sp. Whereas | b—shows the early spring morph of the Horny-scaled Ground Agama (Kabir-kuh, Malekshahi, Zagros mountains, Iran), matching finely lichens: *Verrucaria* sp. or *Anema* sp. or *Peccania* sp. (© B. Safaei-Mahroo).

animal camouflage, we present examples of three species of reptiles, which are adapted to rocky high steppe habitats. They are Radde's Rock Lizard *Darevskia raddei* (Lacertidae), Caucasian Rock Agama *Paralaudakia caucasia* (Agamidae) and Horny-scaled Ground Agama *Trapelus ruderatus* (Agamidae) (Images 1, 2). The Radde's Rock Lizard is a polymorphic group of lizards. Their dorsal coloration largely corresponds to the lichen-covered rocks on which they live. A similar background matching pattern occurs in both morphs of the Caucasian Rock Agama *Paralaudakia caucasia*. The dorsal coloration of both morphs matches to the crustose lichens *Caloplaca* sp. and *Circinaria* sp. (Image 1c,d). Several crustose lichens *Circinaria* sp. (Megasporaceae) and *Protoparmeliopsis* sp. (Lecanoraceae) and *Rinodina* sp. (Physciaceae) appear to enhance their background matching (Image 1c). Likewise, the Horny-scaled Agama's grey head matches with the color of the following lichens: lim lichen *Lecanora* sp. (Lecanoraceae), sunken disk lichen *Circinaria* sp. (Megasporaceae), *Protoparmeliopsis* sp. (Lecanoraceae), and *Rinodina* sp. and *Anaptychia* sp. (Physciaceae). The dark-orange spots on the dorsal side correspond to the color and pattern of *Caloplaca* sp. (Teloschistaceae) (Image 2a). The dorsal coloration of the Horny-scaled Ground Agama can change seasonally, which also corresponds to growth stage changes in *Verrucaria* sp. (Verrucariaceae), or *Anema* sp., and or *Peccania* sp. (Lichinaceae) (Image 2b).

We acknowledge that the camouflage of various animal species as described above due to the lichen species in their habitat might just be a perception due to limitations of human vision, which is different from what these animal species and their predators or prey perceive. An experimental study by Majerus et al. (2000) compared the ultra-violate characteristics of both forms of the Peppered Moths in the backdrop of foliose and crustose lichens. They report that the colour patterns of the pale-speckled moth is an effective cryptic match to the crustose lichen *Lecanora conizaeoides,* in both human-vision and ultra-violate visions to the crustose lichens. However, the camouflage behaviour in animals via matching habitat does not essentially depend on lichens (Walton & Stevens 2018), because habitat types and their background characteristics can largely vary across time and space and other factors like vegetation might play a role in camouflage as well (Baling et al. 2019). For example, the melanic form of the peppered moth is adapted closely to plain tree barks, whereas the speckled form adapted to the crustose lichens (Walton & Stevens 2018). In urban ecosystems, even the plain anthropogenic substrates such as roads and pavements are voluntarily selected by animal species that can play a crucial role in their adaptation and population persistence (Camacho et al. 2020).

We conclude that despite several examples of the role of lichens in animal camouflage for a handful of faunal species from a few selected ecosystems, there is insufficient knowledge about lichens and their role in animal camouflage in various terrestrial ecosystems of the world. Lichens are omnipresent and their species composition, richness, and phenotypic diversity might facilitate crypsis coloration and habitat matching by various animal species across different trophic levels. Under variable environments and changing climate

scenarios, these traits would also be able to ensure adaptation and survival of those species. We therefore call for more field and experimental studies in various terrestrial ecosystems in other parts of the world to document more examples of habitat matching by animals utilizing local lichen species, and the role of lichens in local adaption and evolutionary plasticity.

References

Allgaier, C. (2007). Active camouflage with lichens in a terrestrial snail, *Napaeus* (*N.*) *barquini* Alonso and Ibáñez, 2006 (Gastropoda, Pulmonata, Enidae). *Zoological Science* 24: 869–876. https://doi.org/10.2108/zsj.24.869

Asplund, J. & D.A. Wardle (2017). How lichens impact on terrestrial community and ecosystem properties. *Biological Review* 92: 1720–1738. https://doi.org/10.1111/brv.12305

Baling, M., D. Stuart-Fox, D. Brunton & J. Dale (2019). Spatial and temporal variation in prey color patterns for background matching across a continuous heterogeneous environment. *Ecology and Evolution,* 10: 2310–2319. https://doi.org/10.1002/ece3.6024

Botsford-Comstock A. (1986). *Handbook of Nature Study*. Comstock Publishing, Sacramento, 912pp.

