



Odonata (Insecta) richness in Atlantic Forests from Minas Gerais state, Brazil

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Abstract. Inventories provide important information about species, both from a biogeographic perspective and in terms of their conservation status. Among insects, dragonflies are extensively surveyed in Brazil; however, significant knowledge gaps still exist regarding the distribution of these organisms in the country, particularly in threatened biomes such as the Atlantic Forest. In this study, we present data on an Odonata community collected in the Serra do Papagaio State Park between 2015 and 2016. We recorded 64 species, including six new records for the state of Minas Gerais, along with ten species with problematic conservation status, either due to a lack of distribution data or some degree of extinction risk. Our results highlight the importance of inventories in expanding our knowledge of species distribution and providing data that can aid in the assessment of their conservation status.

Keywords: Dragonflies; ICMBio; inventory; IUCN; Serra da Mantiqueira.

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The order Odonata encompasses insects commonly known as dragonflies, damselflies, and in some regions of Brazil known as "pito-do-saci," "zig-zig", among others (COSTA *et al.* 2012; BRASIL & VILELA 2019). These organisms play a significant role in the trophic chains of various freshwater ecosystems (COSTA *et al.* 2012), acting as both predators and prey (MOON & SILVA 2013), both in their larval phase in aquatic environments (CORBET 1999; MANDAL *et al.* 2008; ACQUAH-LAMPTEY & BRANDLE 2018), and in their winged adult phase in terrestrial ecosystems (SOUZA *et al.* 2022; FERNANDES *et al.* 2023). Besides their role in interspecific relationships, dragonflies also provide other ecosystem services and can even be used as bioindicators of environmental quality, both in their larval phase indicating water quality and in their adult phase, where they explore riparian vegetation areas (CORBET 1999; SMITH *et al.* 2007).

Despite their ecological significance, the study of Odonata still requires significant advancements to comprehensively understand certain areas of their knowledge (MAY 2019), such as: (i) their phylogenetic relationships, which despite receiving substantial contributions from recent phylogenies (BYBEE *et al.* 2021), still require more support in terms of relationships and additional material collection for analysis; (ii) their taxonomy, especially for larvae and females, with various groups needing revisions (GARRISON *et al.* 2010; VILELA *et al.* 2019); and (iii) their distribution, which remains quite limited for several groups, hindering conservation efforts such as Red List assessments by the Brazilian Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) and the International Union for Conservation of Nature (IUCN), and also impeding taxonomic progress that is closely linked to collecting expeditions.

Therefore, conducting inventory work contributes to understanding species distribution across different biomes, providing data for ecosystem monitoring (BRASIL *et al.* 2020), and aiding in the establishment of Conservation Units (GOUVÊA *et al.* 2023) or justifying those already established, which serve as a primary tool for conserving biodiversity in Brazil (SALVIO 2017).

The information presented in this study explains why there is a growing effort to better understand the distribution of Odonata in the state of Minas Gerais in the 21st century, especially within Conservation Units, particularly in the Atlantic Forest biome (FERREIRA-PERUQUETTI & DE MARCO JR 2002; AMORIM *et al.* 2018; SILVA & SOUZA 2020; ÁVILA JÚNIOR *et al.* 2020; STEFANI-SANTOS *et al.* 2021; GUEDES *et al.* 2022). The Atlantic Forest is considered a global hotspot due to its biodiversity, endemism, threatened species, and its reduced, modified, and fragmented geographical area (MYERS *et al.* 2000; MITTERMEIER *et al.* 2011; RIBEIRO *et al.* 2011; SCARANO & CEOTTO 2015). Despite this, some plant formations within this biome such as mixed forests and high-altitude grasslands are under sampled in terms of dragonfly fauna (OLIVEIRA FILHO 2006), with only one study recorded to this date (STEFANI-SANTOS *et al.* 2021). Based on this, the aim of the present study was to recognize and quantify the Odonata richness in the Atlantic Forest within the Serra do Papagaio State Park (PESP), located in the southern region of the state of Minas Gerais.

