PHYOLOGENY OF *CARRERAPYRGOTA* ACZÉL (DIPTERA, PYRGOTIDAE)

Running title: PHYOLOGENY of *CARRERAPYRGOTA*

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ABSTRACT

Carrerapyrgota (Aczél, 1956) is a genus of Neotropical Diptera belonging to the family Pyrgotidae. The genus is currently composed of four species: *C. miliaria* Aczél, 1956 (type species), *C. personata* (Lutz & Lima, 1918), *C. aczeli* Mello, Lamas & Rafael, 2010, and *C. bernardii* Mello, Lamas & Rafael, 2010. This work aimed to test the monophyletism of the genus and to establish a phylogenetic hypothesis among its species. For this, we performed phylogenetic analyses based on a survey of 22 taxonomic characteristics of the external morphology of adults using the principle of parsimony. Analyses with equal and implied weighting of characters resulted in the monophyletism of the genus supported by the following synapomorphies: absent postscutellum, presence of spurious apical vein in R_{2+3}, lower calypter with a longitudinal row of bristles, and the female forefemur with a longitudinal groove on the posterior surface. Furthermore, the species *C. aczeli*, *C. bernardii,* and *C. miliaria* formed a monophyletic group, supported by the synapomorphic condition of a spot on the forehead; *C. bernardii* and *C. miliaria* appear to be sister species, supported by the synapomorphic condition of a less sclerotized M vein, after dm-cu in relation to the anterior region, as well as the homoplastic condition of the presence of a spot on the median occipital sclerite. The monophyly of *Carrerapyrgota* confirmed the synonymy proposed by Bernardi (1990), which considers *Anapyrgota* a junior synonym of *Carrerapyrgota*. The parenthetical notation elected to represent the phylogenetic relationship among the species of the genus is (*C. personata* (*C. aczeli* (*C. bernardii* + *C. miliaria*))).

Key words: Cladistic, Monophyly, Pyrgotinae, South America, Tephritoidea.

INTRODUCTION

Pyrgotidae is a dipteran family that is distributed worldwide and it is composed of approximately 365 species, classified into 55 genera (Korneyev, 2006). In the Neotropics, 58 species are known, which are divided into 12 genera (Steyskal, 1967; Bernardi, 1991; Mello *et al*., 2010; Mello & Lamas, 2014). Members of this family are known to be nocturnal and their larvae develop as endoparasitoids of adult beetles of the family Scarabaeidae (Forbes, 1908; Davis, 1913, 1919; De Meijere, 1916; Wolcott, 1922; Aldrich, 1928; Claussen *et al*., 1933; Moutia, 1940; Ritcher, 1940; Gardner & Parker, 1940; Jepson, 1941; Paramonov, 1958).

Carrerapyrgota was proposed by Aczél (1956a) to host the new species *Carrerapyrgota miliaria* described on the basis of male and female specimens from Brazil and Argentina. Lutz & Lima (1918) described the species *Apyrgota personata* based on a single specimen (which was of unidentified sex, because the specimen lacked the abdomen) from Pernambuco, Brazil. Hennig (1936) and Aczél (1956b) observed that the genus *Apyrgota* is absent from the neotropics, and that the species identified by Lutz & Lima should be transferred to the genus *Pyrgota* (Hennig, 1936) or included in a new genus (Aczél, 1956b). Steyskal (1967) presented a taxonomic catalog of the Neotropical Pyrgotidae, in which the genus *Anapyrgota* was proposed to host the species *A*. *personata*. Bernardi (1990) considered *Anapyrgota* to be synonymous with *Carrerapyrgota*, proposing *C. personata* as a new combination into *Carrerapyrgota*.

Mello *et al.* (2010) presented a revision for *Carrerapyrgota*, in which the synonymy and new combination proposed by Bernardi (1990) were retained, two species were described from Brazil: *C*. *aczeli* Mello, Lamas & Rafael, 2010; (Rio de Janeiro, São Paulo, Paraná, and Santa Catarina) and *C*. *bernardii* Mello, Lamas & Rafael, 2010; (Bahia), and additionally, presented the first record from South American Pyrgotidae species, *C*. *bernardii*, in association with the beetle species *Pelidnota sordida* (Germar, 1824) (Mello *et al.*, 2010).

Carrerapyrgota is delimited by the following combination of characters: medial vertical seta crossed with postocellar seta; mesofacial plate without carina; one notopleural seta; postscutellum absent; female forefemur of with a longitudinal groove on posterior surface; vein C with break in vein Sc; vein Sc incomplete; vein R_{2+3} with apical spur vein; lower calypter covered by a row of longitudinal hairs; and ovipositor without apical hook.

This study aimed to test the monophyly of *Carrerapyrgota* and to propose a hypothesis of phylogenetic relationship among its species. For this purpose, phylogenetic parsimony analyses were performed based on the morphological characteristics of adults.

MATERIAL AND METHODS

The specimens analyzed in this study were obtained from the following institutions: Coleção Entomológica Padre Jesus Santiago Moure, Departamento de Zoologia, Universidade Federal do Paraná, Curitiba, Brasil (DZUP); Fundação e Instituto Oswaldo Cruz, Rio de Janeiro, Brasil (FIOCRUZ); Fundácion e Instituto Miguel Lillo, San Miguel de Tucumán, Argentina (IMLA); Instituto Nacional de Pesquisas da Amazônia, Manaus, Brasil (INPA); Museu de Zoologia da Universidade de São Paulo, São Paulo, Brasil (MZUSP); and Museu Nacional, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brasil (MNRJ). The list of specimens studied is the same of Mello *et al*. (2010).

The taxa used as outgroups were: *Ceratitis capitata* (Wiedemann, 1824) (Tephritidae, Dacinae); *Descoleia teretrura* (Aczél, 1956) (Tephritoidea *incertae sedis*); *Leptopyrgota sahlbergiana* (Frey, 1918) (Pyrgotidae, Pyrgotinae); *Idiopyrgota setiventris* (Aczél, 1956) (Pyrgotidae, Pyrgotinae); and *Stenopyrgota crassitibia* (Aczél, 1956) (Pyrgotidae, Pyrgotinae).

