Dispersion and Ecological Plasticity Patterns of *Haemagogus capricornii* and *H. janthinomys* (Diptera: Culicidae) Populations in Different Regions of Brazil1

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DISPERSION AND ECOLOGICAL PLASTICITY PATTERNS OF *HAEMAGOGUS CAPRICORNII* AND *H. JANTHINOMYS* (DIPTERA: CULICIDAE) POPULATIONS IN DIFFERENT REGIONS OF BRAZIL[1]

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ABSTRACT: With the aim of analyzing the dispersion and degree of ecological plasticity of populations of *Haemagogus capricornii* Lutz, 1904, and *Hg. janthinomys* Dyar, 1921, in different phytogeographical areas of Brazil, from specimens originating from 32 municipalities, biostatistical analyses were carried out on female and male specimens by means of the Fager affinity index (1957) and the real dominance coefficient. Based on the affinity index, it was observed that the populations of these two taxa did not present any tendency towards sympatry. Based on the dominance coefficient, it was found from mapping the geographical distribution of the species that *Hg. janthinomys* is the dominant species in Brazil. However, in some geographical areas, such as Rio de Janeiro and probably São Paulo, Santa Catarina, and Rio Grande do Sul, *Hg. capricornii* is the species with greater dominance. The real relationship between the species with regard to geographical space reinforces the idea that the two species occupy different habitats.

KEY WORDS: *Haemagogus*, geographical distribution, Culicidae, Diptera, vectors, dispersion, ecological plasticity, Brazil

The genus *Haemagogus* is mostly distributed Central America and northern parts of South America (Arnell, 1973). Although this genus includes species of enormous epidemiological importance, there is still little knowledge of the real affinity of these species for the very diverse ecotopes that they occupy.

Because *Haemagogus capricornii* Lutz, 1904 is a Brazilian species capable of efficiently transmitting the virus that causes wild-type yellow fever (Waddell and Kumm, 1948; Waddell, 1949), and because its behavior is very similar to that of other species in the same genus, for a long time it was confused with *Haemagogus janthinomys* Dyar, 1921. Arnell (1973) discussed the geographical distribution of *Hg. capricornii*, and affirmed that it is restricted to Brazil, occurring between southern regions of Bahia and northern regions of Rio Grande do Sul. According to Forattini (2002), *Hg. capricornii* is typically silvatic and follows the localities of the Atlantic Forest and the semi-deciduous vegetation of the plateau. Because of the overlapping distribution and morphological similarity between *Hg. capricornii* and *Hg. janthinomys*, Consoli and Lourenço-de-Oliveira (1994) believed that much of the information relating to the geographical and biological distribution of *Hg. capricornii* might be wrong. Currently, *Hg. janthinomys* is reported in all Brazilian states to the north of Paraná, and its

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occurrence has also been recorded in practically all other countries in Neotropical regions. Arnell (1973) already considered *Hg. janthinomys* as the principal vector of the virus-causing wild-type yellow fever, since its geographical distribution coincided with the endemic areas for this disease.

Other species of *Haemagogus*, such as *Hg. spegazzinii* Brethes, 1912 present greater prevalence in dry regions of northeastern Brazil, where the annual rainfall never reaches 1,000 mm. Conversely, these areas do not appear to be favorable for *Hg. capricornii*, which prefers areas in the southern and southeastern regions, or for *Hg. janthinomys*, which has been found more frequently in the northern region, particularly within the areas influenced by the Amazon River, where the annual rainfall often exceeds 2,000 mm.

Since knowledge of the distribution and degree of isolation of the species depends on the location of favorable biotopes and on the capacity to adapt to the environment, Dégallier et al. (1992) emphasized the need to investigate the frequency and abundance of mosquitoes of this group in different endemic areas. Camargo-Neves et al. (2005) emphasized the need to evaluate the capacity of some species, including *Hg. janthinomys*, to survive in degraded areas. In this study, our main aim was to record and correlate the dispersion and the degree of ecological plasticity of populations of *Hg. capricornii* and *Hg. janthinomys* in different phytogeographical areas. This mapping would provide us with supporting data for a better understanding of the areas where populations of different taxa overlap. We deemed spatial discontinuities between the populations of given species to be a general characteristic of the geographical or ecological distribution of these populations, in which sporadic contacts by transient individuals maintain the genetic inheritance within the different population pockets of a species. Ávila-Pires (2000) again discussed the importance of more accurate knowledge of this distribution, to make it possible to identify the factors that act in relation to the dispersion of different populations of *Hg capricornii* and *Hg. janthinomys.*