MATERIAL AND METHODS

Study area. The study was conducted within the PESP (22°12'18.22" S and 44°47'11.30" W), which is the largest Strict Nature Reserve Conservation Unit in the southern region of Minas Gerais state, covering a total area of 25,084 hectares (Figure 1) (MMA 2023). The PESP area comprises five municipalities (*i.e.*, Alagoa, Aiuruoca, Baependi, Itamonte, Pouso Alto) and the surrounding land areas of the park in such municipalities are affected by urbanization and agriculture, with small plantations of *Eucalyptus* sp. and other cultures (IEF 2023). The park is influenced by a high-altitude tropical climate, with temperatures ranging from 18° to 22°, with higher temperatures in the summer, and precipitation higher than 1,500 mm per year. It is located within the ecological corridor of the Serra da Mantiqueira complex and is geographically interconnected with the northern portion of the Itatiaia National Park (HERRMANN *et al.* 2011), forming an area considered crucial for invertebrate conservation in Minas Gerais (DRUMMOND *et al.* 2005).

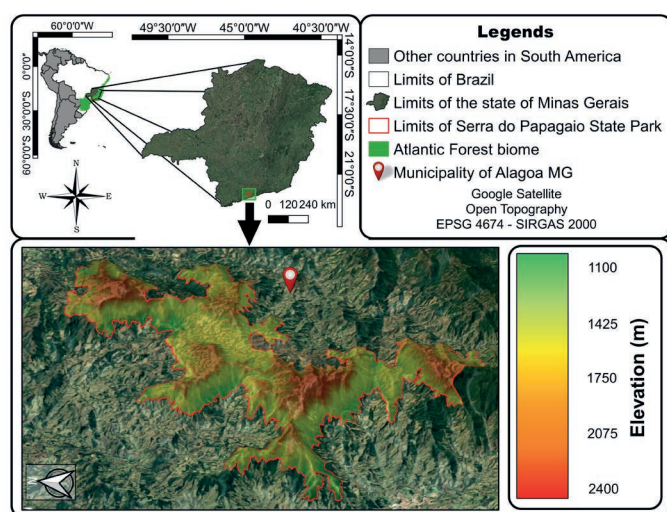


Figure 1. Geographic location, limits and altimetry of the Serra do Papagaio State Park, south of the state of Minas Gerais, Brazil. Source: The authors.

Specimen collection. Collections were conducted over a span of 25 sampling days, from July 2015 to April 2016, with five consecutive days per season (winter, spring, summer, and autumn), each day involving eight hours of collecting effort. This accumulated to a total of 200 hours of collection, undertaken by four researchers. Sampling was concentrated in the eastern portion of the Conservation Unit (municipality of Alagoas), based on logistical considerations. Only adult individuals were sampled, and they were collected using entomological nets, through active searching, in a variety of aquatic environments within the park (Figure 2). The dragonflies were then stored in entomological envelopes and fixed in PA acetone to preserve their coloration (LENCIONI 2005).

Taxonomic treatment. The taxonomic treatment was carried out using identification keys from GARRISON *et al.* (2006, 2010), LENCIONI (2005, 2006, 2017), and specialized literature (*i.e.*, review articles and species descriptions) as needed. Identifications were conducted by Dr. Ângelo Parise Pinto.

Conservation status data. Data regarding the threat status of species were obtained by consulting the websites of the International Union for Conservation of Nature (IUCN 2022) and the Chico Mendes Institute for Biodiversity Conservation (ICMBio, salve.icmbio.gov.br).

Data analysis. To assess the success of the sampling effort, an accumulation curve was constructed using the observed

richness with a 95% confidence interval under the Bootstrap 1 estimator in the software EstimateS 9.1.0 (COWELL 2013). This estimator utilizes information from all collected species rather than just rare species (SANTOS 2003).

