

Conquering Brazil: the invasion by the exotic gekkonid lizard *Hemidactylus mabouia* (Squamata) in Brazilian natural environments

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ABSTRACT. In this study we review the records regarding occurrence of *Hemidactylus mabouia* Moreau De Jonnès, 1818 in Brazil, looking for records of the species in natural habitats, in order to assess the present *status* of this gecko as an exotic or invasive alien species in the country. We surveyed the available records of *H. mabouia* living in natural conditions, considering secondary data obtained from the literature, supplemented with original field records obtained by the authors during fieldwork. We found a total of 36 records in the literature and/or field records reporting the occurrence of *H. mabouia* in natural habitats in 36 different localities in 13 Brazilian states. The states presenting a higher number of records were Rio de Janeiro (seven), Bahia, São Paulo (six), and Espírito Santo (five different areas). We show that the invasion of Brazilian natural habitats by *H. mabouia* has taken place for some decades. Presently we have consistent records that it has invaded natural habitats in 13 Brazilian states. This suggests that it is important to start monitoring *H. mabouia* in order to measure the rate and effectiveness of its establishment in natural habitats in Brazil and also to evaluate the potential negative effects of this invasion on sympatric species.

KEY WORDS. Exotic species; invasive lizard; monitoring of species; open habitat invasion; status of invasion.

Hemidactylus mabouia Moreau De Jonnès, 1818 is an exotic (African) species which has been introduced and is successfully established in the New World, having colonized many countries in South America (including Brazil) (VANZOLINI 1978, ANJOS & ROCHA 2008a), Central America and the Caribbean (except Jamaica – KLUGE 1969, HOWARD *et al.* 2001) and parts of North America. A recent phylogenetic study (CARRANZA & ARNOLD 2006) suggests that African lineages have naturally crossed the Atlantic at least twice and colonized the New World, sometimes with devastating consequences for other geckos. In North America this gekkonid has rapidly colonized extensive areas (LAWSON *et al.* 1991, BUTTERFIELD *et al.* 1993, MESHAKA *et al.* 1994, MESHAKA 2000), causing niche displacement of two other exotic congeners, *H. garnotti* and *H. turcicus* (MESHAKA 1995, 2000).

Hemidactylus mabouia is a nocturnal lizard that can be commonly found in anthropic or perianthropic environments (VANZOLINI *et al.* 1980) in different Brazilian ecosystems (ROCHA *et al.* 2011) such as the Amazon forest, the Atlantic forest, the Cerrado (savannah-like vegetation areas of central Brazil), the Caatinga (the semi-arid areas of northeastern Brazil), the Restingas (coastal sand-dune habitats of Brazil) and on some islands off the Brazilian coast (VANZOLINI 1968, 1978, VANZOLINI *et al.* 1980, VITT 1986, ARAÚJO 1991, AVILA-PIRES, 1995, ROCHA *et al.* 2000, 2002, ANJOS & ROCHA 2008a, ROCHA & BERGALLO 2011). Most information regarding occurrence and/or ecological as-

pects of this exotic species in Brazil comes from anecdotal/general field observations (VANZOLINI *et al.* 1980, TEIXEIRA *et al.* 2003), from auto-ecological studies (e.g., ZAMPROGNO & TEIXEIRA 1998, ROCHA *et al.* 2002, BONFIGLIO *et al.* 2006, ANJOS *et al.* 2007, ROCHA & ANJOS 2007, ANJOS & ROCHA 2008b) and from community studies (ARAÚJO 1991, VITT 1995, ROCHA & VRCIBRADIC 1998, HATANO *et al.* 2001, TEIXEIRA 2001, ALMEIDA-GOMES *et al.* 2008).

Although *H. mabouia* has been usually considered an exotic species in Brazil, restricted to anthropic environments, recent evidence suggests that this species has already invaded some natural environments, which would change its *status* from exotic to invasive exotic. Here, we review the records regarding *H. mabouia* in Brazil, looking for registered cases of invasion of natural environments by the species in order to assess classify the present *status* of this gecko as exotic or as an invasive exotic species in Brazil.

