Zoosymposia 22: 089–093 (2022)
https://www.mapress.com/j/zs

Correspondence

ISSN 1178-9905 (print edition)
ZOOSYMPOSIA
ISSN 1178-9913 (online edition)

https://doi.org/10.11646/zoosymposia.22.1.51

Global mite diversity is in crisis: what can we do about it?*

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**In*: Zhang, Z.-Q., Fan, Q.-H., Heath, A.C.G. & Minor, M.A. (Eds) (2022) *Acarological Frontiers: Proceedings of the XVI International Congress of Acarology (1–5 Dec. 2022, Auckland, New Zealand)*. Magnolia Press, Auckland, 328 pp.

Abstract

Since the 1970's, biodiversity, conservation and ecology journals have published increasing numbers of reports of major, widespread losses of the diversity and abundance of plants, vertebrates and invertebrates, mostly insects, especially in tropical regions. Mites make a major contribution to global ecosystem services and ecological functioning. Reports on diversity and abundance losses among mites, including ticks, have appeared more recently. The huge problems of population decline and direct extinction among free-living invertebrate species across the world are compounded by the host dependency of enormous numbers of other invertebrate species, which puts them at serious risk of secondary endangerment and co-extinction. They include huge numbers of mite species in symbiotic relationships, including phoretic and parasitic relationships, and the highly host-specific, phytophagous eriophyoids. The destruction and degradation of terrestrial and aquatic ecosystems and habitats across the world, especially for agricultural expansion and intensification, are the major causes of biodiversity loss, with climate change, pollution, overexploitation, invasive species and pesticide use among other contributors. Measures and activities that would substantially contribute to saving the great majority of the world's remaining biodiversity include the protection of all remaining areas of natural and semi-natural habitat, especially the subtropical and tropical forests, with the 36 global biodiversity hotspots an absolute priority; habitat restoration with local species; higher global soil carbon levels; rapid transition from fossil fuel use to renewable energy sources to stop climate change; minimization of pollution; universal education and social justice; a lower human population; and sustainable use of global resources. The rapid implementation of these and other practical measures at the local, national and global scales is essential to ensure the long term survival of the vast majority of biodiversity, including mite species.

Keywords: symbiosis, extinction cascade, conservation, ecocentrism, sustainability, social justice

Biodiversity, which includes all of the world's taxonomic diversity and the full range of behaviours and lifestyles (Walter & Proctor 2013), provides the food resources, ecosystem services and ecological functionality on which humanity depends. That enormous biodiversity includes an estimated global total of seven million terrestrial arthropod species (Stork 2018), with the tropical rainforest arthropods being the most species rich group of eukaryotes on Earth (Basset *et al.* 2012). The mites, which represent ~ 20% of all arthropods (Stork 2018), are an extremely large and particularly diverse group. Conservative estimates of the number of mite species globally range from 500,000 to 1,000,000 (Walter & Proctor 2013); ~ 1,000,000 (Seeman 2020); ~ 1,250,000 (Sullivan & Ozman-Sullivan 2021) and < 1,500,000 (Stork 2018). The mites, which have an enormous range of morphologies, ecologies and behaviours, can be found in ecosystems, habitats and microhabitats from the ocean depths to high altitudes and from the equator to the polar regions (Krantz 2009; Walter & Proctor 2013).

However, there is a compelling and growing body of evidence that a mass extinction of biodiversity, including mites, is underway across the world. The biodiversity that makes our world so fascinating, beautiful and functional

Submitted: 30 Sept. 2022; Accepted by Zhi-Qiang Zhang: 20 Oct. 2022; published: 30 Nov. 2022

is disappearing at an unprecedented rate (Cowie *et al*. 2022). Worsening the problem of population decline and direct extinction is host dependency which also puts huge numbers of species, especially invertebrate species, in serious jeopardy of secondary endangerment and coextinction; Dunn *et al.* (2009) and Cowie *et al.* (2022) termed the ongoing phenomena of population decline, extinction and coextinction, the Sixth Mass Extinction. Its causes and measures that can address this monumental global challenge, especially in relation to mites, are discussed below.

The global biodiversity crisis is being caused by land-use changes, especially deforestation for agricultural expansion and intensification; overexploitation; climate change; introduced species; and pollution (Ehrlich & Ehrlich 1981; Diamond 1989; Stork & Lyal 1993; Pimm & Raven 2000; Koh *et al.* 2004; Urban 2015; Cardoso *et al.* 2020; Cowie *et al.* 2022). However, the full extent of biodiversity loss is greatly underestimated because the vast majority of population declines, extinctions and coextinctions are occurring in groups of small, mostly neglected organisms (Cardoso *et al.* 2011), such as insects (Koh *et al.* 2004; Cardoso *et al.* 2011; Kehoe *et al.* 2021; Wagner *et al.* 2021) and mites, including ticks (Koh *et al.* 2004; Mihalca *et al.* 2011; Goldschmidt 2016; Carlson *et al.* 2017; Napierala *et al.* 2018; Esser *et al*. 2019; Ozman-Sullivan & Sullivan 2021; Sullivan & Ozman-Sullivan 2021).