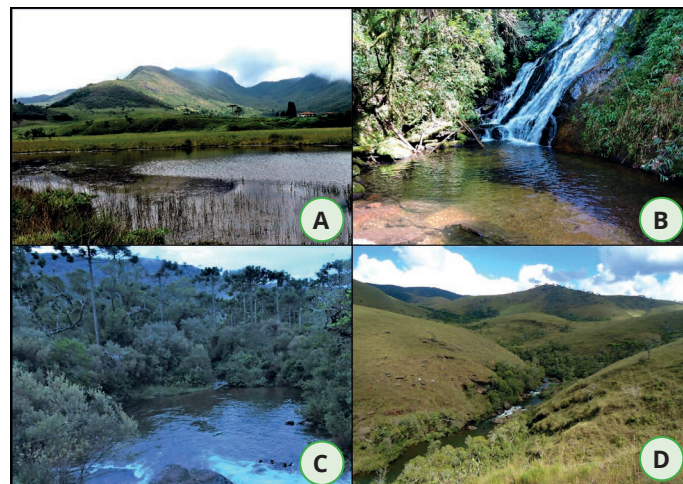


Figure 2. Ecosystems of the PESP where Odonata collections were conducted. A: lentic environment in an altitude field; B, C, and D: lotic environments with varying flow levels in mixed forest and altitude field areas. Source: Marcos Magalhães de Souza.

RESULTS AND DISCUSSION

A total of 64 Odonata species belonging to nine families were recorded (Figure 3), including six new records for the state of Minas Gerais: *Erythrodiplax acantha* Borror; *Fredyagrion siqueirai* Santos; *Oxyagrion sulinum* Costa; *Peristicta guarellae* Anjos-Santos & Pessacq; *Lestes tricolor* Erichson in Schomburgk; *Rhionaeschna decessus* (Calvert), and ten species with some degree of extinction threat or insufficient data for risk assessment, according to IUCN and ICMBio (Table 1).

Among the sampled species, we detected some degree of conservation risk, or even the inability to assess environmental status due to a lack of distribution data. Something that caught our attention were certain discrepancies between the international listing (IUCN) and the national listing (ICMBio). The reasons for such discrepancies can be attributed to two main factors: (i) the evaluation teams (provided by IUCN and ICMBio) are different and heterogeneous within themselves, which can lead to different interpretations of the available data; and/or (ii) the dataset available to each assessing team is not necessarily the same, that is, some researchers may have access to unpublished information and use this data to perform more robust assessments. We discuss each case in more detail below:

Rhionaeschna decessus (IUCN: DD; ICMBio: LC): Recently assessed by the IUCN as having insufficient data for evaluation (DD, BOTA-SIERRA & SANDOVAL-H 2021), *R. decessus* has issues related to its taxonomic identity, and therefore the authors decided to refrain from evaluation pending the resolution of such issues. In the more recent evaluation by the ICMBio, this taxon was evaluated as Least Concern (LC), even though the taxonomic problems regarding the species are mentioned in their rationale (DE MARCO JR *et al.* 2023e).

Castoraeschna januaria (Hagen) (IUCN: LC; ICMBio: VU): This species from the family Aeshnidae was classified as Least Concern (LC) by the IUCN assessment (LOZANO 2021a). The last assessment of this species by IUCN was in the year 2019 and, in the rationale, it is mentioned that the species has a wide distribution area (>170,000 km²) and occurs in protected areas, therefore being outside the environmental risk conditions for extinction. On the other hand, in the ICMBio assessment, the same species is categorized as Vulnerable

Table 1. List of species sampled in PESP, along with their respective conservation status assessments by IUCN and ICMBio. *New record for Minas Gerais state. The list is organized according to the last comprehensive phylogenetic analysis of Odonata (Bybee *et al.* 2021).

