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SHORT COMMUNICATION

# Real and potential distribution of the hyperparasitoid genus *Mesochorus* Gravenhorst (Ichneumonidae: Mesochorinae) in Brazil

## Distribución real y potencial del género hiperparasitoide *Mesochorus* Gravenhorst (Ichneumonidae: Mesochorinae) en Brasil

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**ABSTRACT**

*Mesochorus* species are hyperparasitoids capable of nullifying biological control agents. This study is the first to map and predict the distribution of this genus in Brazil. Species distribution modeling was used to estimate the potential distribution of *Mesochorus*. We obtained 72 occurrence records of 49 *Mesochorus* species, being 30 endemics. According to our prediction model, this genus can be distributed in all Brazilian biomes, with higher suitability of occurrence in the Atlantic Forest and lower in the Caatinga and Pampa.

**Keywords:** Ichneumonoidea, parasitoid wasp, species distribution modeling.

**RESUMEN**

Las especies de *Mesochorus* son hiperparasitoides capaces de anular los agentes de control biológico. Este estudio es el primero en mapear y predecir la distribución de este género en Brasil. Se utilizó un modelo de distribución de especies para estimar la distribución potencial de *Mesochorus*. Obtuvimos 72 registros de ocurrencia de 49 especies de *Mesochorus*, siendo 30 endémicas. De acuerdo con nuestro modelo de predicción, este género se puede distribuir en todos los biomas brasileños, con una mayor idoneidad de ocurrencia en el Bosque Atlántico y menor en la Caatinga y Pampa.

**Palabras clave:** avispa parasitoide, Ichneumonoidea, modelación de distribución de especies.

The genus *Mesochorus* Gravenhorst is by far the largest of the subfamily Mesochorinae, with approximately 700 species (Yu *et al*. 2012). Being secondary parasitoids, also known as hyperparasitoids, this genus attacks many species of primary parasitoids in a variety of lepidopteran, coleopteran, and other hosts (Yeargan & Braman 1989).

Most insects that are parasitoid of other insects are themselves attacked by hyperparasitoids. However, hyperparasitoids have been much less studied in nature, compared with the primary parasitoids (Day 2002). This is probably the result of several factors: most field studies of parasites are a major part of biological control studies, which are directed toward reducing the abundance of a plant pest, so the focus is on the primary parasitoids which may reduce pest densities (Day 2002). The hyperparasitism is an important factor to be considered in places that implement the biological control of pests, since it is traditionally been viewed as injurious to biological control efforts as the hyperparasitoid may limit populations of the beneficial primary parasitoid (Ashfaq *et al*. 2005).

Despite their potentially serious effect on primary parasitoids involved in biological control, there have been few biological studies of *Mesochorus* species (Yeargan & Braman 1989). Considering the deleterious effect of this genus on biological pest control, this study aims to be the first to map and predict the potential distribution of this hyperparasitoid genus in Brazil using a species distribution modeling.

We gathered distributional data on *Mesochorus* species in Brazil from literature records and online databases [Taxonomic Catalog of the Brazilian Fauna (Fernandes *et al*. 2018), Taxapad 2012 (Yu *et al*. 2012)]. Geographic coordinates (decimals degrees) were obtained from the species occurrence data informed in the studied literature (Table 1). For records lacking the exact sampling site information, we used Google Earth (Google Inc. 2012) to find city center coordinates as proxy information for sampling sites. All these compiled data allowed the spatial location and thus the relation of these with the environmental data.

The study area of this work considers the geographic distribution of *Mesochorus* species in Brazil and is projected to Central America and South America. Concerning the input data for the model, it was chosen as M area (Barve *et al*. 2011) the biomes where *Mesochorus* species have been found in Brazil, following the current official classification of vegetation in Brazil by IBGE (2004): Amazonia , Atlantic Forest (with inserted discontinuous grassland areas, especially on plateau sites in its southern part), Caatinga, Cerrado, Pantanal and Pampa.

The environmental variables are obtained from the Worldclim website (Hijmans *et al*. 2005). Based on a correlation analysis (Spearman's correlation) among the 19 bioclimatic Wordclim variables (Peterson *et al*. 2011), the four variables that presented the lowest correlation among themselves were chosen: Annual Mean Temperature; Temperature Seasonality (standard deviation *100); Precipitation Seasonality (Coefficient of Variation) and Annual Precipitation. Environmental layers of 30 seconds resolution (approximately 1 $km^2$) were used. R project 3.4.1 was used for the analysis of correlation between environmental variables.