METHODS

Description of the study areas

The study areas were formed by the biomes of tropical forest characteristic of the Atlantic Forest and the Brazilian savanna (*Cerrado*). The region of the Atlantic Forest includes all the coastal strip of the northeastern, southeastern and southern regions of Brazil. Its climate is equatorial in the northeast and gradually transforms into hot and humid temperate in the south, presenting high mean temperatures throughout the year. This high rainfall is due to the barriers formed by the several mountain ranges that stand in the way of the winds that blow westwards from the sea. The soil is generally poor and the topography is very rugged, presenting relief consisting of significant chains of mountain which follow the Brazilian coastline from Rio Grande do Sul to Rio Grande do Norte, with a mean altitude of 900 meters. At various points, the vegetation typical of the Atlantic Forest advances in broad swaths into the interior of the country.

These features together make the region extremely humid and make it possible for the occurrence of a dense coastal forest with trees of 20 to 30 meters in height. This dense arboreal vegetation, forming substrates with dark, wet and poorly ventilated undergrowth, makes it possible for different microclimates in the layers of the rainforest, even though they are under the same macroclimatic conditions (Ferri, 1980).

In broad terms, according to Eiten (1972) and Peixoto and Coradin (1993), the vegetation characteristic of the Brazilian savanna has a very diversified appearance, going from very open landscapes like savanna grasslands (*campos limpos*) to relatively densely vegetated forms such as riverbank forests and dry forest (*cerradão*). Between these two extremes, there are intermediate forms with the appearance of savanna, such as shrub savanna (*campos sujos*) or savanna with scattered trees (*campos cerrados*), which are the typical configurations of the Brazilian savanna. Thus, the biome of the *Cerrado* mostly presents a mosaic of physical forms, and by simply traveling a few kilometers, all these different forms can be found.

The vegetation is generally made up of sparse trees of relatively modest height, rarely reaching 10 meters, numerous bushes and a bottom layer of grasses. Trees present large rough leaves, with twisted trunks and boughs and very thick bark. These characteristics are associated with high aluminum concentrations in the soil and not with lack of water. The twisted nature of the trunks and branches is related to the fires that frequently occur, which cause the loss of the main shoots and stimulate random budding of side shoots, thus forming irregular branches that are very twisted.

Mosquitoes Studied

The adult mosquitoes analyzed in this study were from specimens in the entomological collection of the Department of Entomology of the Oswaldo Cruz Institute (Rio de Janeiro, Brazil). The other specimens had recently been collected from preserved areas in the five geographical regions of Brazil. These other specimens came from the following municipalities: Teresópolis, State of Rio de Janeiro (Serra dos Órgãos National Park-SONP); Picinguaba, State of São Paulo (Serra do Mar State Park-SMSP), Nova Iguaçu, State of Rio de Janeiro (Tinguá Biological Reserve-TBR), Linhares, State of Espírito Santo (Vale do Rio Doce Forest Reserve-VRFR), São José do Barreiro, State of São Paulo (Serra da Bocaina National Park-SBNP); Caldas Novas and Uruaçu, State of Goiás; Chapada dos Guimarães, State of Mato Grosso (Chapada dos Guimarães National Park-CGNP); and Peixe, State of Tocantins. The adult mosquitoes were collected by means of a manual suction tube and entomological net with an opening of 30 m in diameter and 60 cm in length, with a short handle. The mosquitoes captured were put into polyethylene capsules, labeled according to place of origin, which were stored in thermal boxes and transported to the laboratory.

The specimens were identified by means of direct observation of the morphological characteristics that could be seen under the stereoscopic microscope and transmitted light microscope, using the dichotomous keys proposed by Arnell (1973) and Forattini (2002). The generic and subgeneric names were abbreviated in accordance with Reinert (1975) (Table 1).

Statistical Analyses

The geographical distribution pattern of the individuals of each species was estimated by means of the Fager affinity index (1957), which has the aim of recognizing the occurrence of real, frequently manifested interspecies associations that are independent of variations in species abundance.

$$I_{ab} = 2n_j / (n_a + n_b),$$

where I_{ab} = affinity index for species a and b, n_j = number of geographical regions where the two species of mosquitoes are simultaneously present (sympatric), in terms of the geographical regions considered, and n_a as well as n_b = the number of geographical regions for mosquito species a and b, respectively.