Suborder/Superfamily-Family/Species	IUCN	ICMBio
ANISOPTERA		
Aeshnidae		
<i>Castoraeschna januaria</i> (Hagen)	LC	VU
<i>Limnetron</i> sp.	-	-
<i>Rhionaeschna planaltica</i> (Calvert)	LC	LC
<i>Rhionaeschna punctata</i> (Martin)	LC	LC
<i>Rhionaeschna decessus</i> (Calvert)*	DD	LC
Libelluloidea - Incertae Sedis		
<i>Neocordulia androgynis</i> (Selys)	LC	LC
<i>Neocordulia</i> sp.	-	-
Gomphidae		
<i>Phyllogomphoides regularis</i> (Selys)	LC	LC
<i>Progomphus complicatus</i> Selys	LC	LC
<i>Progomphus gracilis</i> Hagen in Selys	LC	LC
Libellulidae		
<i>Brechmorhoga goncalvensis</i> Vilela, Stefani-Santos & Ávila Júnior	-	-
<i>Dasythemis mincki</i> (Karsch)	LC	LC
<i>Elasmothemis schubarti</i> (Santos)	DD	EN
<i>Erythrodiplax acantha</i> Borrer*	CR	LC
<i>Erythrodiplax castanea</i> (Burmeister)	LC	LC
<i>Erythrodiplax fusca</i> (Rambur)	LC	LC
<i>Erythrodiplax hyalina</i> Förster	LC	LC
<i>Erythrodiplax juliana</i> Ris	LC	LC
<i>Erythrodiplax lygaea</i> Ris	LC	LC
<i>Erythrodiplax media</i> Borrer	LC	LC
<i>Erythrodiplax paraguayensis</i> (Förster)	LC	LC
<i>Erythrodiplax umbrata</i> (Linnaeus)	LC	LC
<i>Macrothemis heteronycha</i> (Calvert)	LC	LC
<i>Macrothemis imitans</i> Karsch	LC	LC
<i>Macrothemis tenuis</i> Hagen	LC	LC
<i>Micrathyria athenais</i> Calvert	DD	LC
<i>Micrathyria stawiarskii</i> Santos	LC	LC
<i>Orthemis discolor</i> (Burmeister)	LC	LC
<i>Tramea binotata</i> (Rambur)	LC	LC
ZYGOPTERA		
Calopterygidae		
<i>Bryoplathanon globifer</i> (Hagen)	LC	LC
<i>Hetaerina longipes</i> Hagen in Selys	LC	LC
<i>Hetaerina proxima</i> Selys	LC	LC
Coenagrionidae		
<i>Acanthagrion gracile</i> (Rambur)	LC	LC
<i>Acanthagrion lancea</i> Selys	LC	LC
<i>Acanthagrion cuyabae</i> Calvert	LC	LC
<i>Acanthagrion truncatum</i> Selys	LC	LC
<i>Argia croceipennis</i> Selys	LC	LC
<i>Argia mollis</i> Hagen in Selys	LC	LC
<i>Argia sordida</i> Hagen in Selys	LC	LC
<i>Cyanallagma angelae</i> Lencioni	DD	LC
<i>Cyanallagma nigrinuchale</i> (Selys)	LC	LC
<i>Cyanallagma</i> sp.	-	-
<i>Forcepsioneura sancta</i> (Hagen in Selys)	LC	LC

To be continued...

Table 1. Continue...

Suborder/Superfamily-Family/Species	IUCN	ICMBio
<i>Ischnura capreolus</i> (Hagen)	LC	LC
<i>Ischnura</i> sp.	-	-
<i>Fredyagrion siqueirai</i> (Santos)*	DD	DD
<i>Minagrion caldense</i> Santos	VU	NT
<i>Minagrion waltheri</i> (Selys)	LC	LC
<i>Oxyagrion brevistigma</i> Selys	LC	LC
<i>Oxyagrion</i> cf. <i>simile</i> Costa	LC	LC
<i>Oxyagrion evanescens</i> Calvert	LC	LC
<i>Oxyagrion microstigma</i> Selys	LC	LC
<i>Oxyagrion santosi</i> Costa	LC	LC
<i>Oxyagrion sulinum</i> Costa*	LC	LC
<i>Oxyagrion terminale</i> Selys	LC	LC
<i>Peristicta guarellae</i> Anjos-Santos & Pessacq*	DD	LC
<i>Telebasis</i> sp.	-	-
Heteragrionidae		
<i>Heteragrion rogetaylori</i> Lencioni	DD	-
<i>Heteragrion</i> cf. <i>denisye</i> Vilela, Guillermo-Ferreira & Koroiva	DD	-
<i>Heteragrion</i> sp.	-	-
Lestidae		
<i>Lestes pictus</i> Hagen in Selys	LC	LC
<i>Lestes tricolor</i> Erichson in Schomburgk*	LC	LC
Megapodagrionidae		
<i>Allopodagrion contortum</i> (Hagen in Selys)	LC	LC
Perilestidae		
<i>Perilestes fragilis</i> Hagen in Selys	LC	LC