MATERIAL AND METHODS

We surveyed the available records of occurrence of *H. mabouia* living in natural conditions, considering secondary data available from literature, supplemented with original field records from the authors obtained during several years of fieldwork, mostly in southeastern, but also in some southern, northeastern and Amazonian areas. We made an effort to check the

widest array of available literature reporting herpetofaunal surveys in Brazil, as well as other more specific herpetofaunal studies (e.g., species-specific studies). For the purpose of the present study, we only considered secondary data that clearly mentioned microhabitat and/or habitat occupation by *H. mabouia* in a natural environment at the time the lizard was collected or registered. For each record, we took note of the following (when available): date and time of collection, locality, municipality and state, coordinates of the area, microhabitat used by the gecko, general environment, and the source of the record.

RESULTS

We found a total of 36 literature and/or field records (Tab. I) reporting the occurrence of *H. mabouia* in natural habitats in 36 different localities of Brazilian states (Tab. I, Fig. 1). Of these, 18 records (or 50%) were in restinga and/or sand dune habitats, five (or 13.9%) in Cerrado environments, five (or 13.9%) in forests, five (or 13.9%) in rocky islands, two (or 5.6%) in coastal rock faces and one (or 2.8%) in rock outcrops dominated by Cerrado vegetation. Most of these records are from the eastern Brazil (Figs 1-5). The states presenting a higher number of records were Rio de Janeiro (seven), Bahia, São Paulo (six), and Espírito Santo (five different areas), but we also recorded *H. mabouia* in natural areas in Santa Catarina, Paraná, Pernambuco, Rio Grande do Norte, Ceará, Piauí, Maranhão, Mato Grosso and Goiás (Tab. I, Fig. 1). We found no record of this gekkonid as an invader in the Brazilian Amazonian region, although it has been recorded in different localities as an exotic species in anthropic and peri-anthropic areas in this Biome (e.g., VANZOLINI 1986, VITT 1996, VITT *et al.* 1998, AVILA-PIRES, 1995, VITT & ZANI 1998). Figures 2-5 show the spread of *H. mabouia* in natural habitats in Brazil registered in literature during the last 70 years.

DISCUSSION

Hemidactylus mabouia occurs as an exotic species in virtually all urban environments in Brazil (VANZOLINI 1968, ANJOS & ROCHA 2008a, DOSSIÉ PERNAMBUCO 2009, ROCHA *et al.* 2011). Our data indicate that during the first decades after its first record in the country (1945) the species was recorded as invasive in natural environments in the following states: Paraná, Rio de Janeiro, São Paulo, and Piauí (Figs 2-5). Presently, the states with most records of invasions are Rio de Janeiro [both in restinga habitats (MYERS 1945, ARAÚJO 1984, 1991, 1994, FREIRE 1996, TELXEIRA 2001, ROCHA *et al.* 2004, CARVALHO *et al.* 2007) and in Evergreen Forest (CARVALHO *et al.* 2007, ALMEIDA-GOMES *et al.* 2008)]; Bahia (in restinga areas, DIAS & ROCHA 2005), in the dunes of the São Francisco River (RODRIGUES 1996) and in the insular environment of the Abrolhos archipelago (ROCHA *et al.* 2002); Ceará (in Cerrado and Cerradão habitats, RIBEIRO *et al.* 2008); São Paulo [in ruderal fields (ROCHA & ANJOS 2007) and in continental islands (VANZOLINI 1968, DUARTE *et al.* 1995, VRCIBRADIC & ROCHA 2005)], and in

