REPTILES & AMPHIBIANS

Microplastics in Invasive Geckos (*Hemidactylus mabouia* and *H. angulatus*): First Evidence in Cuba and the Caribbean, and Transfer Pathways of Concern

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Abstract.—We report the presence of microplastics in digestive tracts or feces of two invasive House Geckos (*Hemidactylus mabouia* and *H. angulatus*) in Cuba, review the subject of microplastic contamination, and discuss possible transfer pathways for plastics and associated toxins.

Many House Geckos (*Hemidactylus* spp.) are ecologically versatile species that have successfully colonized a wide range of habitats in tropical and subtropical regions, where they can attain wide distributions, high abundance, have varied and substantive effects on biodiversity and human life, and are among the world's most widely distributed and invasive lizards (Rödder et al. 2008; Simberloff and Rejmánek 2011; Weterings and Vetter 2018).

Seven species of geckos have been introduced to Cuba: *Hemidactylus mabouia*, *H. angulatus*, *H. frenatus*, *H. turcicus*, *Gonatodes albogularis fuscus*, *Sphaerodactylus argus*, and *Lepidodactylus lugubris*. The Tropical House Gecko (*H. mabouia*) is the most abundant and widely distributed invasive reptilian species in both urban and rural areas of Cuba and other Caribbean islands, whereas the West African House Gecko (*H. angulatus*) today is less abundant and widely distributed (Borroto-Páez et al. 2015).

Both species are invasive, arriving in Cuba with the slave trade during the early colonial period. These species are effective human commensals that share buildings, including human habitations, using these structures as refuges, perches, and nesting sites (Borroto-Páez et al. 2015). These invasive geckos have become frequent entities in trophic web relations, preying on arthropod pests such as insects (cockroaches, mosquitos, flies, moths, etc.) and spiders (Bonfiglio et al. 2006; Hiscock et al. 2023) and as prey of both native (Cuban Treefrog, *Osteopilus septentrionalis*; Spotted Brown Trope, *Tropidophis pardalis*; and *Anolis* lizards) and invasive vertebrates (Black Rats, *Rattus rattus*; Domestic Cats, *Felis catus*) (Armas and Iturreaga 2017; Borroto-Páez and Reyes Pérez 2020; Reyes Pérez and Borroto-Páez 2022; Borroto-Páez and Fabres 2023).

Herein we document the presence of microplastics in the digestive tracts and fecal pellets of two species of invasive House Geckos (*Hemidactylus mabouia* and *H. angulatus*) in Cuba and call attention to the problem of microplastics and their roles as new and important environmental stressors. We also identify the possible role of other urban invasive vertebrates as vectors that spread macroplastics, impacting environmental and human health when interacting with accumulated solid waste in dumps or landfills. Microplastics and invasive species are both anthropogenic stressors that have received increased attention in recent decades and represent two socio-environmental problems in the now globalized economy, with many negative effects on biodiversity, business, and public health (e.g., Lowe et al. 2000; Bucci et al. 2020). However, the synergy and relationships of these stressors have been infrequently addressed.

The Microplastics Problem

Plastics are important environmental contaminants, a situation described as a planetary crisis, negatively impacting environmental, social, and economic dimensions of sustainable development (Savino et al. 2018; Persson et al. 2022). Along with global problems such as climate change, ocean acidification, and biodiversity loss, pollution and especially plastics have become contentious international issues (Kershaw and Rochman 2015; Geyer et al. 2017; Hu et al. 2019). Plastics production has increased exponentially in the last 60 years, from 0.5 million tons in 1960 to 390.7 million tons in 2021 (Plastics Europe

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2022). Most studies have focused on marine environments and aquatic animals (Auta et al. 2017; Bosker et al. 2018; Susanti et al. 2020; Möhrke et al. 2022), reporting ingestion of plastics in 914 marine species ranging from microinvertebrates to large marine mammals (Kühn and van Franeker 2020) and including at least 117 species of seabirds (e.g., Hyrenbach et al. 2017; Rapp et al. 2017; Flemming et al. 2022).

However, terrestrial ecosystems also are affected (e.g., Prata and Dias-Pereira 2023), as most plastic waste originates from multiple sources on land (especially landfills and dumps). Moreover, studies conducted on terrestrial environments are generally less focused on plants (Rillig et al. 2019) and invertebrates (e.g., Colpaert et al. 2022; Simakova et al. 2022; Li et al. 2024) than on terrestrial vertebrates. Among the latter, more studies address amphibians (especially tadpoles, 26 species) than reptiles, of which most studies have focused on marine turtles (Hou and Rao 2022).

Few studies have addressed how microplastics can be transferred from different ecosystems and habitats, despite trophic transfer of microplastics having been observed from aquatic to terrestrial environments from tadpoles to fish to mice (da Costa Araújo and Malafaia 2021) and ontogenetic transfers of microplastics from larvae to pupae and to adults as well as to other vertebrates via mosquito bites (Simakova et al. 2022; Li et al. 2024).

