A new species of Desmopachria Babington (Coleoptera: Dytiscidae) from Cuba with a prediction of its geographic distribution and notes on other Cuban species of the genus

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Abstract

A new species, Desmopachria andreae sp. n. is described from Cuba. Diagnostic characters including illustrations of male genitalia are provided and illustrated for the five species of the genus occurring on the island. For these five species both a simple key to adults and maps of their known distribution in Cuba are also provided. Using a Maximum Entropy method (MaxEnt), a distribution model was developed for D. andreae sp. n. Based on the model’s predictions, this species has a higher probability of occurring in high altitude forests (above 1000 m a.s.l.), characterised by relatively low temperatures especially during the hottest and wettest seasons, specifically, the mountainous areas of the Macizo de Guamuhaya (Central Cuba), Sierra Maestra (S Cuba) and Nipe-Sagua-Baracoa (NE Cuba). In some of these areas the species has not yet been recorded, and should be searched for in future field surveys.

Key words: Hydroporinae, Neotropical, diving beetle, morphology, MaxEnt, species distribution models

Introduction

The predaceous water beetles of the genus Desmopachria Babington, 1841 are small dytiscids ranging from 1.1 to 3.0 mm in length (Young 1981, 1989; Miller 2001, 2005). The genus comprises 99 species widely distributed in the New World (see Nilsson 2001; Miller 2001, 2005; Braga & Ferreira-JR 2010), although it is most speciose in Neotropical lowlands (Miller 1999).

Desmopachria is postulated to represent a monophyletic group based on both adult (Biström et al. 1997; Miller 2001) and larval characters (Michat & Archangelsky 2007). The adults are characterized by antennomeres 1–2 wider than the following ones, antennomeres 5–10 short and slightly expanded in the apical half, the labial palpus with an apical pair of sensilla that are widely separated, the maxillary palpus with an apical sensillum and the pronotum with posterolateral angles produced (Miller 2001). The species of this genus are easily distinguished by the shape of the male genitalia (Epler 2010) and, based on this new species have been recently described (Miller 2001, 2005; Braga & Ferreira-JR 2010). Miller (2001) rejected the use of subgenera within Desmopachria based on an analysis of male genitalia and external features and reorganized the species into eight informal groups, with several species ungrouped.

Four species of Desmopachria have been reported in Cuba to date (Desmopachria aspera Young, 1981, D. darlingtoni Young, 1989, D. glabella Young, 1981 and D. tarda Spangler, 1973), two of which are endemic to the island (D. glabella and D. tarda) (Spangler 1973, 1981; Young 1981, 1989; Peck 2005). However, little is known on the biogeography of Desmopachria species in Cuba. In this study, a new species of Desmopachria is described and illustrated. In addition, we develop a maximum entropy (Phillips et al. 2006) presence-only distribution model to determine i) the potential distribution of D. andreae in Cuba and ii) the ecological variables that may determine its distribution. In this sense, predicting the species distribution using ecological niche modelling offers a powerful approach to identify unsampled areas that are potentially inhabited (Elith et al. 2006; Phillips et al. 2006).
Material and methods

Morphological observations. A total of 10 specimens were measured at random from all available collection localities. In the descriptions and diagnoses, measurements are given as a minimum-maximum range followed by the mean. The following abbreviations are used for body measurements: DBE—minimum distance between eyes; EL—elytral length (along midline from anterior margin to apex); EW—elytral width (across greatest transverse width of both elytra combined); HL—head length (along midline from the anterior clypeal margin to the anterior pronotal margin); HW—head width (maximum width near posterior margin of the head); PL—pronotal length (along midline from anterior to posterior margin); PW—pronotal width at level of posterior margin; TL—total length (TL= HL+PL+EL). Finally, general body shape was quantified with the ratios PL/PW and TL/EW.

Type Specimen. The holotype of the new species is placed in the Zoological Collection of the Museum of Natural History "Charles Ramsden", Cuba (CZCTR). Paratypes are distributed in CZCTR and the National Museum, Prague, Czech Republic (NMPC).

Dissection of male genitalia. The diagnosis of the new species is based on the form of the male genitalia. The terminology denoting the orientation of the genitalia follows Miller & Nilsson (2003). Prior to dissection, dry specimens were relaxed in hot water for 10 minutes. The genitalia were extracted by inserting a needle into the abdominal opening. The median lobe of the aedeagus and the parameres were disarticulated and mounted together with the specimen, or placed in a microvial of glycerin and pinned with the specimen. If the abdomen was removed, it was also mounted on the same card/point as the genitalia or specimen.