Braun, R.F., J.W. Ferner & A.C. Diesmos (1997). Definition of the Philippine parachute gecko, Ptychozon intermedium Taylor 1915 (Reptilia: Squamata: Gekkonidae): rede-scription, designation of a neotype, and comparison with related species. *Herpetologica* 53: 357–373.

Camacho, C., A. Sanabria-Fernández, A. Baños-Villalba & P. Edelaar (2020). Experimental evidence that matching habitat choice drives local adaptation in a wild population. Proceedings of the Royal Society B: *Biological Sciences* 287(1927): 20200721. http://doi/10.1098/rspb.2020.0721

Cannon, P. (2010). Lichen camouflage and lichen mimicry. *The British Lichen Society Bulletin* 106: 39–41.

Carlson, S.M., C.J. Cunningham & P.A.H. Westley (2014). Evolutionary rescue in a changing world. *Trends in Ecology & Evolution* 29: 521–530. https://doi.org/10.1016/j.tree.2014.06.005

Cuthill, I.C. (2019). Camouflage. *Journal of Zoology* 308: 75–92. https://doi.org/10.1111/jzo.12682

Gonzalez, A., O. Ronce, R. Ferriere & M.E. Hochberg (2013). Evolutionary rescue: an emerging focus at the intersection between ecology and evolution. *Philosophical Transections of the Royal Society B* 368: 20120404. https://doi.org/10.1098/rstb.2012.0404

Gomulkiewicz, R. & R.D. Holt (1995). When does evolution by natural selection prevent extinction?. *Evolution*, 49: 201–207. https://doi.org/10.2307/2410305

Grant, B. & R.J. Howlett (1988). Background selection by the peppered moth (*Biston betularia* Linn.) individual differences. *Biological Journal of the Linnean Society* 33(3): 217–232. https://doi.org/10.1111/j.1095-8312.1988.tb00809.x

Gressit, J.L. (1977). Symbiosis runs wild on the backs of high-living weevils. *Smithsonian* 7: 135–136.

Hocking, D.J. & R.D. Semlitsch (2007). Effects of timber harvest on breeding-site selection by gray treefrogs (*Hyla versicolor*). *Biological Conservation* 138: 506–513. https://doi.org/10.1016/j.biocon.2007.05.018

Joly, K., R. Randi, R.R. Jandt & D.R. Klein (2009). Decrease of lichens in Arctic ecosystems: the role of wildfire, caribou, reindeer, competition and climate in north-western Alaska. *Polar Research* 28: 433–442. https://doi.org/10.1111/j.1751-8369.2009.00113.x

Kettlewell, H.B.D. (1955). Recognition of appropriate backgrounds by the pale and black phases of Lepidoptera. *Nature* 175: 943–944. https://doi.org/10.1038/175943a0

Pèrez i de Lanuza, G. & E. Font (2016). The evolution of colour pattern complexity: selection for conspicuousness favours contrasting within-body colour combinations in lizards. *Journal of Evolutionary Biology* 29: 942–951. https://doi.org/10.1111/jeb.12835

Marchese, C. (2015). Biodiversity hotspots: A shortcut for a more complicated concept. *Global Ecology and Conservation* 3: 297–309. https://doi.org/10.1016/j.gecco.2014.12.008

Majerus, M.E.N., C.A.F. Brunton & J. Stalker (2000). A bird's eye view of the peppered moth. *Journal of Evolutionary Biology* 13: 155-159. https://doi.org/10.1046/j.1420-9101.2000.00170.x

Maxwell, S.L., R.A. Fuller, T.M. Brooks & J.E.M. Watson (2016). The ravages of guns, nets and bulldozers. Nature 536: 143–145. https://doi.org/10.1038/536143a

Mills, L.S., M. Zimov, J. Oyler, S. Running, J.T. Abatzoglou & M.P. Lukacs (2013). Camouflage mismatch in seasonal coat color due to decreased snow duration. *Proceedings of the National Academy of Sciences of the United States of America* 110: 7360–7365.