Phylogenetic analyses of parsimony were conducted on data concerning the external morphology of males and females adults. We used the terminology of Korneyev (2006), Cumming & Wood (2009), and Mello et al. (2010). The morphological characters, binary or multistate, were coded and organized in a matrix using the program Mesquite v3.61. The character codification followed the logic proposed by Sereno (2007).

Multistate characters were treated as unordered (Fitch, 1971) and Wagner's parsimony algorithm was used (Farris, 1970). Analysis was carried out in Tree Analysis Using New Technology v1.1 (Goloboff et al., 2008).

Analyses were performed with equal weighting of characters using heuristic analysis with 1000 replicates, keeping the top 100 trees. Analyses were also performed with implied weighting using concavity *K values* between 1–10. The result of each analysis was summarized through strict consensus (Sokal & Rohlf, 1981).

Bremer's Absolute Support were calculated for the resultant trees of the equal weighting analysis (Bremer, 1994), while Bremer's Relative Support was used for analysis of implied weighting (Goloboff & Farris, 2001). The trees were edited in the program WINCLADA v1.00.08 (Nixon, 2002).

RESULTS AND DISCUSSION

The list containing 22 characters of the external morphology of adults is as follows: one characteristic of the body, nine of the head, 11 of the thorax, and one of the male abdomen. The length (L), consistency index (CI), and retention index (RI) are presented in parentheses, from the tree optimal (see below). Table 1 shows the Matrix of characters.

List of Characters

1. Body, setae and setulae, color (L: 3; IC: 33; IR: 33): **(0)** reddish yellow; **(1)** black.

2. Frons, spot (L: 1; IC: 100; IR: 100): **(0)** absent; **(1)** present.

3. Antennal groove, median carina (L: 2; IC: 50; IR:0): **(0)** present; **(1)** absent.

4. Antennal groove, lower margin, spot (L: 2; IC: 50; IR: 66): **(0)** present; **(1)** absent.

5. Pedicel, dorsal surface, size in relation to the first flagellomere (L: 2; IC: 50; IR: 0): **(0)** shorter; **(1)** longer.

6. Arista, position in the dorsal surface of the first flagellomere (L: 2; IC: 100; IR: 100): **(0)** apical; **(1)** basal; **(2)** middle.

7. Ocelli (L: 1; IC: 100; IR: 100): **(0)** present; **(1)** absent.

8. Ocellar seta (L: 2; IC: 50; IR: 0): **(0)** present; **(1)** absent.

9. Postocellar seta, position in relation to the medial vertical seta (L: 2; IC: uninformed; IR: uninformed): **(0)** convergent, not crossed; **(1)** parallel; **(2)** convergent, crossed like X.

10. Median occipital sclerite, spot (L: 3; IC: 33; IR: 33): **(0)** absent; **(1)** present.

11. Postscutelum (L: 1; IC: 100; IR: 100): **(0)** present; **(1)** absent.

12. Notopleural seta (L: 2; IC: 50; IR: 50): **(0)** two setae; **(1)** one seta.

13. Wing, color pattern (L: 5; IC: 60; IR: 33): **(0)** hyaline with apical spot; **(1)** reticulate; **(2)** bicolor; **(3)** banded.

14. Costal vein (L: 2; IC: 50; IR: 0): **(1)** **(0)** ending at vein M; ending before reach vein M

15. Costal vein (L: 2; IC: 50; IR:0): **(0)** unbroken on Sc; **(1)** broken on Sc.

16. Vein R_{2+3}, apical spur vein (L: 1; IC: 100; IR: 100): **(0)** absent; **(1)** present.

17. Vein R_{4+5}, dorsal surface (L: 1; IC: 100; IR: 100): **(0)** setulose; **(1)** bare.

18. Vein M, sclerotization (L: 1; IC: 100; IR: 100): **(0)** uniformly esclerotized; **(1)** less sclerotized in front of dm-cu.

19. Veia M, in front of dm-cu, position in relation to the vein R_{4+5} (L: 3; IC: 33; IR: 0): **(0)** straight; **(1)** sinuose.

20. Lower calypter, longitudinal row of hairs (L: 1; IC: 100; IR: 100): **(0)** absent; **(1)** present.

21. Female forefemur, posterior surface, longitudinal groove (L: 1; IC: 100; IR: 100): **(0)** absent; **(1)** present.

22. Male sternite 5, anterior margin, shape (L: 3; IC: 66; IR: 0): (**0)** bilobate **(1)** straight; **(2)** rounded.

Analysis with equal weighting resulted in six most parsimonious trees, which are presented in Figures 1–6. The most parsimonious trees had L value of 43 steps, CI 62, and RI 60. In all six trees, the monophyly of the genus is supported by four synapomorphies: postscutellum absent (11:1), R_{2+3} with apical spur vein (16:1), lower calypter with a longitudinal row of hairs (20:1), and the female forefemur with a longitudinal groove on the posterior surface (21:1). In addition to the monophyly of the genus, in all six cladograms, *C. bernardii* and *C. miliaria* appear as sister species, which is supported by the apomorphic condition of the vein M being less sclerotized after dm-cu compared to the anterior region (18:1) and by the homoplasic condition of the presence of a spot on the median occipital sclerite (10:1). In three of the trees, the clade composed of *C. personata*, *C. bernardii,* and *C. miliaria* was supported by the presence of a spot on the frons.

The strict consensus of the trees in terms of the analysis with equal weighting, as well as Bremer's Absolute Support analysis are presented in Figure 7. The monophy of the groups obtained in the analysis with equal weighting *Carrerapyrgota* and the clade composed of *C. bernardii* and *C. miliaria* were present in trees with up to two steps from the most parsimonious trees (Fig. 7).