Distribution. We compiled all available geographical data for each species of Desmopachria in Cuba. Although most of the data comes from our own sampling, we also compiled all published records for these species in Cuba. The main faunistic studies consulted were Spangler (1973), Young (1981, 1989), and Peck (2005). Maps showing the known distribution of each species were generated using the ArcGis 9.3. software (ESRI, Inc).

Species distribution modelling. Environmental variables. We used climatic data obtained from WORLDCLIM, version 1.4 (http://www.worldclim.org; Hijmans et al. 2005). Climate data were obtained by interpolation of climate station records from 1950–2000. The WORLDCLIM database contains 19 bioclimatic variables. After a Spearman correlation analysis (as recommended for non-parametric data), we selected 13 of the 19 variables (autocorrelated variables were eliminated, Spearman correlation coefficient >0.8; p<0.01). Thus, we used the following climatic predictors for the present study: annual mean temperature, mean diurnal range, isothermality, temperature seasonality, maximum temperature of the warmest month, minimum temperature of the coldest month, mean temperature of the wettest quarter, mean temperature of the warmest quarter, precipitation of the driest month, precipitation seasonality, precipitation of warmest quarter, and precipitation of coldest quarter. We also used topographical data (elevation) obtained from the model of digital elevation proposed by NASA (http://glcfapp.umiacs.umd.edu:8080/esdi/index.jsp), with an original spatial resolution of 90 m for all of Cuba. We also included a variable related to vegetation type. This variable was divided in 32 categories or types of vegetation according to Capote et al. (1989; see Appendix 1). All the variables used in modelling the distribution of D. andreae were obtained at a resolution of 2.5 minutes (approx. 4.4 × 4.4 km = 19.4 km² at the equator).

Modelling procedure. To model the geographical distribution of D. andreae sp.n., we used MaxEnt v.3.3.0 (Maximum Entropy Species Distribution Modelling; Phillips et al. 2006). Maximum entropy modelling is a machine-learning method that estimates an organism’s distribution by finding the probability distribution using maximum entropy (i.e. the highest uniformity), given the constraint that the expected value of each environmental predictor under this estimated distribution matches the empirical average of sample locations. This algorithm was chosen because it is applicable to presence-only data (Phillips et al. 2006), has been shown to perform well when compared to other methods (Wisz et al. 2008) and it has been reported to be relatively robust for small sample sizes (Hernandez et al. 2006; Pearson et al. 2007). In addition, this approach is especially valuable for species whose available presence data are limited and where false absence in surveys is a significant risk (Elith et al. 2006; Phillips & Dudik 2008). To build the model, we used all the D. andreae presence records and the above mentioned environmental variables. Default values for the convergence threshold, and the logistic output format to generate response curves and Jackknife results were selected. Finally, 20 replicates were run, and MaxEnt output a single average model. The final map obtained shows the probability of occurrence according to a 0–1 scale.
Validation of the model. Eighty percent of the records were used for model training and twenty percent for testing. To evaluate model performance, the Area Under the receiver operating characteristic Curve (AUC) was used (Elith et al. 2006; Hu and Jiang 2010). This analysis, although can sometimes produce misleading results (see Lobo et al. 2008), provides a single measure of model performance and ranges from 0.5 (randomness) to 1 (perfect discrimination). Thuiller et al. (2003) established a scale to enable interpretation of AUC values and for model validation: 0.90 to 1.00 = excellent; 0.80 to 0.90 = good; 0.70 to 0.80 = average; 0.60 to 0.70 = poor; 0.50 to 0.60 = insufficient. Additionally a Jackknife analysis was adopted to estimate which variables were most important for model building. During this process, we generated a number of models. First, each environmental variable was excluded in turn and a model created with the remaining variables in order to check which variable was most informative. Then, a model was created for each individual variable to find which variable had the most information that was not present in the others, i.e., the most uncorrelated variable.