To evaluate the significance of this index, the "t" test was applied, taking an arbitrary significance level of 5%. The "t" was calculated according to the formula:

$$t = \{[(n_a + n_b).\ [(2n_j) - 1] / (2\ .\ n_a\ .\ n_b)] - 1\}\ .\ \sqrt{\ }\ (-\ [(n_a + n_b) - 1]).$$

The real dominance coefficient (RDC) was used to measure the dominance pattern among the species in a given habitat, in relation to the whole community analyzed. The RDC was calculated in accordance with Serra-Freire (2002),

$$RDC = (\sum x_i / \sum t_i).\ 100,$$

where $\sum x_i$ = the sum of the number of mosquitoes of a given species found in each geographical region and $\sum t_i$ = the sum of the number of mosquitoes of all the species found in each geographical region.

To quantitatively analyze the degree of association between the samples in relation to altitude and abundance, a correlation coefficient was used, as follows:

$$rj = \sum(dx_j\ .\ dy_j) / (n\ .\ s_x\ .\ sy_y),$$

where: rj = correlation coefficient, dx_j = deviation of altitude values in relation to mean altitude, dy_j = deviation of the number of insects in relation to the mean number of insects, s_x = standard deviation for the altitudes, sy = standard deviation for the number of mosquitoes, and n = number of observations.

Table 1. Geographical distribution of *Haemagogus capricornii* and *Hg. janthinomys* specimens analyzed, according to municipalities. Abbreviations for municipalities, as follows: TBR = Tinguá Biological Reserve, Nova Iguaçu; VRFR = Vale do Rio Doce Forest Reserve, Linhares; SONP = Serra dos Órgãos National Park, Teresópolis; SBNP = Serra da Bocaina National Park, São José do Barreiro; SMSP = Serra do Mar State Park, Picinguaba; CGNP = Chapada dos Guimarães National Park, Chapada dos Guimarães.

Municipalities	Latitude (S)	Longitude (W)	Altitude (m)	*Hg. janthinomys*		*Hg. capricornii*		
				Male	Female	Male	Female	Total
Caldas Novas – GO	17° 44' 30"	48° 37' 30"	686	2	41	0	0	43
Canavieiras – BA	15° 40' 30"	38° 56' 50"	4	20	47	0	0	67
Carolina – MA	07° 19' 58"	47° 28' 10"	167	5	0	0	0	5
Curvelo – MG	18° 45' 23"	44° 25' 51"	632	0	2	0	0	2
Atalaia – AL	09° 30' 07"	36° 01' 22"	54	83	42	0	0	125
Alem Paraíba – MG	21° 53' 16"	42° 47' 16"	140	6	0	0	0	6
Benjamin Constant – AM	04° 22' 59"	70° 01' 52"	65	3	0	0	0	3
Campina Verde – MG	19° 32' 08"	49° 29' 11"	494	8	16	0	0	24
CGNP – MT	15° 27' 38"	55° 44' 59"	811	4	158	0	0	162
Duque de Caxias – RJ	22° 47' 08"	43° 18' 42"	19	98	29	0	0	127
Frutal – MG	20° 01' 29"	48° 56' 26"	516	1	6	0	0	7
Ibirama – SC	27° 03' 25"	49° 31' 04"	150	4	4	0	0	8
Ituiutaba – MG	18° 58' 08"	49° 17' 54"	544	8	14	0	0	22
VRFR – Linhares – ES	19° 23' 28"	40° 04' 20"	33	10	6	0	0	16
Pirapora – MG	17° 20' 04"	44° 56' 31"	489	4	13	0	0	17
Maraú – BA	14° 06' 11"	39° 00' 53"	36	5	3	0	0	8
Minaçu – GO	13° 31' 59"	48° 13' 12"	351	2	16	0	0	18
Monte Carmelo – MG	18° 43' 29"	47° 29' 55"	870	1	0	0	0	1
Patrocínio – MG	18° 56' 38"	46° 59' 33"	965	3	0	0	0	3
TBR - Nova Iguaçu – RJ	22° 45' 33"	43° 13' 12"	25	0	0	22	23	45
São Luiz Gonzaga – RS	28° 24' 30"	54° 57' 39"	231	0	0	5	4	9
SONP - Teresopolis – RJ	22° 24' 44"	42° 57' 56"	871	0	0	21	72	93
SBNP – São José do Barreiro – SP	22° 38' 42"	44° 34' 40"	800	0	0	0	4	4
SMSP – Pinciguaba – SP	20° 49' 11"	49° 22' 46"	489	0	0	1	11	12
Patos de Minas – MG	18° 34' 44"	46° 31' 05"	832	3	3	0	0	6
Peixe – TO	12° 01' 30"	48° 32' 21"	240	3	103	0	0	106
Pedro Afonso – TO	08° 58' 03"	48° 10' 29"	201	5	0	0	0	5
Porto Nacional – TO	10° 42' 29"	48° 25' 02"	212	1	3	0	0	4
Teofilo Otoni – MG	17° 51' 27"	41° 30' 19"	334	1	6	0	0	7
Uberaba – MG	19° 44' 54"	47° 55' 55"	801	27	1	0	0	28
Uberlandia – MG	18° 55' 07"	48° 16' 38"	863	3	8	0	0	11
Uruaçu – GO	49° 08' 27"	14° 31' 29"	520	4	16	0	0	20
Total	—	—	—	**314**	**537**	**49**	**114**	**1014**