Mukherjee, A., B. Wilske, R.A. Navarro, A. Dippenaar-Schoeman & L.G. Underhill (2010). Association of spiders and lichen on Robben Island, South Africa: a case report. *Journal of Threatened Taxa* 2(4): 815–819. https://doi.org/10.11609/JoTT.o2295.815-9

Munzi, S., O. Correia, P. Silva, N. Lopes, C. Freitas, C. Branquinho & P. Pinho (2014). Lichens as ecological indicators in urban areas: beyond the effects of pollutants. *Journal of Applied Ecology*. 51: 1750–1757. https://doi.org/10.1111/1365-2664.12304

Nash, T.H. (2008). *Lichen Biology*. Cambridge University Press, Cambridge, 486pp.

Olson, D.M. & E. Dinerstein (2008). The Global 200: a representation approach to conserving the Earth's most biologically valuable ecoregions. *Conservation Biology* 12: 502–515. https://doi.org/10.1046/j.1523-1739.1998.012003502.x

Price, N., S. Green, J. Troscianko, T. Tregenza & M. Stevens (2019). Background matching and disruptive coloration as habitat specific strategies for camouflage. *Scientific Reports* 9: 7840. https://doi.org/10.1038/s41598-019-44349-2

Pocock, R.I. (1927). XXVII. Description of two subspecies of leopards. *Annals and Magazine of Natural History* 2: 213–214.

Root, H.T., L.H. Geiser, S. Jovan & Neitlich, P. (2015). Epiphytic macrolichen indication of air quality and climate in interior forested mountains of the Pacific Northwest, USA. *Ecological Indicators* 53: 95–105. https://doi.org/10.1016/j.ecolind.2015.01.029

Skorepa, A.C. & A.J. Sharp (1971). Lichens in "packets" of lacewing larvae (Chrysopidae). *Bryologist* 74: 363–364.

Smith, M.Q.R.P. & G.D. Ruxton (2020). Camouflage in predators. *Biological Reviews*, 95: 1325–1340. https://doi.org/10.1111/brv.12612

Stone, R. (2015). Fragile ecosystems under pressure. *Science*, 349: 1046–47. https://doi.org/10.1126/science.349.6252.1046

Sumotha, M., O.S.G. Pauwels, K. Kunya, C. Limlikhitaksorn, S. Ruksue, A. Taokratok, M. Ansermet & L. Chanhome (2012). A new species of Parachute Gecko (Squamata: Gekkonidae: genus Ptychozoon) from Kaeng Krachan National Park, western Thailand. *Zootaxa* 3513: 68–78.

Walton, O.C. & M. Stevens (2018). Avian vision models and field experiments determine the survival value of peppered moth camouflage. *Communications Biology* 1–118. https://doi.org/10.1038/s42003-018-0126-3

Jacobson, A.P., P. Gerngross, J.R. Lemeris, R.F. Schoonover, C. Anco, Ch. Breitenmoser-Würsten, S.M. Durant, M.S. Farhadinia, P. Hensche, J.F. Kamler, A. Laguardia, S. Rostro-Garcı´a, A.B. Stein & D. Dollar (2016). Leopard (*Panthera pardus*) status, distribution, and the research efforts across its range. *PeerJ* 4:e1974. https://doi.org/10.7717/peerj.1974

Zedda, L. & G. Rambold (2011). Lichens and their importance for the monitoring of environmental changes in southern Africa. http://publikationen.ub.uni-frankfurt.de/frontdoor/index/index/docId/23334

Journal of Threatened Taxa is indexed/abstracted in Bibliography of Systematic Mycology, Biological Abstracts, BIOSIS Previews, CAB Abstracts, EBSCO, Google Scholar, Index Copernicus, Index Fungorum, JournalSeek, National Academy of Agricultural Sciences, NewJour, OCLC WorldCat, SCOPUS, Stanford University Libraries, Virtual Library of Biology, Zoological Records.

NAAS rating (India) 5.64

Print copies of the Journal are available at cost. Write to:
The Managing Editor, JoTT,
c/o Wildlife Information Liaison Development Society,
No. 12, Thiruvannamalai Nagar, Saravanampatti - Kalapatti Road,
Saravanampatti, Coimbatore, Tamil Nadu 641035, India
ravi@threatenedtaxa.org

Journal of Threatened Taxa

www.threatenedtaxa.org

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

February 2022 | Vol. 14 | No. 2 | Pages: 20539–20702
Date of Publication: 26 February 2022 (Online & Print)
DOI: 10.11609/jott.2022.14.2.20539-20702

Publisher & Host

WILD ZOOREACH
Threatened Taxa