Results

Taxonomy

Desmopachria andreae Megna & Sánchez-Fernández, sp. n.
(Figs. 1, 6a, 7–9)

Type material: Holotype male (CZCTR): CUBA. Sancti Spíritus: Codina, 01–VII–10, Y. S. Megna leg. 21°54′42′′N, 80°03′36′′W, elevation ca. 891 m [printed], Holotype, Desmopachria andreae sp. n., Megna det. 2012 [red, printed]. Paratypes (CZCTR if not stated otherwise): 6 males, 5 females, with same data as holotype. 1 male, CUBA: Sancti Spíritus: Salto del Caburní, 29–VI–10, Y. S. Megna leg. 21°55′17′′N, 80°00′20′′W, elevation ca. 520 m. 1 male, CUBA: Santiago de Cuba: Cabezadas del Rio Cauto, 01–XII–2005, Y. S. Megna leg. 20°02′38′′N, 76°10′42′′W, elevation ca. 620 m. 1 male, CUBA: Santiago de Cuba: La Marsella, 02–XII–2005, Y. S. Megna, leg. 20°00′4′′N, 76°13′06′′W, elevation ca. 370 m. 3 males, 1 female (NMPC), CUBA: Santiago de Cuba: La Majagua, 14–VIII–2004, Y. S. Megna, leg. 19°57′38′′N, 76°52′32′′W. Each paratype is provided with its respective red label.

Description (male). Habitus (Fig. 1a). Body oval, broadly rounded in dorsal view; slightly flattened dorsoventrally; greatest width slightly anterior to midlength.

Measurements and ratios (minimum-maximum, mean), in mm (n=10): HL 0.2–0.3, 0.3; HW 0.7–0.8, 0.7; DBE 0.3–0.4, 0.3; PL 0.4–0.5, 0.5; PW 1.2–1.3, 1.2; PW/PL 0.3–0.4, 0.4; EL 1.2–1.5, 1.4; EW 1.3–1.4, 1.4; TL/EW 1.5–1.9, 1.6; TL 1.9–2.2, 2.1.

Color. Dorsally, head testaceous, darker posteriorly (Fig. 1a); pronotum testaceous, darker along posterior margin. Elytra testaceous, darker along the elytral suture and anterior margin (Fig. 1a); venter testaceous. Antennae and palpi yellow. Pro- and mesothoracic legs yellow; metathoracic legs brown.

Sculpture and punctation. Head inconspicuously punctate, clypeus indistinctly beaded; pronotum with rows of fine punctures along anterior margin, posteriorly with some fine sparse punctures, lateral bead of even width (Fig. 1a); elytron inconspicuously punctate. Venter without punctuation.

Structure. Antenna with segments 1-2 wider than following segments; pronotum with posterolateral angles produced, rounded laterally and continuous in outline with elytra; elytra with apex rounded; convex in lateral view; prosternal process short, with apex acute, contacting metaventrite; metacoxal process without lateral lobe; abdomen with last ventrite rounded; protarsis and mesotarsis pentamerous without modification; metatarsal claws unequal.

Male genitalia. Median lobe with acute apex in dorsal view (Fig. 1b), in lateral view as in figure 1c. Parameres symmetrical, narrowing apically, with short setae on apex (Fig. 1d).

Female. Similar in habitus, vestiture and coloration to male, except lighter in colour.

Measurements and ratios (minimum-maximum, mean), in mm (n=10): HL 0.2–0.3, 0.3; HW 0.7–0.8, 0.7; DBE 0.3–0.4, 0.3; PL 0.4–0.5, 0.5; PW 1.1–1.3, 1.2; PW/PL 0.3–0.4, 0.4; EL 1.3–1.4, 1.3; EW 1.2–1.4, 1.3; TL/EW 1.5–1.8, 1.6; TL 2.0–2.2, 2.1.
Diagnosis. Adults of *D. andreae* can be readily distinguished from other species of the genus by the aedeagus, with the median lobe having an unsclerotized and acute apically (Fig. 1b); and parameres without a preapical, articulated process and the apex narrowing evenly (Fig. 1d).

Etymology. The new species is dedicated to Andrea Megna Alicio, mother of the first author, for her love. The species name is a noun in the genitive case.

Distribution. *D. andreae* has been recorded from localities in mountainous areas of the Sierra Maestra (Oriental region) and Guamuhaya (Central region) (Fig. 6a).

Ecology. According to Miller (2005) species of *Desmopachria* can occupy a wide variety of habitats including ponds, streams, forest pools and phytotelmata. Specimens of *D. andreae* were collected in the backwaters of freshwaters with clear water and muddy-stony bottoms, located in highlands with little exposure to sun, with abundant cover vegetation but without aquatic vegetation (Fig. 7).

Species distribution modelling. The predictive map for *D. andreae* shows a high suitability (red areas in Fig. 9) in a few areas of the Sierra Maestra (S-SW of Cuba), while other suitable areas are distributed in the south of the
island, mainly in the mountainous areas and also in the Macizo de Guanahay (central part of Cuba). Our model also predicted that most of the study area has a low (<0.5) probability of presence (mainly in the western parts of Cuba; blue areas in Fig. 9).