Analyses with implied weighting were conducted using concavity indices *K* between 1–10. A total of 25 trees were obtained with a single topology for the ingroup and four distinct topologies for the outgroups (Figs. 1, 3, 4). Figure 8 presents the topology resulting from the analyses with the values of *K*1, *k2,* and *K3*, which did not have a corresponding topology in the analyses with equal weighting. The four different topologies differed in relation to the positioning of the outgroups, as shown in Table 2.

The strict consensus showing the Bremer's Relative Support, of the analyses with implied weighting, is shown in Figure 9. The optimal tree selected to represent the monophyly of *Carrerapyrgota* and the evolutionary relationship among their species is shown in Figure 1, whose correspondents in the implied weighting are those resulting from the analyses with the values *K*3d, *K*4a, *K*5a, *K*6a, *K*7a, *K*8a, and *K*10a. The distribution of characteristics and their respective states, concerning the optimal topology, are shown in Figure 10.

CONCLUSION

Both analyses, with equal and implied weighting, supported the hypothesis of monophyly in the genus *Carrerapyrgota*, as demonstrated by the following apomorphic conditions: postscutellum absent, R_{2+3} with apical spur vein, lower calypter with a longitudinal row of hairs, and female forefemur with a longitudinal groove on the posterior surface. The monophyly between the species *C. bernardii* and *C. miliaria* is supported by the apomorphic condition of M less sclerotized, after dm-cu in relation to the anterior region and by the homoplastic condition of the presence of a spot in the median occipital sclerite.

The monophyly of *Carrerapyrgota* confirms the synonymy proposed by Bernardi (1990), which considers *Anapyrgota* a junior synonym of *Carrerapyrgota*.

AUTHORS' CONTRIBUTIONS

The two authors participate actively in the conceptualization, analysis, investigation; methodology, discussion, writing, review and editing. To the Willi Hennig Society for making TNT freely available, to Wayne Maddison and David Maddison (University of Arizona) for making available the software Mesquite. The first author was responsible to get a fellowship from FUNDECT.

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Taxon/Character	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Ceratitis capitata	1	0	1	1	0	1	0	0	1	1	0	1	3	1	1	0	0	0	1	0	0	1
Descoleia teretrura	0	0	0	1	1	1	0	1	–	0	0	0	3	0	1	0	0	0	0	0	0	1
Stenopyrgota crassitiba	1	0	1	1	0	2	1	1	–	0	0	–	1	1	0	0	1	0	0	0	0	–
Idiopyrgota setiventris	0	0	0	0	–	2	1	0	2	1	0	0	2	1	0	0	1	0	0	0	0	0
Leptopyrgota sahlbergiana	0	0	1	0	1	0	1	1	0	0	0	0	0	0	1	1	1	0	0	0	0	?
C. aczeli	0	1	1	1	–	2	1	1	2	0	1	1	2	1	1	1	1	0	1	1	1	1
C. bernardii	1	1	1	0	1	2	1	1	2	1	1	1	1	1	1	1	1	1	0	1	1	1
C. miliaria	1	1	1	0	1	2	1	1	2	1	1	1	1	1	1	1	1	1	0	1	1	0
C. personata	1	0	1	0	1	2	1	1	2	0	1	1	3	1	1	1	1	0	1	1	1	–

Index of concavity *k*	Analysis with implied weighting
**k*1, *k*2, *k*3a	Fig. 8
*k*3d, *k*4a, *k*5a, *k*6a, *k*7a, *k*8a, *k*10a	Fig. 1
*k*3b, *k*4b, *k*5b, *k*6b, *k*7b, *k*8b, *k*10b	Fig. 3
*k*3c, *k*4c, *k*5c, *k*6c, *k*7c, *k*8c, *k*9, *k*10c	Fig. 4

FIGURE LEGENDS

Table 1. Matrix from Morphological Characters of *Carrerapyrgota*.

Table 2. Trees resulting from the analysis with implied weighting of the characters (*k* = 1 – 10), with their respective correspondents resulting from the analysis with equal weighting of characters. *Analysis with *k*1, *k*2, *k*3a (Fig. 8) recovered the only tree that did not have a match in the analysis with equal weighting of the characters.

Figures 1–6: parsimonious trees of *Carrerapyrgota*, resulted from analysis with equal weighting of characters.

Figure 7: Strict consensus tree and Absolute Bremer Support of *Carrerapyrgota*, resulted from analysis with equal weighting of characters.

Figure 8: Tree resulted from analysis with implied weighting of characters with concavity values of *k*1, *k*2 and *k*3a.

Figure 9: Strict consensus tree and Relative Bremer Support of *Carrerapyrgota*, resulted from analysis with implied weighting of characters.

Figure 10: Optimal tree selected to represents the phylogenetic relationship among the species of *Carrerapyrgota*. Black circles represents synapomorphies, white circles represents homoplasies.

FIGURE

Figura. 1.