RESULTS AND DISCUSSION

The affinity index can vary from 0 to 1 and was significant in the populations of these two taxa (I_{ab} = 0.12), demonstrating a weak affinity between the species, regarding occupation of the same habitat [$t = 5.31$ ($p < 0.05$)]. From the dominance coefficient (RDC) and analysis of the mapped geographical distribution of the populations, *Hg. janthinomys* can be considered to be the dominant species in Brazil: $\sum$ *Hg. janthinomys* = 764 and $\sum$ *Hg. capricornii* = 247, where: RDC *Hg. janthinomys* = 75.57% and RDC *Hg. capricornii* = 24.43%. However, in the geopolitical regions of Rio de Janeiro, São Paulo, Santa Catarina and Rio Grande do Sul, where zones of sympatry occur, *Hg. capricornii* is the dominant species.

In the geographical region of the state of Rio de Janeiro, the real association between the two species is nonsignificant ($p > 0.05$; $t = 0.75$), although the dominance coefficient (RDC) in this state were very different: RDC *Hg. janthinomys* = 25.09% and RDC *Hg. capricornii* = 74.91%.

From these results, it is suggested that some limitations on the distribution of *Hg. capricornii* may be occurring, thereby restricting it to the remaining areas of the Atlantic Forest. These limitations may relate to obstacles formed by external physical, climatic, or biological factors. Analyses correlating altitude and abundance show that both *Hg. capricornii* and *Hg. janthinomys* present negligible correlation: $r_{janthinomys} \cong 0.04$ and $r_{capricornii} \cong 0.14$.

In addition, the values are nonsignificant, even considering the altitudes independently from the geographical region. These results suggest that the altitude of the different geographical regions analyzed does not influence the abundance of species distribution. In studies carried out in Colombia, Kumm et al. (1946) observed that seven species of *Haemagogus* were found at low altitudes and only one at high altitude. *Haemagogus andinus* Osorno-Mesa, 1944, was the only species that occurred with greater abundance at altitudes of around 2,000 m. Thus, it was not thought that the *Haemagogus* species would present any marked correlation with altitude dispersion in other geographical units at altitudes lower than 2000 m. According to Kumm and Cerqueira (1951), the distribution of *Haemagogus* correlates more with rainfall regime than with altitude. Vasconcelos et al. (2001) observed that increases in *Haemagogus* populations could be directly correlated with increased duration of the rainy season and with temperature raising. In Brazil, *Haemagogus capricornii* and *Hg. janthinomys* are not restricted only to lowland regions, but are also found in areas at altitudes greater than 800 m above sea level. The low values presented by the real affinity index for the *Haemagogus* species in Brazil may perhaps be explained by geomorphology, since only 7% of its vast territory is at altitudes greater than 800 m and only 0.7% reaches more than 1,200 m.

Forattini (2002) observed that population survival depends on their ability to tolerate the environment or adaptability, resulting from the equilibrium between the endogenous mechanisms particular to the organisms that make up these populations and the exogenous stimuli that come from the environment within which they live. Although the species analyzed in this study are difficult to compare due to morphological similarity, *Hg. janthinomys* has greater geographical distribution, and seems to be highly adapted to the different biomes and to abiotic variables, like temperature and humidity. Thus, *Hg. capricornii* can be defined as the typical species of the Atlantic Forest region, while *Hg. janthinomys* is sympatric with *Hg. capricornii* in several biocenoses. The real relationship between these two species regarding geographical space is nonsignificant, which reinforces the idea that the two species occupy different habitats.

Maybe the adaptation of *Hg. janthinomys* to several regions could indicate heterogeneity of the species or a "*janthinomys* complex," like those formed by *Anopheles gambiae* s.l. (Parmakelis, et al., 2008) or *Lutzomyia intermedia* s.l. (Marcondes, 1996).

LITERATURE CITED

Ávila-Pires, F. D. 2000. Princípios de ecologia médica. Editora da Universidade Federal Santa Catarina. Florianópolis, Brasil. 328 pp.