Latin America is responsible for 8% of the global consumption of plastics and produces more than 17,000 tons per day of plastic waste (Savino et al. 2018; Brooks et al. 2020; UNEP 2022) but with a very small percentage (4.5%) of recycled wastes (Kaza et al. 2018). Studies of microplastics in Latin America and the Caribbean represent only 4.8% of global studies, including a minute contribution from Caribbean islands, and generally are centered on marine and beach issues with minimal coverage of terrestrial ecosystems and vertebrates (Orona-Návar et al. 2022, Plaul et al 2024). Only 5% of Latin American investigations addressed terrestrial ecosystems with few contributions and insufficient data from the Caribbean region (Fernandes et al. 2022), in spite of the Caribbean region being a Global Biodiversity Hotspot (Myers et al. 2000).

Plastic pollution, with a particular focus on micro- and nanoplastics (particles ≤5 mm and ≤1 µm, respectively) (Andrady 2011; Gao et al. 2021), is a contaminant of emerging concern in ecosystems worldwide (Bucci et al. 2020). For example, van Sebille et al. (2020) estimated that microplastics (MPs) in the oceans have reached 52.2 × 1,012 particles, 236,000 metric tons, mainly distributed in the centers of subtropical gyres. Erikson et al. (2014) estimated that over 250,000 tons of nano- and microplastics were in the world's oceans, whereas Erikson et al. (2023) estimated that in 2019 the amount had increased to 170 trillion plastic particles (equivalent to 2 million tons). Risk models indicate a high level of plastics in the Caribbean Sea (Tambutti and Gómez 2020), and plastics in oceans and seas are continuously fragmented into micro- and nanoplastics due to meteorological (UV radiation, wind, wave energy, etc.), mechanical, biological, and/or chemical factors (Thompson et al. 2004; Cole et al. 2011; Galgani et al. 2015).

Once ingested or incorporated (from air, dust, water, etc.), the biological effects of microplastics include, for example, dysfunctions of the intestine, liver, and excretory and reproductive systems, many behavioral and physiological responses such as changes to filtration dynamics, impairment of reproductive health, expression of stress hormones, interruption of nutrient absorption, and hindered growth and survival of avian chicks (Rochman 2015; Foley et al. 2018; Boyero et al. 2020; da Costa Araújo et al. 2020; Susanti et al. 2020; Zhang et al. 2020; Zolotova et al. 2022). Plaul et al (2024) recently reviewed the many and different effects of microplastics on aquatic vertebrates in Latin America.

Microplastics can be ingested directly by primary consumption of prey, indirectly by consumption of prey animals containing microplastics (Colpaert et al. 2022; Möhrke et al. 2022), or assimilated through gills (Sigler 2014; de Souza Machado et al. 2018; da Costa Araújo et al. 2020). Moreover, for terrestrial domestic and especially commensal invasive animals, which usually live in urban ecosystems close to human populations, no integration of current data has so far been conducted on possible consequences to human and animal health risks and their assessment (Prata and Dias-Pereira 2023).

Methods

During an initial analysis of the diet of *Hemidactylus mabouia*, we examined 17 digestive tracts (stomach and intestinal contents) and eight fecal pellets in which we found small blue plastic microfibers. We subsequently examined digestive tracts of three *H. angulatus* preserved in alcohol and three fecal samples. The specimens of *H. mabouia* were from buildings in Corralillo, Villa Clara, in central Cuba (18 samples) and Víbora, Havana (7 samples). The six *H. angulatus* were from Corralillo. We examined fecal pellets and digestive tract contents diluted with distilled water in a glass petri dish using a Hinotek NSZ-800LCD series digital stereoscope with the objective of detecting microplastics. Microplastic fibers and fragments were identified by color, mostly blue, violet, or green in sharp contrast with brown digestive material. We did not detect black or transparent microplastics. To avoid contamination of samples, none of the equipment used (i.e., containers, bottles, droppers) were plastic.

To investigate potential transmission pathways, we looked for invasive vertebrates foraging in and around dumps, landfills, and trash containers in Habana and Villa Clara Provinces by day and night in June–August, 2021 and 2022, and documented any invasive vertebrate with photographs.

Results and Discussion

Analysis showed that 72% of the samples of *Hemidactylus mabouia* and 50% of *H. angulatus* were positive for the presence of microfibers or fragments of microplastic (Fig. 1A–F), and were more commonly found in digestive tracts with large volumes of food content than in fecal pellets (Table 1). Only two other papers have reported the presence of microplastics in invasive *H. mabouia*, both in Paraguay (Mackenzie and Vladimirova 2021; Hiscock et al 2023). To the best of our knowledge, our observations are the first to record microplastic ingestion by terrestrial herpetofauna (i.e., except marine turtles) in Cuba and on any Caribbean island and the first report for *H. angulatus* anywhere. The only previous report of microplastics in any Caribbean vertebrate was in the Red-billed Tropicbird (*Phaethon aethereus*) on St. Eustatius in the Lesser Antilles (Madden and Eggermont 2020).