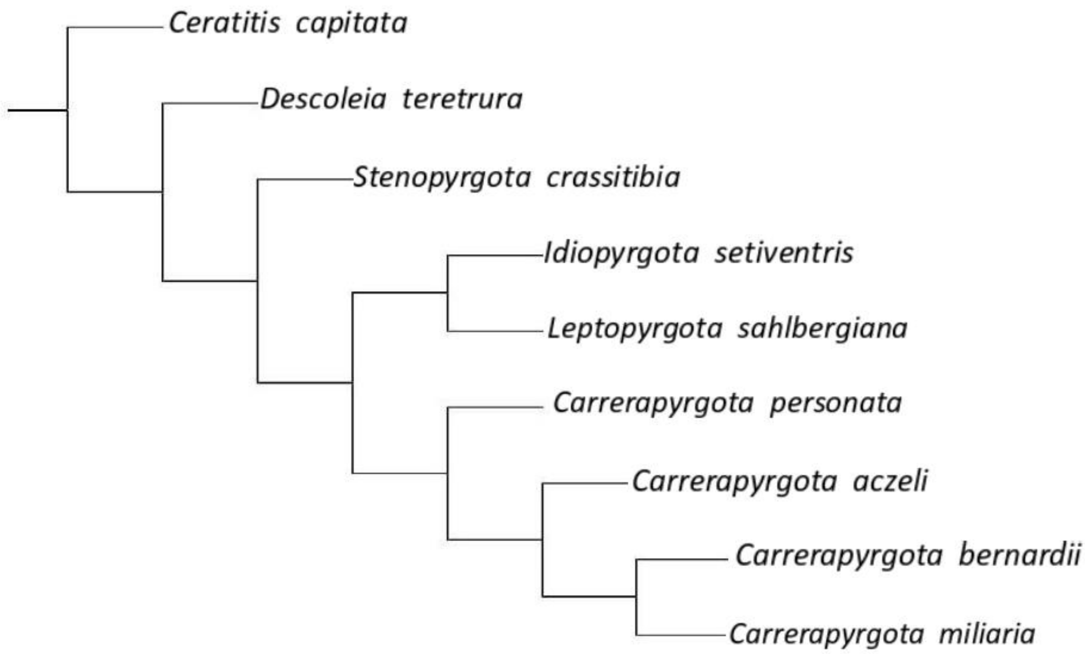
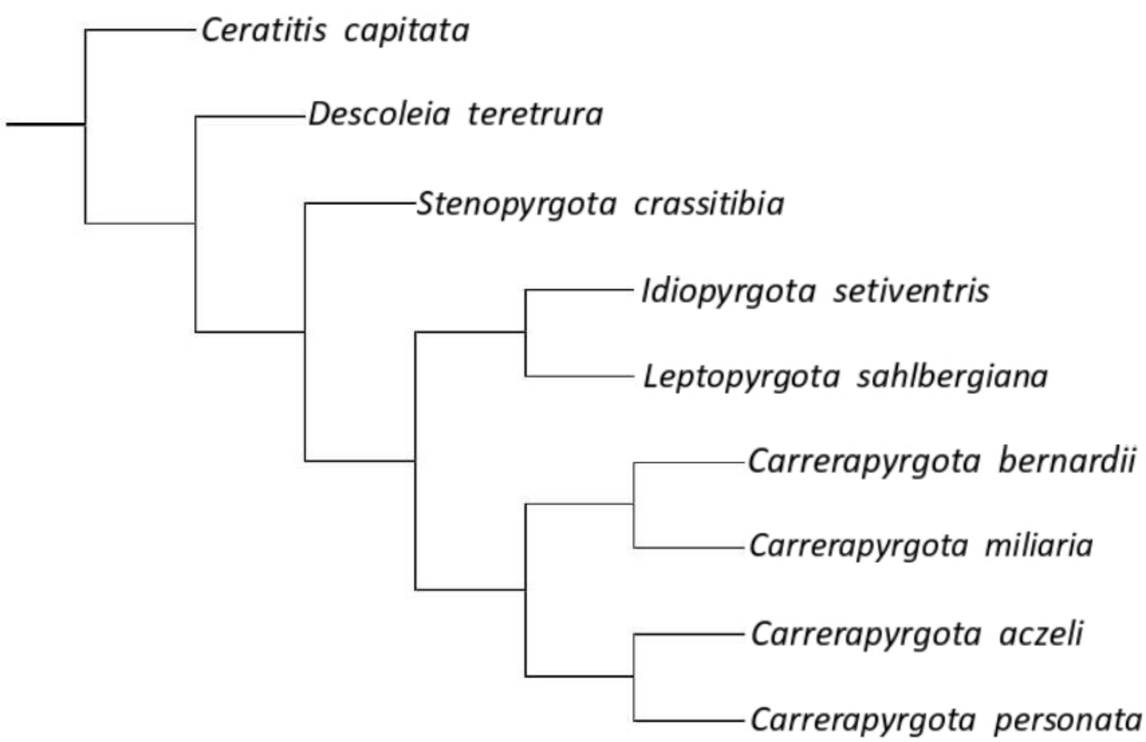


Figura. 2.