The species distribution model used for potential distribution of the *Mesochorus* in Brazil corresponds to Maxent (Phillips *et al*. 2006), one of the most occupied software`s for species distribution modelling (Qiao *et al*. 2015; Merow *et al*. 2013). Maxent corresponds to a matching-learning method where the maximum entropy function is used, predicting ideal species areas using occurrences and environmental variables (Elith *et al*. 2011; Philips *et al*. 2006). We used the following configuration (Anderson 2013; Owens *et al*. 2013; Peterson *et al*. 2011): the auto features function is chosen, jackknife is performed for the variables, response curves are generated, and the output of the model is logistic. Also, the functions clamping and extrapolate are turned off.

Regarding the model evaluation, crossvalidate with 7 replicas was used. The behavior of the model was evaluated using AUC -Area under the ROC curve- (Phillips *et al*. 2006). The AUC value ranges from 0.5 to 1, for models that fit better than chance. The model performs better when the values are closer to 1 (Phillips *et al*. 2006).

A total of 72 occurrence records of 49 *Mesochorus* species were obtained according to available literature (Fernandes *et al*. 2018; Dasch 1974; Say 1835), of which 30 are endemic to Brazil. The list of species that occur in Brazil, as well as their respective distribution (in geographical coordinates) can be observed in Table 1.

Considering the potential occurrence area of the *Mesochorus* species considered in this study, it is observed through its potential distribution that this genus is better represented in the Neotropical Region (*sensu* Morrone 2014), being less represented in the Andean biogeographic zone (*sensu* Morrone 2015). This distribution pattern corroborates what has been suggested by Dasch (1974) and Hanson & Gauld (2006). Although the potential distribution pattern corroborates the standard distribution cited in the literature, we focus on the potential and real distribution of *Mesochorus* in Brazil, since only Brazilian species were considered.

Among the 49 *Mesochorus* species recorded for Brazil, 46 occur in the Atlantic Forest biome (44 exclusives), the others three occurring in the Amazon (*M. paraensis* Dasch), Caatinga (*M. bahiae* Dasch) and Cerrado (*M. caribbeanus* Dasch) biomes. Considering the potential distribution of *Mesochorus*, it is estimated that this genus can be found in all Brazilian biomes, being the least suitable areas of occurrence in the Caatinga and Pampa, and more suitable in the Atlantic Forest (Figure 1). Both the real and potential distribution of the studied species reinforce that the Atlantic Forest biome combines unique biotic and abiotic characteristics, being considered the Brazilian biome with the greatest biodiversity and the fourth biodiversity hotspot among the 25 most important of the world (Myers *et al*. 2000).

Some studies consider hyperparasitoids as potential targets in biological control and investigate methods to buffer their negative impacts on pest suppression (Tougeron & Tena 2018). As species at high trophic levels, hyperparasitoids undergo many ecological and physiological constraints on which we could act to reduce their fitness or their establishment and persistence in the target environment (Tougeron & Tena 2018).

Observing the potential distribution of this genus, it is probable that the number of Brazilian *Mesochorus* species is underestimated, since most of the specimens collected in the field and/or from the creation of pest insects remain identified at the genus level. The mapping of occurrence areas as well as species identification are fundamental to clarify the effects (positive and/or negative) of these hyperparasitoids on the biological control of pest species present in the different crops of great economic importance for Brazil, thus providing subsidies for biological control of pests and systematic studies.

**Table 1.** Geographical coordinates of the distribution of *Mesochorus* in Brazil (decimal degrees), endemic species highlighted with an asterisk (*). / Coordenadas geográficas de la distribución de *Mesochorus* en Brasil (grados decimales), especies endémicas resaltadas con un asterisco (*).