The model achieved a 1.26 regularised gain value indicating good fit to presence data. The AUC was high, with a mean value of 0.94 for test data; i.e., values indicate an excellent predictive ability.

**FIGURE 6.** Map of the known distribution of *Desmopachria* species in Cuba. a) *D. andreae* sp. n; b) *D. aspera*; c) *D. darlingtonii*; d) *D. glabella*; e) *D. tarda*. See Appendix 2 for additional information on the localities reported in each map.
The analysis of single variable contribution (Fig. 8) showed that mean temperature of the wettest quarter (63%), maximum temperature of the warmest month (10%) and altitude (10%) were the main factors influencing model performance. Mean temperature of the wettest quarter seems to provide more information by itself than the other variables, as derived from the Jackknife procedure (Fig. 8).

FIGURE 7. Type locality of *D. andreae* sp. n. Codina (Cuba, Sancti Spiritus). Photo D. Leyva.
A NEW SPECIES OF DESMOPACHRIA FROM CUBA

FIGURE 8. Representation of the contribution provided by the environmental variables considered to develop the MaxEnt model for \textit{D. andreae} sp. n. Grey bars show the percent contribution of each variable to the model and corresponding values are given on the right axis. Jackknife results for the model (values on the left axis) are also shown for single variables (diagonal shade), for all variables except the one selected (black bars) and for all variables (white).

FIGURE 9. Maximum entropy model developed for \textit{D. andreae} sp. n in Cuba. Values range from high (red areas) to low environmental suitability (blue areas).

**Key to Desmopachria of Cuba**

1. Parameres with apex deeply bifid (Fig. 3) and with long apical setae; Jamaica, Hispaniola, Colombia, eastern Cuba (Fig. 6c) . 

   \textit{D. darlingtoni} Young, 1989

- Parameres not deeply bifid, apical setae absent or very short; USA, Bahamas, Cuba .

2. Larger, TL > 1.9 mm; parameres without a preapical, articulated process (Fig. 1b); central and eastern parts of Cuba (Fig. 6a) .

   \textit{D. andreae} sp. n.

- Smaller, TL < 1.7 mm; parameres with a preapical, articulated process .

3. Median lobe of aedeagus with a single tip and apex narrowed (Fig. 2); USA, Bahamas, central part Cuba (Fig. 6b) .

   \textit{D. aspera} Young, 1981

- Median lobe of aedeagus with two tips and apex expanded; Cuba .

A NEW SPECIES OF \textit{DESMOPACHRIA} FROM CUBA

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Discussion

This study increases the number of Desmopachria species of Cuba to five. Cuban species belong to two groups: 1) D. convexa group (D. aspera, D. glabella, and D. tarda) which has parameres with an anteapical, articulable process; 2) D. nitida group (D. darlingtoni) which has parameres with apex deeply bifid (Miller 2001). The new species is not placed in any group because the anterior clypeal margin is not sexually dimorphic; pronotum without basal striae; parameres symmetrical, not deeply bifid and shape of the male genitalia does not resemble any of these species. In this sense, molecular studies could be useful in order to unravel the taxonomic position of the new species.

In general, for the identification of the Desmopachria species of Cuba a simple combination of two morphological characters could be used: i) the shape of the median lobe of the aedeagus, and ii) the body size. D. andreae is similar in pattern coloration and morphology to D. tarda, but it is the largest species (TL 1.9–2.2) of the genus in Cuba. On the other hand, the male genitalia are different from the other Desmopachria species of Cuba. Only D. geijskesi Young, 1990 (TL 1.1–1.3) from Suriname (Young 1990) has an aedeagus somewhat similar to that of D. andreae, but it has a different coloration, metatarsal legs without long and conspicuous setae, and parameres with short apical setae. Geographic distribution may be useful in the identification of some allopatric species. Here, this could be the case with D. darlingtoni and D. glabella (see Fig. 6c and 6d), but not D. andreae sp. n. because it is broadly sympatric with D. tarda. These two species have been collected even in the same localities (Fig 6a, 6e).