We believe that the ingestion of microplastics by both species of geckos was indirect, resulting from consumption of arthropod or other invertebrate prey contaminated with plastics (consumed or by adherence), resulting in trophic-level transfer of microplastics and bioaccumulation in the food web, as has been found in other taxa (Hui 2004; Farrell and Nelson 2013; da Costa Araújo and Malafaia 2021).

Based on the samples examined, we concluded that cockroaches (Blattodea) are the most likely source of microplastic contamination in the two House Geckos. Cockroaches are known to ingest macroplastics (Wang et al. 2015; Lu et al. 2019; R. Siddiqui and Khan 2023). Cockroaches are frequent prey of House Geckos (Fig. 2) and remnants of cockroach were abundant in the digestive tracts of both species of lizards.

We cannot, however, eliminate the possibility that microplastics were acquired by consumption of other arthropods such as dipterans (e.g., House Fly, *Musca domestica*) or mosquitoes (i.e., *Aedes* spp. or *Culex* spp.), all of which are common prey of *Hemidactylus* spp. Mosquitoes can ingest microplastics as aquatic larvae and transfer them to pupal and adult stages and ultimately to geckos through a bite or as prey (Simakova et al. 2022; Li et al. 2024). House Flies can function as microplastic vectors as a result of electrostatic adherence to its body (Li et al. 2024). Inhalation or ingestion of contaminated dust also are possible sources by, for example, ingesting ants (Hymenoptera) after they came into contact with contaminated surfaces.

Wider ecological and human public-health implications accrue from the presence of micro- and nanoplastics and associated toxic chemical additives in tissues and organs of

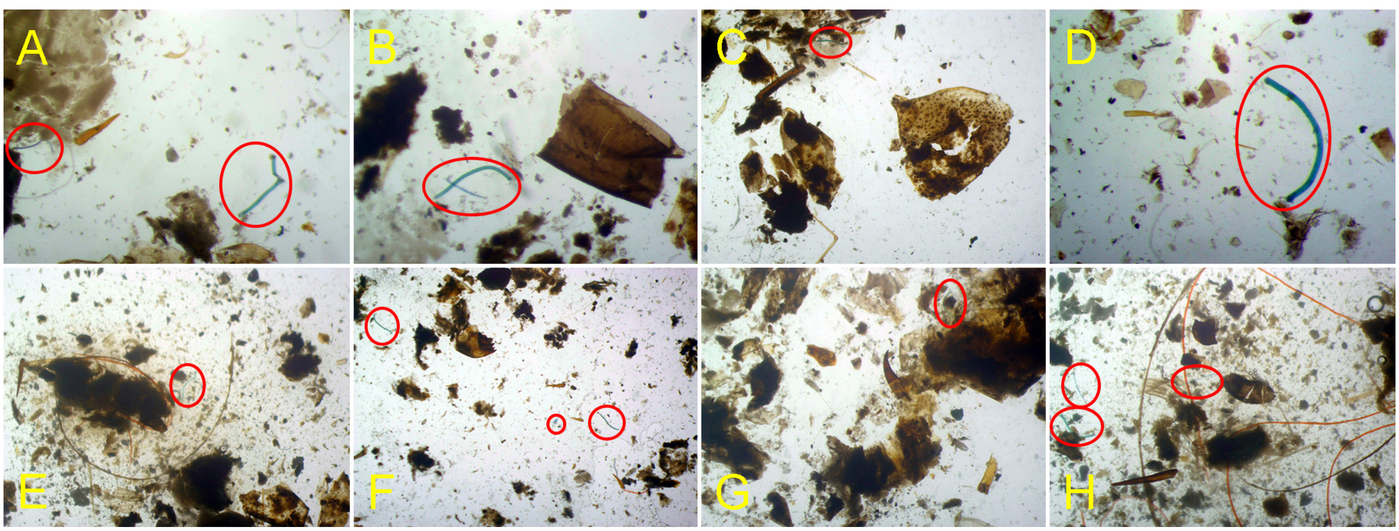

Figure 1. Examples of microplastics in digestive tracts or feces of two invasive species of geckos from two localities in Cuba: Tropical House Gecko, *Hemidactylus mabouia* (A–F), and West African House Gecko, *Hemidactylus angulatus* (G–H); from feces: *H. mabouia* (E) and *H. angulatus* (H); all others were found in digestive tracts. Photographs by R. Borroto-Páez.