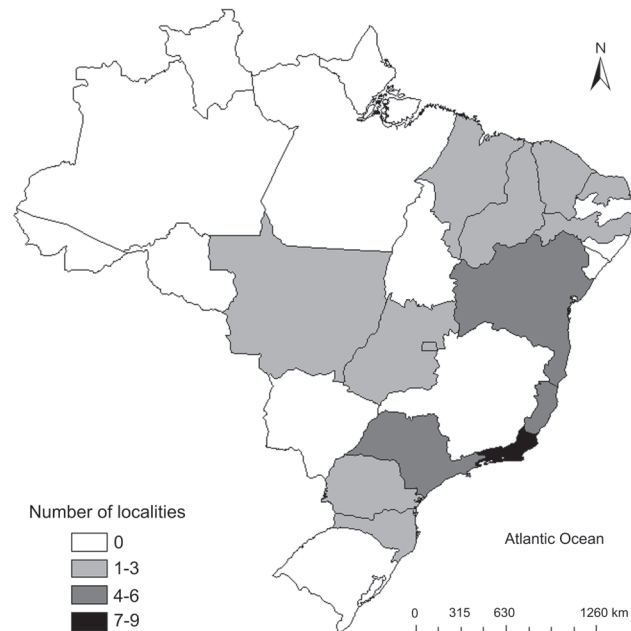
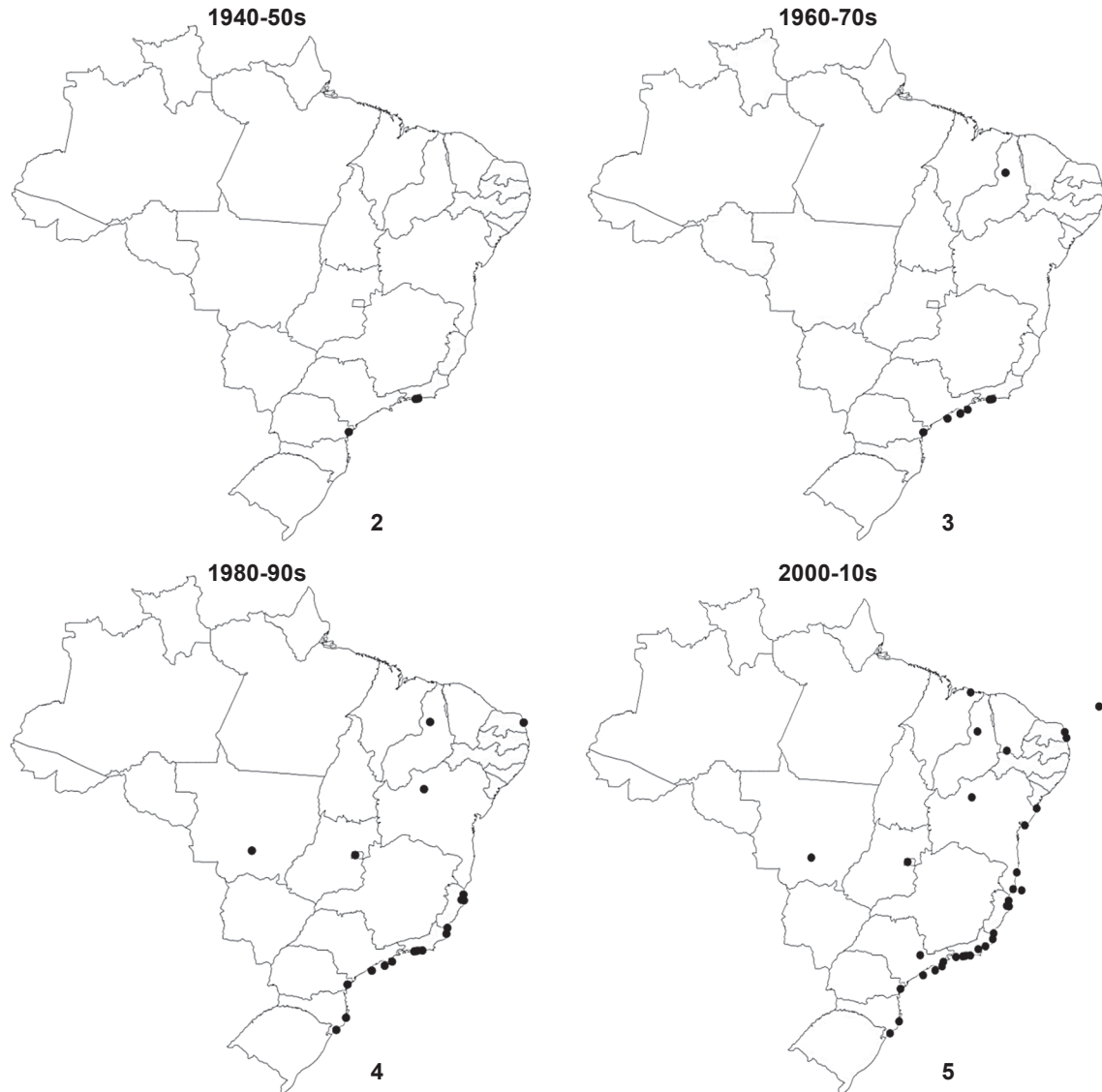


Figure 1. Map showing for each state of Brazil, the number of records of occurrence of the exotic gekkonid lizard *Hemidactylus mabouia* as an invader species in natural environments. The gradation of gray color intensities indicates the number of records for each particular state.