Colwell *et al*. (2012) stated that dependent parasites, commensals and mutualists face the risk of co-extinction as their hosts or partners decline and go extinct. There are many tens of thousands of mite species in symbiotic relationships with plants, animals and fungi, e. g., the ecologies of mites and insects are closely linked through the sharing of habitat and intimate relationships that include phoresy and parasitism by mites (Campbell *et al*. 2013; Baumann 2018; Elo & Sorvari 2019; Seeman 2020).

The following studies highlight the harmful effects of habitat destruction and degradation, and other human activities, on mite biodiversity. Koh *et al.* (2004) estimated that 20 affiliate bird mite species were lost to extinction (= coextinction) with their hosts and that another 193 mite species will be lost if all the currently endangered bird species go extinct. In another case, the IUCN Red List status of their host species was used to evaluate the conservation status of host-specific hard ticks, with 63 and one hard-tick species listed as coendangered and extinct, respectively (Mihalca *et al.* 2011). Also, Napierala *et al*. (2018) reported that nearly 80% of 93 uropodid mite species from soil samples collected for more than 55 years across Poland were categorised in the range from 'vulnerable' to 'extinct', with 25% categorized as 'critically endangered', based on modified IUCN Red List criteria. In a study from the Cerrado biome in northern Brazil, Azevedo *et al*. (2020) reported that the soil of the naturally vegetated areas had nearly twice the number of gamasid mite species (36) as the soybean cultivation areas (20) and pasture areas (19). In addition, 19 of the total of 45 gamasid species collected in the study were only found under the natural vegetation.

Also, one-third of an estimated 450,000 plant species on Earth are threatened with extinction, with extinctions occurring at 1,000 to 10,000 the natural rate (Pimm & Joppa 2015). The highly host-specific, phytophagous eriophyoid mites (Eriophyoidea) (Skoracka *et al.* 2010; de Lillo *et al*. 2018) are an extremely species rich group, estimated to include at least 240,000 species, that is at highly elevated risk of coextinction (Sullivan & Ozman-Sullivan 2021). Not only terrestrial mites are threatened by the loss of habitat quantity and quality. Goldschmidt (2016) stated that freshwater ecosystems are increasingly threatened by human induced stressors, such as structural and hydrological changes to water courses and riparian areas, inorganic and organic pollution, land use changes and climate change. All of these threats collectively result in reduced water quality and the loss of aquatic biodiversity, including mites.

All insect species are worth protecting for their own sake but the current crisis is much larger than individual species and rises to the level of losing key ecological functions in terrestrial and aquatic ecosystems (Forister *et al.* 2019). Mites also play a fundamental role in global ecology through their active involvement in the flow of energy, matter and information (Gwiazdowicz 2021), and should be protected with the insects and multitudes of other invertebrates.

The great and growing challenge for humanity is to conserve the maximum amount of biodiversity, including mites, in the face of multiple, concurrent drivers of loss. However, implementing the solutions to global problems like biodiversity loss is extremely difficult because they require the transnational integration of major social, political and economic changes. Raven & Wagner (2021) stated that, to limit the extent of the mass biodiversity extinction event that humanity is causing, the following three overarching actions are necessary - a stable and almost certainly a lower global human population, sustainable levels of consumption, and social justice for the disadvantaged majority. In addition, Bradshaw *et al.* (2021) asserted that the global environmental emergency requires fundamental changes to global capitalism, education programs and society, including the abandonment of the focus on perpetual economic growth, social equality, a rapid transition from fossil-fuel use to renewable energy sources, and the empowerment of minority and disadvantaged groups in all societies.

The United Nations Biodiversity Conference (COP 15) in Montreal, Canada in December 2022 will bring together governments from around the world to determine a new set of goals for nature conservation over the next decade through the Convention on Biological Diversity (Biodiversity Convention) post-2020 framework. That framework contains an ambitious plan for broad-based action to achieve a radical transformation in society's relationship with biodiversity that ensures, by 2050, a shared vision of living in harmony with nature is fulfilled. This ambitious framework has the potential to substantially reduce biodiversity losses but requires an enormous amount of funding and absolute long term commitment at all levels of government across the world. Moreover, the 28 years to 2050 when 'the shared vision of living in harmony with nature' is expected to be fulfilled is an agonizingly long time for the destruction of global biodiversity to continue.

In the interim, concerned scientists, community groups and citizen activists across the world must take the lead in driving the required fundamental social, political and economic change, if we are to achieve a sustainable society that values and protects the biodiversity, including mites, on which we depend for our physical, emotional and economic well-being.

Acknowledgements

The authors dedicate this work to the many persons around the world who have contributed, often at the cost of their lives, to the protection of landscapes and their biodiversity.

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