The preference of D. andreae for pristine habitats would suggest that this species could be a good indicator of mountain freshwater ecosystem health (see e.g. Ribera & Foster (1993) and Sánchez-Fernández et al. (2006) for examples of studies using water beetles as indicators for conservation purposes). The following water beetles were collected in El Olimpo and Nacimiento del Río Cauto together with D. andreae: Dineutus longimanus Olivier, 1792 (Gyrinidae), Desmopachria tarda, Laccophilus bifasciatus Chevrolat, 1863, Laccophilus venustus Chevrolat, 1863, Copelatus insolitus Chevrolat, 1863 and Copelatus posticatus (Fabricius, 1801) (all Dytiscidae). Most of these species are typical of springs or mountain streams (Megna & Deler-Hernández 2006; Deler-Hernández & Megna 2007; Megna & Epler 2012). However, L. venustus and C. posticatus are generalists with wide distribution (Spangler 1981; Peck 2005).

Based on the model’s predictions D. andreae has a higher probability of occurrence in forests at relatively high altitudes (above 1000 m a.s.l.), characterised by relatively low temperatures especially during the hottest and wettest seasons (i.e. as we pointed above, the mountainous areas of the Macizo de Guamuhyaya, Sierra Maestra and Nipe-Sagua-Baracoa in Cuba. It is worth noting that for some of these areas, the species has not been recorded yet, mainly the mountainous areas in the NE of Cuba (Nipe-Sagua-Baracoa). Although our model provides a robust picture of D. andreae distribution, it was satisfactorily validated, and its final representation can be considered as close to the “realized distribution” (see Jiménez-Valverde et al. 2008). We are aware that some limitations accompany these modelling procedures, e.g., biotic interactions and dispersal are not taken into account and could prevent the presence of the species in environmentally suitable areas, such as the above mentioned mountainous areas in the NE of Cuba. Thus, species distribution models are useful for estimating the potential of species occurrence in poorly surveyed areas and for directing new surveys to places where the species are likely to be found (Hernández et al. 2008; Sánchez-Fernández et al. 2011). These areas should be prioritized in order to carry out sampling programs to detect the presence of the species. These data could also be used for a further validation of the predictive model.
Acknowledgements

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**APPENDIX 1. Vegetation units of Cuba according to Capote et al. (1989).**

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<th>Category</th>
<th>Type vegetation</th>
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<tbody>
<tr>
<td>1</td>
<td>Lowland tropical or subtropical semi-deciduous forest</td>
</tr>
<tr>
<td>2</td>
<td>Submontane tropical or subtropical rainforest</td>
</tr>
<tr>
<td>3</td>
<td>Montane tropical or subtropical rainforest</td>
</tr>
<tr>
<td>4</td>
<td>Montane tropical or subtropical cloud forest (on volcanic rocks)</td>
</tr>
<tr>
<td>5</td>
<td>Montane tropical or subtropical cloud forest (on serpentine rocks)</td>
</tr>
<tr>
<td>6</td>
<td>Lowland tropical or subtropical seasonal evergreen forest</td>
</tr>
<tr>
<td>7</td>
<td>Submontane tropical or subtropical seasonal evergreen forest</td>
</tr>
<tr>
<td>8</td>
<td>Lowland or submontane tropical or subtropical broad-leaved evergreen sclerophyllous forest</td>
</tr>
<tr>
<td>9</td>
<td>Seasonally flooded/saturated tropical or subtropical semi-deciduous forest</td>
</tr>
<tr>
<td>10</td>
<td>Seasonally/temporarily flooded tropical or subtropical semi-deciduous woodland</td>
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<tr>
<td>11</td>
<td>Mangroves</td>
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<tr>
<td>12</td>
<td>Typical tropical or subtropical semideciduous mesophyllous forest</td>
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<tr>
<td>13</td>
<td>Xeromorphic mixed evergreen-deciduous forest</td>
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<td>14</td>
<td><em>Pinus caribaea</em> forests/woodlands</td>
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<td>15</td>
<td>Mixed <em>Pinus caribaea-Pinus tropicalis</em> forests/woodlands</td>
</tr>
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<td>16</td>
<td>Tropical or subtropical needle-leaved evergreen woodland (with <em>Pinus cubensis</em>)</td>
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<td>17</td>
<td>Mixed tropical and subtropical needle-leaved - broad-leaved evergreen forest (with <em>Pinus maestrensis</em>)</td>
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<td>18</td>
<td>Microphyllous evergreen montane shrubland with succulents</td>
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<td>Montane evergreen extremely xeromorphic serpentine woodland</td>
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<td>Haystack mountain (Mogote) complex</td>
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<td>Karstic formation (on rocky shore)</td>
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<td>Secondary or successional herbaceous and woody vegetation</td>
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<td>Planted/Cultivated vegetation</td>
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<td>Commercial pine and broad-leaved timber plantations</td>
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