Pernambuco, in the Fernando de Noronha archipelago (ROCHA *et al.* 2009) (Figs 1-5). The spread of *H. mabouia* in nature, as extracted from the literature, shows that most invasions are concentrated in the eastern part of Brazil. This may be partially due to the fact that most studies are carried out in this part of Brazil and also due to the capacity of the species to invade open habitats such as restinga and cerrado (ROCHA & BERGALLO 2011). The data show that this gecko has already invaded different types of open (and closed) natural environments in different regions of Brazil, including continental and insular areas. The first records of *H. mabouia* in natural habitats in Brazil we are aware of were provided by MYERS (1945) for a coastal restinga and beach habitats of Rio de Janeiro and Paraná states.

The invasion of exotic species is considered an important cause of loss of biodiversity in protected areas and on oceanic islands (GISP 2005, ZILLER & ZALBA 2007). The invasion of *H. mabouia* in the New World areas has resulted in negative impacts on populations of other native geckos (CARRANZA & ARNOLD 2006 and references therein). This is an indication that the monitoring of the possible expansion of the species in natural environments in Brazil is of strategic importance. The events reported here regarding the invasion of natural environments by *H. mabouia* show that invasion of natural environments in Brazil by this species has taken place at least since 1945 and is steadily increasing, becoming more intense starting in 1980. In most areas in Brazil, the



Figures 2-5. The spread of *Hemidactylus mabouia* in natural habitats in Brazil in the last 70 years based on records available in literature. The maps show (2) records of 1940 to 1959, and (3-5) the accumulation of records in the following decades.

species still remains restricted to urban or periantropic environments, although it is possible that it can change its status from exotic to invasive exotic in these areas in the near future. This change from exotic to invader can be even more critical in island habitats, which are fragile environments and tend to have comparatively lower diversity and richness of fauna.

The data available suggest that the invasion by *H. mabouia* is facilitated in open environments that have a high incidence of solar radiation at the ground level, such as restinga and cerrado habitats. For instance, in some forested Atlantic rainforest areas of Ilha Grande, no record of invasion by *H. mabouia* has been

obtained, even after considerable efforts to find it during herpetological studies carried out during decades (ROCHA *et al.* 2009), or as part of an extensive survey along existing trails in the island (ROCHA & BERGALLO 2011). Similarly, there are still no reported cases of invasion of natural environments by *H. mabouia* in extensive portions of the Amazon rain forest, although the Amazon forest encloses not only the largest territorial area but also constitutes one of the regions of Brazil with the largest number of available studies on herpetofauna (e.g., VANZOLINI 1986, DUELLMAN 1987, MARTINS 1991, VITT 1996, VITT *et al.* 1998, 2008, VITT & ZANI 1998).

Table I. Summary of the existing literature records of occurrence of the exotic gekkonid lizard *Hemidactylus mabouia* as an invader species in some natural environments (including locality and State) in Brazil. ERB = Unpublished records of Expedição Restingas Brasileiras Unpublish Record; (?) indicates that information on microhabitat was not provided.