Arnell, J. H. 1973. Mosquitoes studies (Diptera: Culicidae). XXXII. A revision of the genus *Haemagogus*. Contributions of the American Entomological Institute 10 (2): 1-174.

Bates, M. and M. Roca-Garcia. 1945. The laboratory studies of Saimiri *Haemagogus* cycle of jungle yellow fever. The American Journal of Tropical Medicine 25: 203-216.

Camargo-Neves, V. L. F., D. W. Poletto, L. A. C. Rodas, M. L. Pachioli, R. P. Cardoso, S. A. S. Scandar, S. M. P. Sampaio, P. H. Koyanagui, M. V. Botti, L. F. Mucci, and A. C. Gomes. 2005. Entomological investigation of a sylvatic yellow fever area in São Paulo State, Brasil. Caderno de Saúde Pública, Rio de Janeiro 21(4): 1278-1286.

Consoli, R. A. G. B. and R. Lourenço-de-Oliveira. 1994. Principais mosquitos de importância sanitária no Brasil. Editora da Fiocruz. Rio de Janeiro, Brasil. 225 pp.

Dégallier, N., A. P. A. T. Rosa, P. F. C. Vasconcelos, E. S. T. Rosa, S. G. Rodrigues, and G. C. Sá Filho. 1992. New entomological and virological data on the vectors of sylvatic yellow fever in Brazil. Journal of the Brazilian Association for Advanced Science 44: 136-42.

Eiten, G. 1972. The cerrado vegetation of Brazil. The Botanical Review 38 (2): 201-341.

Fager, E. 1957. Determination and analysis of recurrent groups. Ecology 38: 586-595.

Ferri, M. G. 1980. Vegetação brasileira. Coleção Reconquista Brasil. Editora Itatiaia/EDUSP. São Paulo, Brasil. 631 pp.

Forattini, O. P. 2002. Culicidologia Médica. Edusp. São Paulo, Brasil. 860 pp.

Kumm, H. W., E. Osorno-Mesa, and J. Boshell-Manrique. 1946. Studies on mosquitoes of the genus *Haemagogus* in Colombia (Diptera, Culicidae). American Journal of Hygiene 43: 13-28.

Kumm, H. W. and N. L. Cerqueira. 1951. The *Haemagogus* mosquitos of Brazil. Bulletin of Entomological Research 48: 169-181.

Parmakelis, A., M. Russelo, A. Caccone, C. B. Marcondes, J. Costa, O. P. Forattini, M. A. M. Sallum, R. C. Wilkerson, and J. R. Powell. 2008. Historical analysis of a near disaster: *Anopheles gambiae* in Brazil. American Journal of Tropical Medicine and Hygiene 78: 176-178.

Marcondes, C. B. 1996. A redescription of *Lutzomyia (Nyssomyia) intermedia* (Lutz & Neiva, 1912), and resurrection of *L. neivai* (Pinto, 1926) (Diptera, Psychodidae, Phlebotominae). Memórias do Instituto Oswaldo Cruz 91(4): 457-462.

Peixoto, A. L. and L. Coradin. 1993. Vegetação dos cerrados. *In*, S. Monteiro and L. Kaz (Coordinators.), Cerrados – Vastos espaços, Editora Livroarte. Rio de Janeiro, Brasil. 256 pp.

Reinert, J. F. 1975. Mosquito generic and subgeneric abbreviations (Diptera: Culicidae). Mosquito Systematics 7: 105-110.

Serra-Freire, N. M. 2002. Planejamento e Análise de Pesquisas Parasitológicas. EdUFF Niterói, Rio de Janeiro, Brazil. 199 pp.

Vasconcelos, P. F. C., Z. G. Costa, E. S. Travassos da Rosa, E. Luna, S. G. Rodrigues, V. L. R. S. Barros, J. P. Dias, H. A. O. Monteiro, O. F. P. Oliva, H. B. Vasconcelos, R. C. Oliveira, M. R. S. Sousa, J. Barbosa da Silva, A. C. R. Cruz, E. C. Martins, and J. F. S. Travassos da Rosa. 2001. Epidemic of jungle yellow fever in Brazil, 2000: Implications of climatic Alterations in Disease spread. Journal of Medical Virology 65: 598-604.

Waddell, M. B. and H. W. Kumm. 1948. *Haemagogus capricornii* Lutz as a laboratory vector of yellow fever. American Journal of Tropical Medicine and Hygiene 28: 247-252.

Waddell, M. B. 1949. Comparative efficacy of certain South American *Aedes* and *Haemagogus* mosquitoes laboratory vectors of yellow fever. American Journal of Tropical Medicine and Hygiene 29: 567-575.