| Specie | Latitud | Longitud | Reference |
|---|---|---|---|
| *Mesochorus abruptus* Dasch* | -27.070768° | -52.403724° | Dasch 1974 |
| *M. absonus* Dasch* | -27.070440° | -52.371788° | Dasch 1974 |
| *M. amoenus* Dasch* | -27.090301° | -52.346317° | Dasch 1974 |
| *M. angustistigmatus* Dasch | -8.287476° | -35.970105° | Dasch 1974 |
| | -22.369617° | -44.628541° | |
| | -27.091391° | -52.372335° | |
| | -22.970785° | -43.452009° | |
| | -22.745047° | -44.569384° | |
| | -22.427484° | -42.973118° | |
| *M. argutus* Dasch* | -22.949105° | -43.287261° | Dasch 1974 |
| *M. bahiae* Dasch* | -15.250734° | -40.244126° | Dasch 1974 |
| *M. bocainensis* Dasch* | -22.743788° | -44.587945° | Dasch 1974 |
| *M. brasiliensis* Dasch* | -22.431498° | -42.987610° | Dasch 1974 |
| *M. caribbeanus* Dasch | -15.739142° | -47.927764° | Dasch 1974 |
| *M. cingulatus* Dasch | -27.102512° | -52.385047° | Dasch 1974 |
| *M. concavus* Dasch* | -27.106123° | -52.412184° | Dasch 1974 |
| *M. convexus* Dasch | -22.758794° | -44.597053° | Dasch 1974 |
| | -2.447788° | -43.000434° | |
| | -7.121343° | -52.412884° | |
| | -5.513692° | -49.313746° | |
| *M. cubensis* Dasch | -27.134097° | -52.422743° | Dasch 1974 |
| | 4.193908° | -60.793438° | |
| *M. deltoides* Dasch* | -27.049648° | -52.399678° | Dasch 1974 |
| *M. discitergus* Say | -25.287520° | -49.074391° | Say 1835 |
| | -22.909310° | -47.050075° | |
| | -22.898986° | -43.021904° | |
| | -27.144362° | -52.396715° | |
| | -25.540012° | -49.249350° | |
| | -22.732851° | -44.610365° | |
| | -22.460077° | -43.004886° | |
| | -1.426025° | -48.442344° | |
| *M. facetus* Dasch* | -22.923927° | -43.467352° | Dasch 1974 |
| *M. ferrugineus* Dasch* | -27.147982° | -52.362060° | Dasch 1974 |
| *M. glaucus* Dasch | -27.148692° | -52.330262° | Dasch 1974 |
| | -25.541584° | -49.305956° | |

| Specie | Latitud | Longitud | Reference |
|---|---|---|---|
| *M. grandidentatus* Dasch | -17.879205° | -51.725602° | Dasch 1974 |
| | -27.163553° | -52.342290° | |
| *M. hilaris* Dasch* | -22.942968° | -43.444094° | Dasch 1974 |
| *M. impuctatus* Dasch | -22.943856° | -43.499158° | Dasch 1974 |
| *M. inaequalis* Dasch* | -27.163264° | -52.369567° | Dasch 1974 |
| *M. infensus* Dasch* | -27.157679° | -52.391446° | Dasch 1974 |
| *M. insolitus* Dasch | -27.153935° | -52.411073° | Dasch 1974 |
| *M. inurbanus* Dasch* | -27.149938° | -52.432348° | Dasch 1974 |
| *M. junctus* Dasch* | -27.158114° | -52.451048° | Dasch 1974 |
| *M. longicoleus* Dasch* | -22.774114° | -44.605170° | Dasch 1974 |
| *M. longidens* Dasch* | -27.173150° | -52.437765° | Dasch 1974 |
| | -20.079060° | -43.505559° | |
| *M. luteocintus* Dasch* | -25.304982° | -49.055647° | Dasch 1974 |
| *M. luteolus* Dasch | -27.180723° | -52.421557° | Dasch 1974 |
| *M. macilentus* Dasch* | -22.464190° | -42.993480° | Dasch 1974 |
| *M. magnicrus* Dasch* | -22.942314° | -43.465183° | Dasch 1974 |
| *M. medius* Dasch | -27.181784° | -52.404584° | Dasch 1974 |
| *M. mulleolus* Dasch* | -27.184364° | -52.382179° | Dasch 1974 |
| *M. muscosus* Dasch | -25.436740° | -49.219587° | Kumagai & Graf 2000 |
| *M. nigrifemoratus* Dasch* | -20.096285° | -43.532459° | Dasch 1974 |
| | -22.473083° | -43.015419° | |
| *M. novateutoniae* Dasch* | -27.202601° | -52.377426° | Dasch 1974 |
| *M. paraensis* Dasch* | -1.313651° | -49.908955° | Dasch 1974 |
| *M. placitus* Dasch | -19.924201° | -43.934096° | Dasch 1974 |
| | -27.203611° | -52.401861° | |
| | -22.981203° | -43.524821° | |
| | -22.438879° | -43.037920° | |
| *M. planus* Dasch* | -27.199516° | -52.339307° | Dasch 1974 |
| *M. praeclarus* Dasch | -27.007423° | -52.403445° | Dasch 1974 |
| *M. procerus* Dasch | -27.019865° | -52.385024° | Dasch 1974 |
| *M. properatus* Dasch | -25.420287° | -49.301463° | Kumagai & Graf 2000 |
| *M. puteolus* Dasch | -27.030885° | -52.402510° | Dasch 1974 |
| *M. repandus* Dasch* | -27.034333° | -52.421600° | Dasch 1974 |
| *M. stenotus* Dasch* | -27.045175° | -52.425674° | Dasch 1974 |
| *M. taeniatus* Dasch* | -20.133915° | -43.500161° | Dasch 1974 |
| *M. verecundus* Dasch* | -25.551058° | -49.240400° | Dasch 1974 |
| *M. villosus* Dasch | -27.059294° | -52.442001° | Dasch 1974 |