(VU). The ICMBio assessment was conducted in 2014 and had only two records in the literature, which conferred a threatened status to the species. Faced with this discrepancy in assessments between the two main databases (IUCN and ICMBio), we can consider the IUCN approach as it is more recent and the one that better describes the current conservation status of this taxon. We also highlight the importance of checking the information from both sources regarding assessment dates, amount of data used in the analyses, and bibliographic references, to ensure that we are supported by robust and reliable data.

Elasmothermis schubarti (Santos) (IUCN: DD; ICMBio: EN): A rare species in inventories and collections, *E. schubarti* was assessed as Data Deficient (DD) by the IUCN assessment (VILELA & GUILLERMO-FERREIRA 2021a). At the time of this assessment, which took place in 2019, it was mentioned that the species had last been collected in 1945, and since then, nothing was known about its distribution and other ecological information. In the ICMBio assessment conducted in 2014, this species appears with the status of Endangered (EN), which is applied when a species is facing a high risk of extinction in its natural habitats, either due to population reduction or limited distribution (IUCN 2022). The IUCN assessment (Data Deficient) seems to be the most prudent in this case, due to the very old records and the lack of ecological data about the species. To issue an assessment with some degree of threat to species conservation, current and robust data are needed; otherwise, assessments are determined as DD (IUCN 2022). In the case of *E. schubarti*, new records of the species were only reported by the present study, by BEDÉ et al. (2015) with data from various dates between 1997 and 2012 (reported after the publication of the ICMBio list) and by GOUVÊA et al. (2023). Therefore, the new addition of data

regarding the distribution of *E. schubarti* presented here is of utmost importance to expand our knowledge about its distribution, providing support for future analyses of its real conservation status.

Erythrodiplax acantha Borrer (IUCN: CR; ICMBio: LC): According to the assessment present on the IUCN website (VON ELLENRIEDER 2009a), this species was last collected in 1968, and the main threats identified in the CR (Critically Endangered) justification are habitat loss due to human pressures, even without recent collection records. Subsequently, in 2021, an assessment by ICMBio removed *E. acantha* from the threatened species category due to new collections that expanded knowledge about the species' distribution to six Brazilian states, including its presence in conservation areas (DE MARCO JR et al. 2023a). Therefore, based on this new assessment supported by new data from the literature, this species is evaluated as LC (Least Concern) because it is widely distributed, and there are no known threats to its conservation status. We highlight here the first formal record of *E. acantha* for the state of Minas Gerais.

Micrathyria athenais Calvert (IUCN: DD; ICMBio: LC): In a recent assessment by the IUCN, *M. athenais* was evaluated as DD (Data Deficient) due to the apparent lack of recent data on distribution and biology (LOZANO 2021b). However, in 2022, the ICMBio assessment classified this species as LC (Least Concern), with several occurrence records in at least six Brazilian states, including recent references (ÁVILA JÚNIOR et al. 2020; ARAÚJO & PINTO 2021). This is a clear example that demonstrates where assessments can be conflicting in their results, even when both are recent. The IUCN assessment was not mistaken, as the absence of recent occurrence data was the reason for applying the DD assessment to the species. It is possible that this literature might have been omitted from