Environment/Site	Microhabitat	Locality/State	Source
Restinga and Sand Dune habitats			
Barra de Maricá	On bromeliads	Maricá, RJ	ARAÚJO (1984, 1991)
Jurubatiba	On bromeliads	Macaé, RJ	HATANO <i>et al.</i> (2001), ROCHA <i>et al.</i> (2004)
Grussaí	On bromeliads	Campos dos Goytacazes, RJ	ERB CFD Rocha leg., 20/XI/1999, Reg No. 341
Marambaia	On bromeliads	Rio de Janeiro, RJ	CARVALHO <i>et al.</i> (2007)
Gávea Beach (= São Conrado Beach)	On <i>Fourcroya gigantea</i> leaves	Rio de Janeiro, RJ	MYERS (1945)
Restinga Sernambetiba	On <i>Fourcroya gigantea</i> leaves	Rio de Janeiro, RJ	MYERS (1945)
Neves	On bromeliads	Presidente Kennedy, ES	ARAÚJO (1994)
Campo Nativo of Paraju	On bromeliads	Linhares, ES	ROCHA (1998)
Guriri	On bromeliads & on tree trunks	São Mateus, ES	TEIXEIRA (2001); ERB CFD Rocha leg. 09/XI/1999 Reg. #058
Pontal do Ipiranga	Under fallen tree trunks	Linhares, ES	ZAMPROGNO & TEIXEIRA (1998)
Costa Azul	?	Jandaíra, BA	DIAS & ROCHA (2005)
Abaeté	?	Salvador, BA	DIAS & ROCHA (2005)
Trancoso	?	Porto Seguro, BA	DIAS & ROCHA (2005)
Nova Viçosa	?	Nova Viçosa, BA	DIAS & ROCHA (2005)
Campos de dunas de Xique-Xique	On tree trunks	Ibiraba & Queimadas, BA	RODRIGUES (1996)
Dunes & restinga habitats of Lençóis	Under logs/decomposing tree trunks	Barreirinhas/Santo Amaro, MA	MIRANDA (2007)
Dunes & restinga habitats of Natal	On bromeliads/leaf litter/tree trunks	Natal, RN	FREIRE (1996)
Beach habitat south Paranaguá estuary	On <i>Fourcroya gigantea</i> leaves	Paranaguá, PR	MYERS (1945)
Cerrado (Savannah-like vegetation)			
Cerrado of Brasília	?	Brasília, DF	ARAÚJO (1992)
Cerrado of the Chapada	?	Chapada dos Guimarães, MT	ARAÚJO (1992)
Cerrado and Cerradão of the Chapada	?	Chapada do Araripe, CE	RIBEIRO <i>et al.</i> (2008)
Canal of Salto das Andorinhas	?	Aripuanã, MT	Instituto Horus
Open Cerrado	?	Valença, PI	VANZOLINI (1976)
Forested environments			
Forest of Marambaia	On tree trunks	Rio de Janeiro, RJ	CARVALHO <i>et al.</i> (2007)
Ombrophilous forest	On tree trunks	Casimiro de Abreu, RJ	ALMEIDA-GOMES <i>et al.</i> (2008)
Forest at Fazenda Brunoro	?	Venda Nova do Imigrante, ES	SAMPAIO <i>et al.</i> (2007)
Forest of Ilha Anchieta	?	Ubatuba, SP	CICCHI <i>et al.</i> (2009)
Massaguassu	?	Caraguatatuba, SP	Instituto Horus
Rocky islands			
Abrolhos Archipelago	On & under rocks	Caravelas, BA	ROCHA <i>et al.</i> (2002)
Fernando de Noronha Archipelago	On rocks and on tree trunks	Fernando de Noronha, PE	ROCHA <i>et al.</i> (2009)
Alcatrazes Archipelago	On clumps of bromeliads; in forests	São Sebatião, SP	VANZOLINI (1968), MARQUES <i>et al.</i> (2002a)
Queimada Grande Island	On clumps of bromeliads; in forests	Itanhaém, SP	VANZOLINI (1968) DUARTE <i>et al.</i> (1995) MARQUES <i>et al.</i> (2002b)
Ilha dos Búzios Island	On clumps of bromeliads	Ilhabela, SP	VANZOLINI (1968)
Coastal Rocky Hills			
Coastal Rocky Hills	On hill surface at seaside	Araguariá, SC	LEMA (1994)
Coastal Rocky Hills	On hill surface at seaside	Garopaba, SC	LEMA (1994)
Rock outcrop			
Fazenda Manga	On rock blocks surface	Valinhos, SP	ROCHA & ANJOS (2007), ANJOS & ROCHA (2008b)