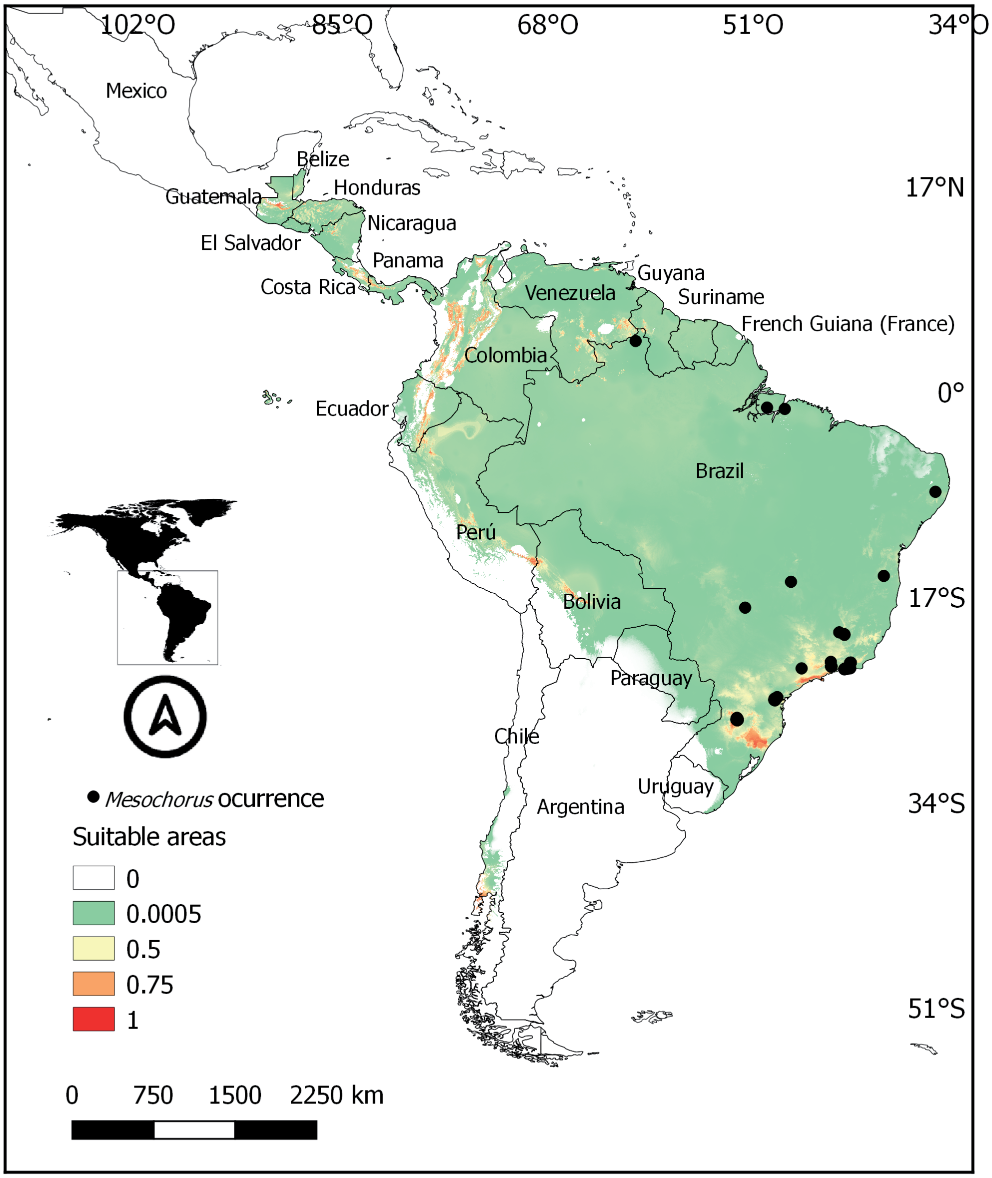


**Figure 1.** Real (black dots) and predicted (colors) geographical distribution of *Mesochorus* in Brazil based on species distribution modeling by Maxent. / Distribución geográfica real (puntos negros) y predicha (colores) de *Mesochorus* en Brasil basada en el modelo de distribución de especies por Maxent.

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