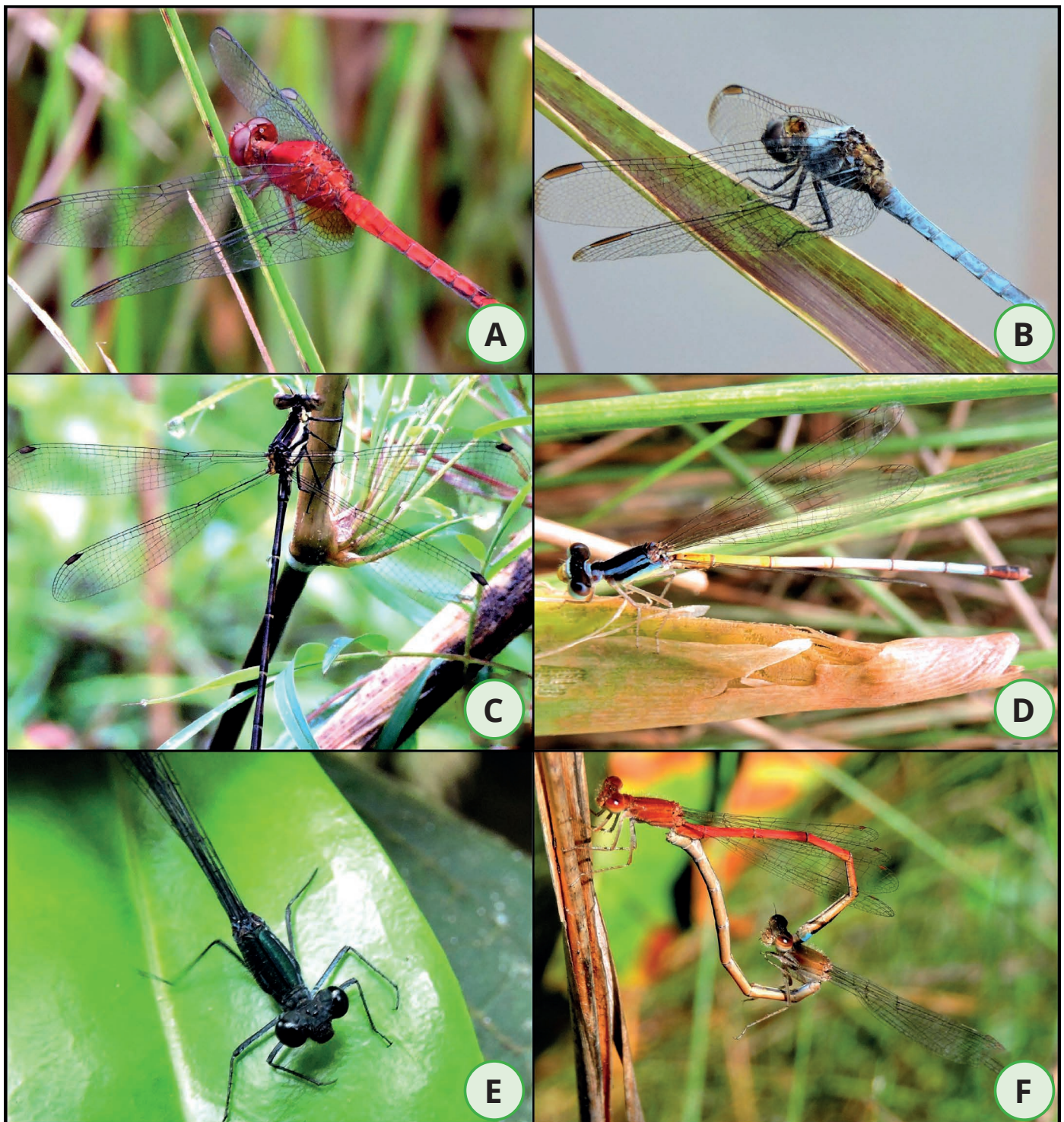


Figure 3. Some Odonata species recorded in the PESP, Southern Minas Gerais, Brazil. (A) *Erythrodiplax castanea*; (B) *Erythrodiplax media*; (C) *Heteragrion cf. denisye*; (D) *Minagrion caldense*; (E) *Peristicta guarellae*; and (F) *Oxyagrion microstigma*. Source: The authors.

the analyses by the authors of the assessment, leading to the conflict between the two lists.

Cyanallagma angelae Lencioni (IUCN: DD; ICMBio: LC): According to the IUCN assessment, *C. angelae* was classified as DD as it was reported from only one locality with 15 collected individuals (VON ELLENRIEDER 2009b). More than a decade later, in 2022, this species was re-evaluated and given an LC (Least Concern) status, due to recent collections that expanded its distributional range (DE MARCO JR *et al.* 2023b). This is also an interesting example of the importance of collections and inventories in expanding our knowledge of species distribution and in constructing threat lists, as illustrated here.