Ceratitis capitata
Descoleia teretrura
Stenopyrgota crassitibia
Idiopyrgota setiventris
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Carrerapyrgota bernardii
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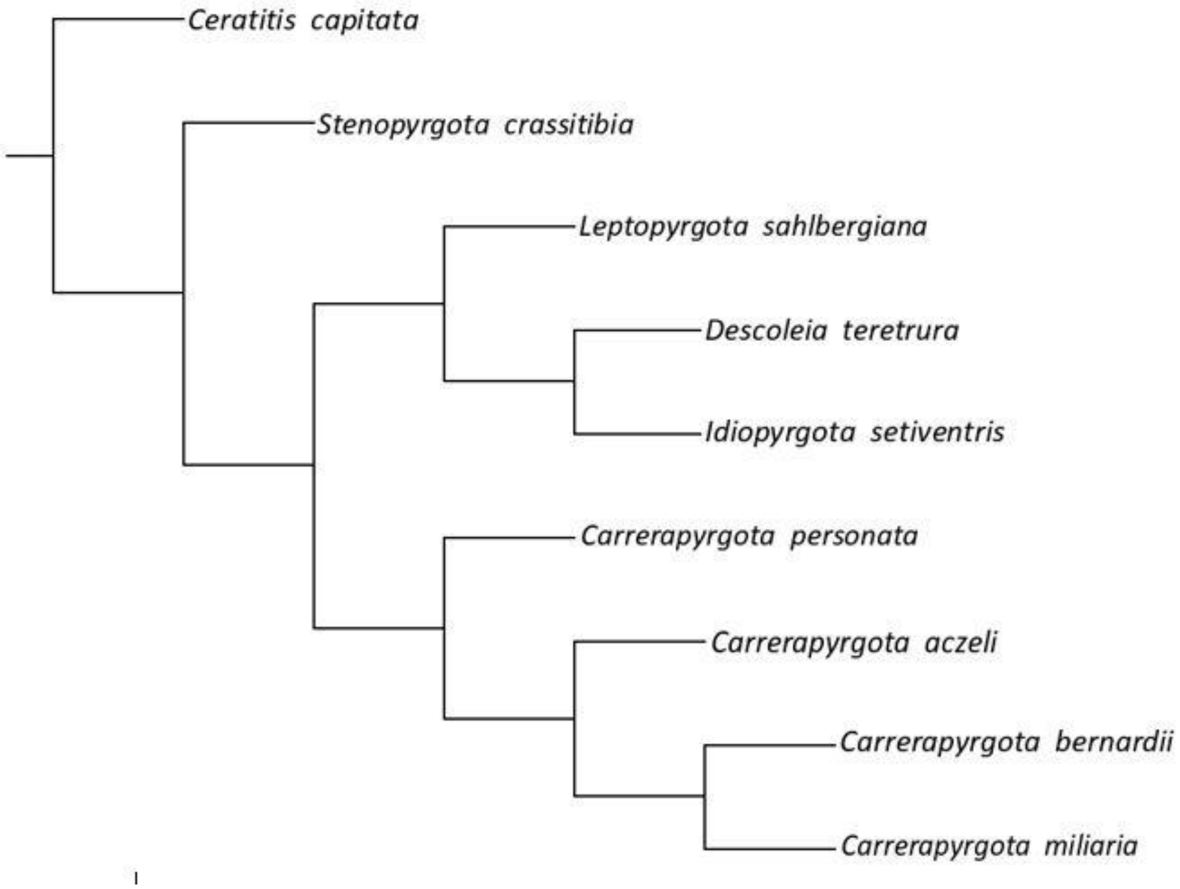
Carrerapyrgota aczeli
Carrerapyrgota personata

Figura. 3.


Ceratitis capitata
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Descoleia teretrura
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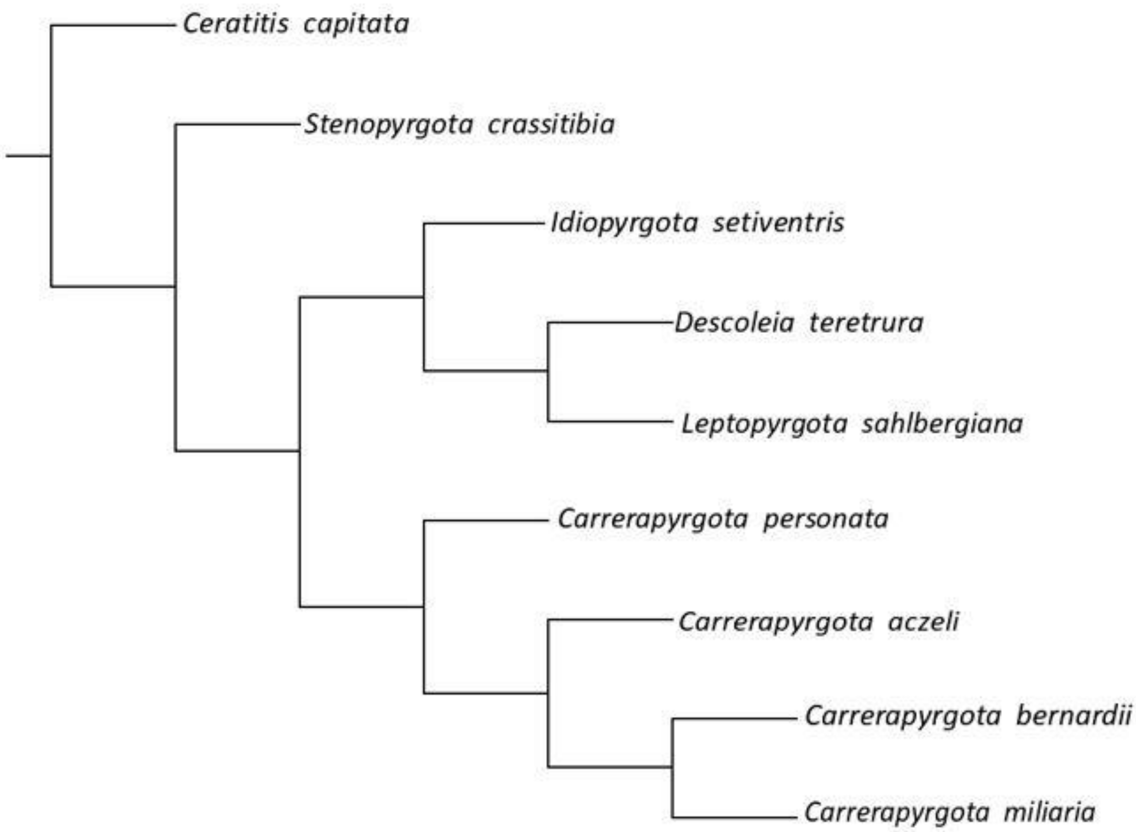
Carrerapyrgota bernardii
Carrerapyrgota miliaria

Figura. 4.