Table 1. Two species of invasive House Geckos (*Hemidactylus mabouia* and *H. angulatus*) in two Cuban localities with microplastics in digestive tracts or feces. E = specimens examined; P = specimens with microplastics in the digestive tract or feces; P (%) = percentage.

		Digestive Tract			Feces		
Species	**Locality**	**E**	**P**	**P (%)**	**E**	**P**	**P (%)**
H. mabouia	Corralillo, Villa Clara	12	9	75.0%	6	4	66.6%
H. mabouia	Víbora, Havana	5	4	80.0%	2	1	50.0%
H. angulatus	Corralillo, Villa Clara	3	2	66.6%	3	1	33.3%

Figure 2. A Tropical House Gecko (*Hemidactylus mabouia*) preying on a cockroach in an apartment in Havana, Cuba. Photograph by R. Borroto-Páez.

invasive species. For example, microplastics integrated into the trophic web could be transferred to native species preying on invasives. In terms of human public health, a number of invasive species are known vectors for a range of pathogens to which we now must add the spread of microplastics and associated toxins. Some common plastic polymers like polyvinyl chloride (PVC) and polystyrene (PS) are known to be toxic (Kudzin et al. 2023; S.A. Siddiqui et al. 2023); also, plastic consumer products often contain metals and other organic compounds. Some of these additives are environmental and human-health hazards (e.g., endocrine disruptors, carcinogens) (Wang et al. 2024). In addition, microplastics can be colonized by pathogenic organisms such as bacteria, viruses, protozoa, fungi, and helminth parasites with zoonotic potential as biofilms (Ormsby et al. 2023, 2024a, 2024b). Plastispheres can act as reservoirs of dangerous clinical pathogens (Chaimusik et al. 2024; Ormsby et al. 2023, 2024a, 2024b); for example, pathogenic fungi (*Penicillium*, *Aspergillus*, *Mucor*) and bacteria (e.g., *Salmonella*) have been associated with *H. mabouia* (da Silva Ferreira et al. 2022; Murphy and Meyers 1993; Svedese et al. 2017). These documented relationships present a new and important direction for further research on commensal House Geckos and their roles in environmental and human health.

Other invasive vertebrates also are vulnerable to plastic contamination and can serve as potential means of dispersal. Latin America and the Caribbean have high rates of plastic consumption and improper waste management (Orona-Návar et al. 2022; UNEP 2022). The rarity of collecting and recycling solid wastes in Cuba today is a major problem resulting in the accumulation of trash in many urban and rural sites. In addition, we are aware of invasive rats and mice (*Rattus rattus*, *R. norvegicus*, *Mus musculus*) gnawing on pipes and other plastic objects, another mechanism that can lead to plastic contamination. Especially in urban situations, many

Figure 3. Invasive vertebrates foraging in garbage on two consecutive days in June 2022 in Boyeros Municipality, Havana: Brown Rats (*Rattus norvegicus*) (A), free-roaming Domestic Dog (*Canis familiaris*) (B), and a free-ranging Domestic Chickens (*Gallus domesticus*) (C). Note the concentration of macroplastics (plastic bags, boxes, bottles, etc). Photographs by R. Borroto-Páez.

invasive vertebrate species are exposed to solid wastes, including considerable quantities of macroplastics (Figs. 3–5), and

Figure 4. Free-roaming Feral Cats (*Felis catus*) foraging in garbage containers by night and day at two different localities in Havana. Photographs by R. Borroto-Páez.

Figure 5. Additional examples of invasive and free-ranging domestic birds foraging in garbage and drainages in Corralillo, a rural town in central Cuba and in Havana: two Domestic Chickens (*Gallus domesticus*) and a Helmeted Guineafowl (*Numida meleagris*) (A) and two free-ranging Domestic Chickens foraging in two different solid waste dumps in Corralillo (B); House Sparrows (*Passer domesticus*) (C) and a Eurasian Collared Dove (*Streptopelia decaocto*) (D) foraging in garbage in Havana; and two Muscovy Ducks (*Cairina moschata*) foraging in a building drainage system in Corralillo (E). Again, note the abundance of macroplastics. Photographs by R. Borroto-Páez.

both native and invasive animals that forage in such areas are vulnerable to incorporating microplastics in their systems and capable of transferring pathogens.

Conclusions

Our goals when implementing this study were to: (1) Increase our understanding of contamination and dispersal of microplastics and associated toxins in the Caribbean region; (2) elucidate the roles of two invasive House Geckos as potential vectors of microplastics; (3) call attention to the need for further research on other invasive vertebrates in close and regular contact with solid wastes containing plastics and other known and potential pathogens; and (4) highlight the potential risks to the environment and to human public health when invasive vertebrates associate with and transfer contaminants and associated pathogens to native fauna and human populations.

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