One interesting feature that arises from the records available regarding invasion of natural environments by *H. mabouia* in Brazil is the lack of records from the state of Minas Gerais (which is clearly depicted in Fig. 1), although reptiles from this state, including considerations on exotic ones, have been recently surveyed (BÉRNILS *et al.* 2009). This is one of the largest states in Brazil and, according to our data, the states surrounding it have records of invasion of natural environments by *H. mabouia*. At this point we do not know to which extent this gap results from a real absence of invasion of natural environments by this gecko up to now, or if it is caused by a lack of reports on the occurrence of the species in natural environments in the state. We strongly recommend that when researchers find *H. mabouia* during herpetological fieldwork, they describe, in as much detail as possible, the habitat and microhabitat used by the gecko and the date and time of the event. Also, we do not know whether the predominance of records of the gecko in natural environments in coastal states of Brazil might be a by-product of the fact that human colonization of the country started from the coast towards inland regions.

Data available indicate that, in natural environments, the main microhabitats used by *H. mabouia* are bromeliads (on green leaves or under the dried leaves of the bromeliad base) and on tree trunks where individuals tend to remain under the bark of the trees. Eggs (and in some cases also hatched egg shells) have been found among dried leaves at the base of bromeliads, both isolated and in groups (C.F.D. ROCHA pers. obs. – in Praia das Neves and in Guriri restingas, Espírito Santo). The finding of hatched eggshells suggests successful completion of the reproductive cycle of this gecko in nature in those restingas.

Although *H. mabouia* is a characteristically nocturnal species, in the natural areas where it was recorded as an invader individuals have been found to be active also during the day (e.g., HATANO *et al.* 2001). For example, in a restinga habitat, which was actively searched for different species of diurnal lizards during different periods of the day, active individuals of *H. mabouia* have been recorded, especially in the afternoon (from 14:00 to 18:00 pm) (HATANO *et al.* 2001). This shows that in that open habitat the gecko extended its activity to daytime, potentially interacting and sharing space and food resources not only with some nocturnally native vertebrates (e.g., frogs, some lizards, small mammals), but also with diurnal ones. Also, the occurrence of *H. mabouia* as prey of some snakes – *Thamnodynastes strigilis*

(Thunberg, 1787) and *Oxyrhopus guibei* Hoge & Romano, 1978, Colubridae – and a lizard species – *Tropidurus torquatus* (Wied, 1820), Tropiduridae – in the restinga habitat of Barra de Maricá in Rio de Janeiro (ROCHA & VRCIBRADIC 1998) is another consistent evidence of this invader species interacting in nature with sympatric native vertebrates. A similar trend can be inferred from the *H. mabouia* population at the Alcatrazes and Queimada Grande islands, off the coast of São Paulo, where this gecko is occasional prey for the local insular pitvipers, *Bothrops alcatraz* (= *Bothropoides alcatraz* (Marques, Martins & Sazima, 2002)

(MARQUES *et al.* 2002a) and *Bothrops insularis* (Amaral, 1921) (DUARTE *et al.* 1995), respectively. Regarding the relationship with parasites, after the process of colonization, a well established invader species might harbor the local parasitic fauna (CRISCIONE & FONT 2001). Concerning the establishment and the interaction with native lizards within a community, another evidence of *H. mabouia* entering the natural system was the acquisition of parasitic fauna from the local sympatric lizards in a rock outcrop area at Valinhos in state of São Paulo (ANJOS *et al.* 2005).

The data available suggest that invasion of *H. mabouia* in forested environments seems to be less favored than in open habitats (only 14.8% in forested habitats and 85.2% in open habitats), an idea to be evaluated. We do not know to which extent this might be caused by more restricted thermal characteristics of forested environments compared with more open habitats (such as restingas, cerrado, and coastal rocky islands), or whether it might be due to the comparatively higher humidity of forests that would not be favorable to this nocturnal gekkonid. Additionally, because this gecko has an African origin and is possibly adapted to open habitats (KLUGE 1969), it is expected to be found in open habitats in Brazil also.

Based on our data, the invasion of open Brazilian natural habitats by *H. mabouia* has already taken place since at least 1945 and presently we have consistent records of its invasion of nature for 13 Brazilian States. This suggests that, at this point, it is important to start monitoring *H. mabouia* species in order to measure the rate and effectiveness of the progress of its colonization of natural habitats in Brazil and also, of its potential negative effects imposed on sympatric species.

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