Ceratitis capitata
Stenopyrgota crassitibia
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Descoleia teretrura
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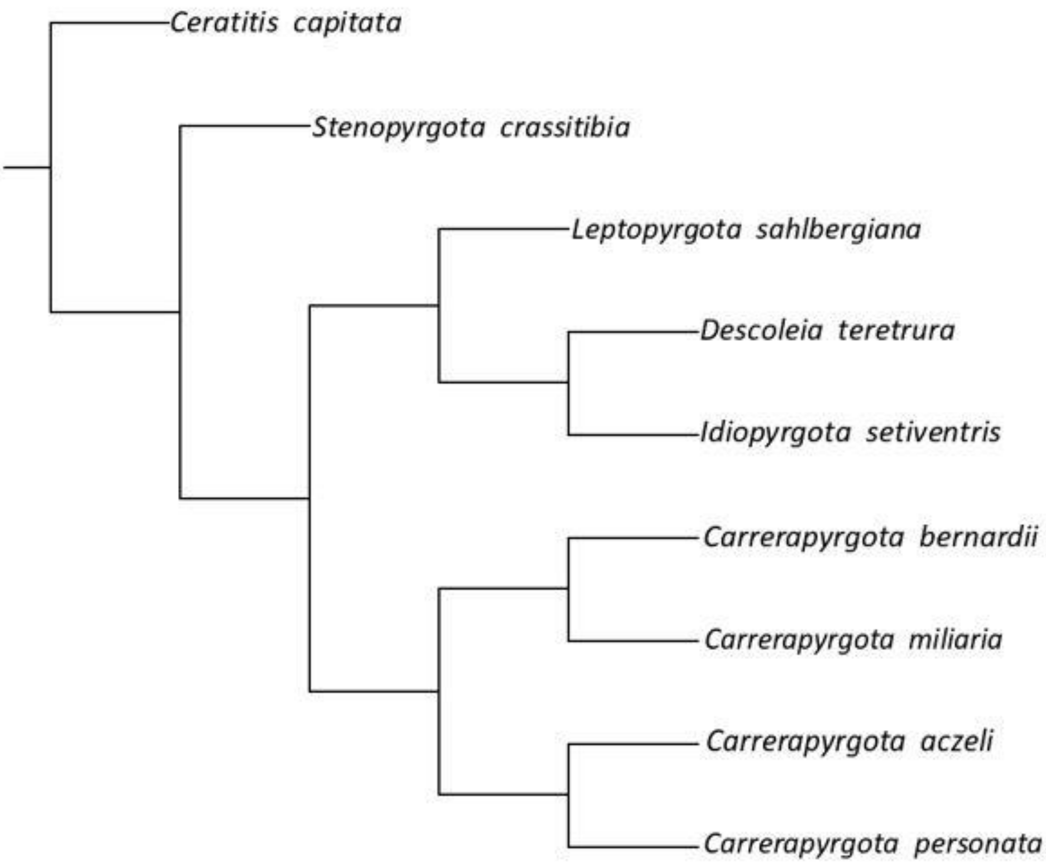
Carrerapyrgota bernardii
Carrerapyrgota miliaria

Figura. 5.


Ceratitis capitata
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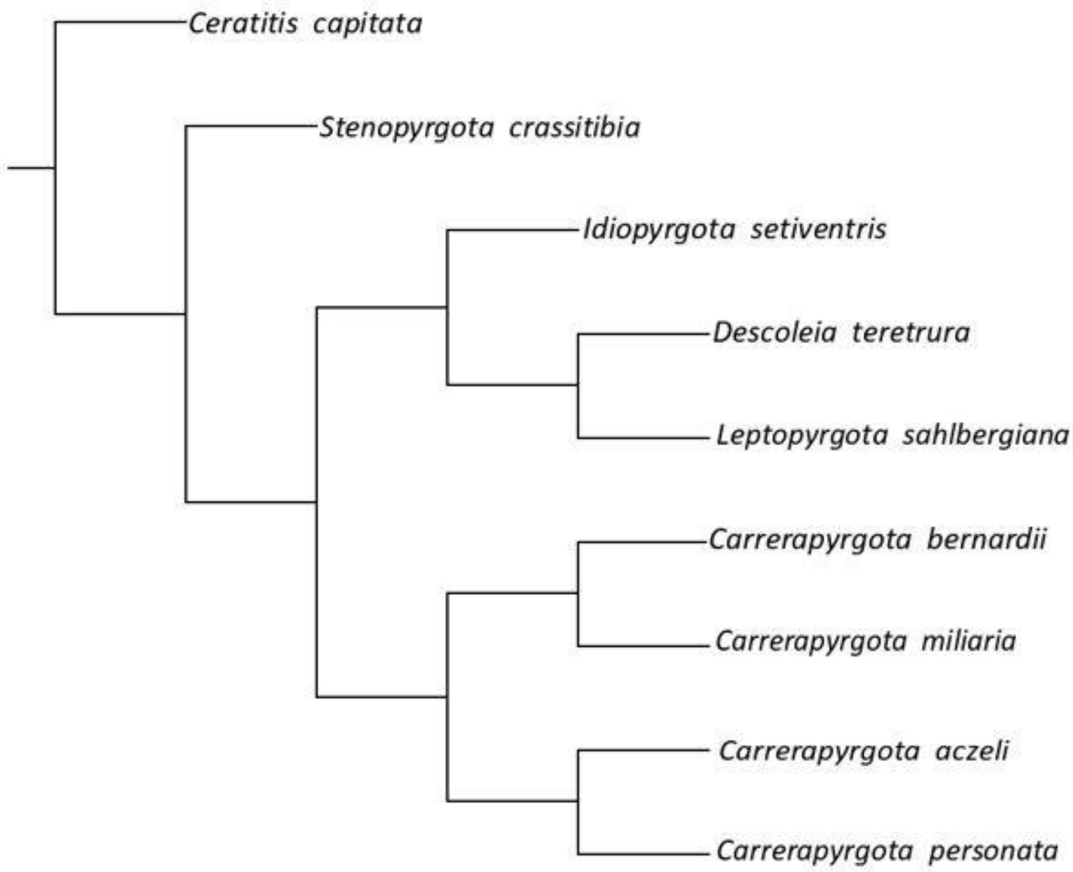
Carrerapyrgota aczeli
Carrerapyrgota personata

Figura. 6.


Ceratitis capitata
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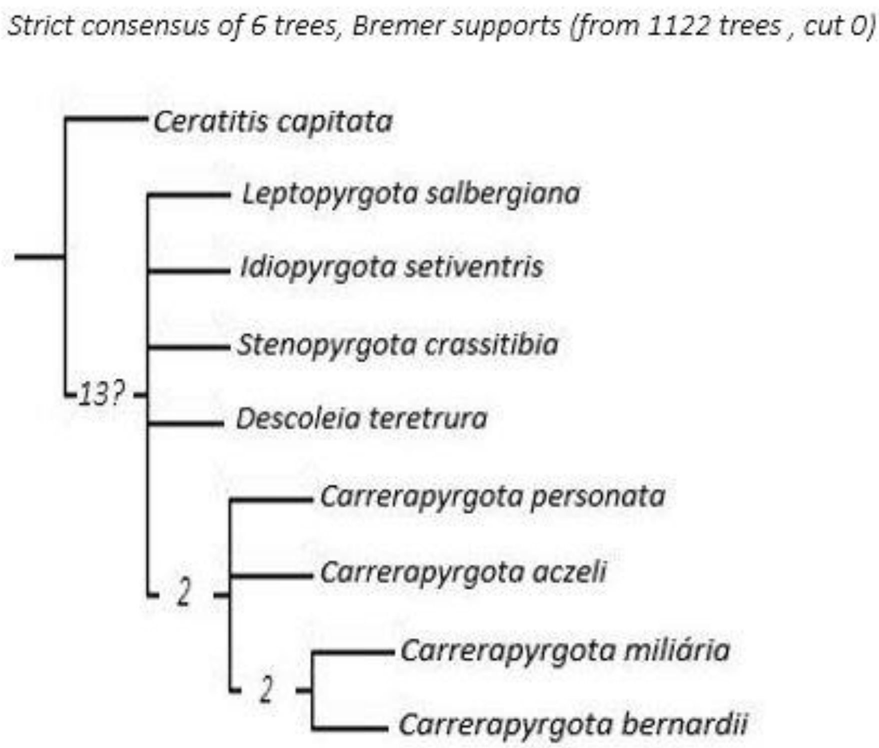
Descoleia teretrura
Leptopyrgota sahlbergiana
Carrerapyrgota bernardii
Carrerapyrgota miliaria
Carrerapyrgota aczeli
Carrerapyrgota personata

Figura. 7.


Strict consensus of 6 trees, Bremer supports (from 1122 trees , cut 0)
Ceratitis capitata
Leptopyrgota salbergiana
Idiopyrgota setiventris
Stenopyrgota crassitibia
13?
Descoleia teretrura
Carrerapyrgota personata
Carrerapyrgota aczeli
2
Carrerapyrgota miliária
2
Carrerapyrgota bernardii

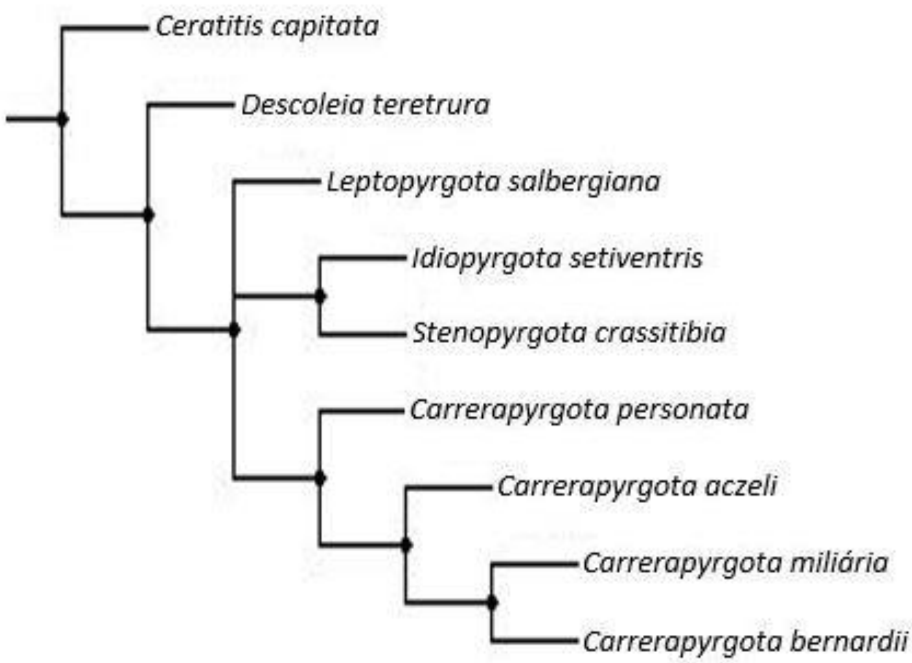

Ceratitis capitata
Descoleia teretrura
Leptopyrgota salbergiana
Idiopyrgota setiventris
Stenopyrgota crassitibia
Carrerapyrgota personata
Carrerapyrgota aczeli
Carrerapyrgota miliária
Carrerapyrgota bernardii

Figura. 9.

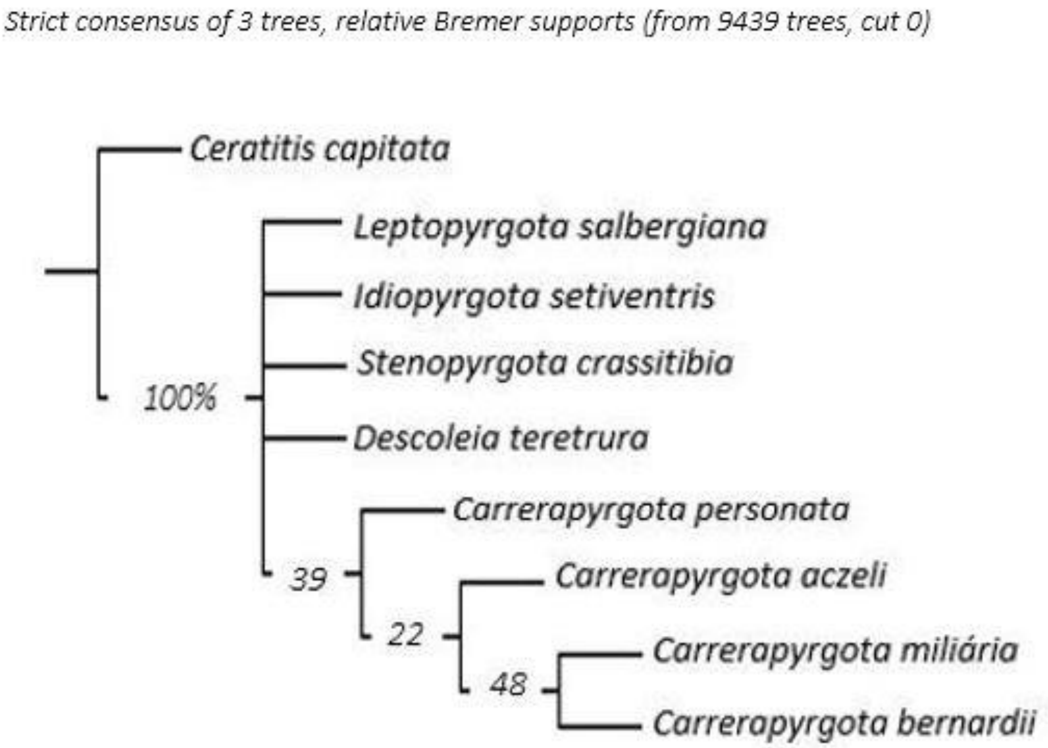
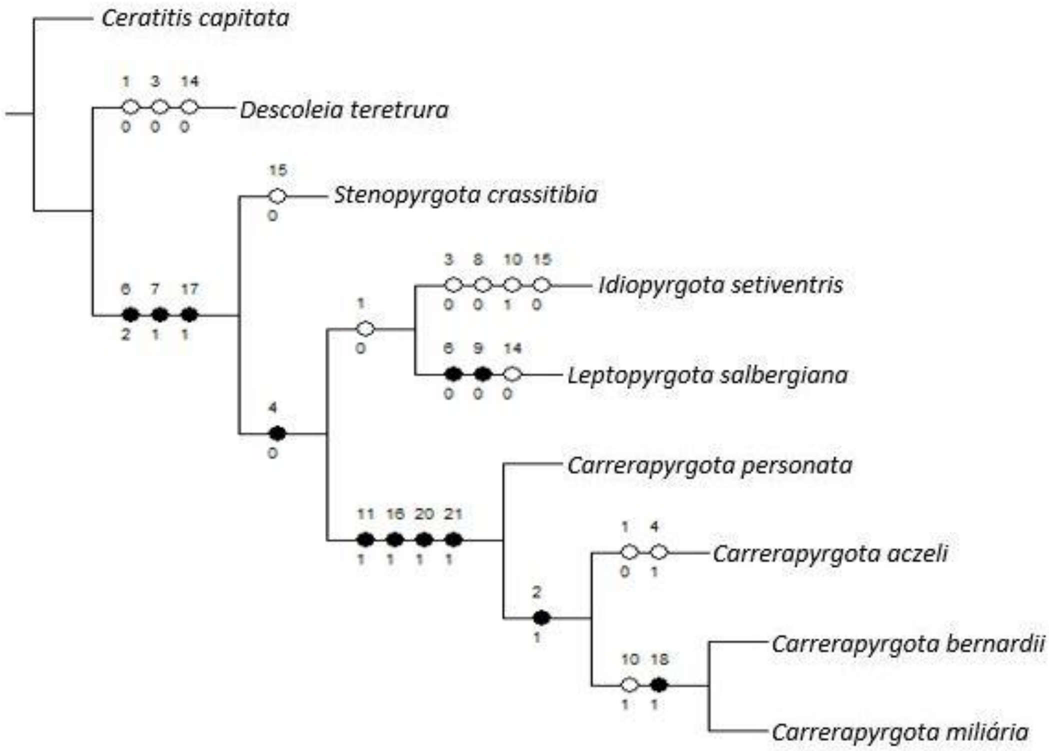

Strict consensus of 3 trees, relative Bremer supports (from 9439 trees, cut 0)
Ceratitis capitata
Leptopyrgota salbergiana
Idiopyrgota setiventris
Stenopyrgota crassitibia
100%
Descoleia teretrura
Carrerapyrgota personata
39
Carrerapyrgota aczeli
22
Carrerapyrgota miliária
48
Carrerapyrgota bernardii

Figura. 10.


Ceratitis capitata
Descoleia teretrura
Stenopyrgota crassitibia
Idiopyrgota setiventris
Leptopyrgota salbergiana
Carrerapyrgota personata
Carrerapyrgota aczeli
Carrerapyrgota bernardii
Carrerapyrgota miliária

Ramon Jose Correa Luciano de Mello <ramon.mello@ufms.br>

Fwd: [PAZ] Submission Acknowledgement

1 mensagem

leidiane alves <leidiane.alves174@gmail.com> 25 de abril de 2022 08:49
Para: Ramon Jose Correa Luciano de Mello <ramon.mello@ufms.br>

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Date: seg, 25 de abr de 2022 08:46
Subject: [PAZ] Submission Acknowledgement
To: Leidiane <leidiane.alves174@gmail.com>

Hello,

Ramon Luciano Mello has submitted the manuscript, "PHYOLOGENY OF CARRERAPYRGOTA ACZÉL (DIPTERA, PYRGOTIDAE): PHYOLOGENY OF CARRERAPYRGOTA" to Papéis Avulsos de Zoologia.

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  United States Department of Health and Human Services. Substance Abuse and Mental Health Services Administration. Office of Applied Studies. 2015. *Treatment Episode Data Set - Discharges (TEDS-D) - Concatenated, 2006 to 2011.* Version V5. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 23 Nov. 2015. Available: https://doi.org/10.3886/ICPSR30122.v5. Access: 30/09/2019.

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