Fredyagrion siqueirai (Santos) (IUCN: DD; ICMBio: DD): Recently, *F. siqueirai* was assessed as having deficient data for a conservation status evaluation by the IUCN (CANO-COBOS *et al.* 2021). The justification at that time was the lack of data on

distribution and the antiquity of available records. Similarly, the ICMBio assessment conducted in 2022 provides a similar rationale for also assessing the species as DD (DE MARCO JR *et al.* 2023c). Additionally, in the review of the genus *Leptagrion* by LENCIONI (2022), he transferred this species to the genus *Fredyagrion* and noted that new records for the species were unknown. Therefore, this new record for *F. siqueirai* represents a rediscovery of the species in a protected area, which could be an important step in learning more about its natural history and distribution through new collections in that region and adjacent areas.

Minagrion caldense Santos (IUCN: VU; ICMBio: NT): This species was described in 1965, and until 2016, there were no new records of its occurrence in the literature (SANTOS 1965; MACHADO & BEDÉ 2016). In 2016, it was rediscovered in Serra da Canastra National Park and, at that time, a new taxon (*Minagrion franciscoi*) was proposed, later synonymized

with *M. caldense* (VILELA et al. 2020). In 2018, this species was assessed as VU (vulnerable) by the IUCN due to its restricted distribution area (<8,000 km²) and continuous decline of its habitats (GUILLERMO-FERREIRA & VILELA 2020). On the other hand, the ICMBio assessment (made in 2022) classified *M. caldense* as NT (near threatened), which is a criterion close to that established by the IUCN. Problems such as the ongoing habitat decline in the occurrence areas were also mentioned in the ICMBio assessment, and the new records provided by VILELA et al. (2020) contributed to modifying the threat level. With the new data presented here, a new assessment of *M. caldense* could further change again its conservation status, considering that it occurs in another protected area and will enhance the current knowledge of its distribution.

Peristicta guarellae Anjos-Santos & Pessacq (IUCN: DD; ICMBio: LC): According to the IUCN assessment, *P. guarellae* was classified as DD due to being known only from material collected from three localities in the 1970s, some of which had uncertain records (VILELA & GUILLERMO-FERREIRA 2021b). Recently, the species was rediscovered in Ibitipoca State Park, in the state of Minas Gerais, which expanded its distribution and led to its reclassification as LC (least concern) by the ICMBio assessment (DE MARCO JR et al. 2023d).

Heteragrion rogersaylori Lencioni (IUCN: DD): This species was described in 2013 based on material collected between 1998 and 1999 (LENCIONI 2013). In 2019, a new record was found from a malaise trap collection, but its conservation status was assessed as DD (data deficient) by the IUCN (no ICMBio assessment is available for this taxon), due to the limited number of distribution records and the old records from the original collection (VILELA & GUILLERMO-FERREIRA 2021c). With this additional record, we have expanded the species' distribution and hope that in a new assessment, the data deficient status will be updated, and a comprehensive conservation analysis for *H. rogersaylori* will be conducted.

Heteragrion denisye Vilela, Guillermo-Ferreira & Koroiva (IUCN: DD): This species has also not been assessed by ICMBio. *H. denisye* was assessed as DD by the IUCN due to being known from only one specimen, its restricted occurrence area within a protected area, making it impossible to conduct a comprehensive conservation status analysis (LOZANO 2022). Similar to the analysis for *H. rogersaylori*, we hope that this new distributional data can further elucidate the distribution of this species and that new assessments will provide more positive insights into its conservation.

The information hereby presented about the odonata community, especially the species threatened with extinction, those with insufficient data, and new occurrence records for the state of Minas Gerais, reinforces the significance of the PESP for the biota conservation in the state. It underscores the role of Conservation Units as the primary instrument for protecting biological heritage in our country (SALVIO 2017).

It is important to note that the odonata richness in PESP could be even higher, reaching up to 77 species according to the Bootstrap estimator (Figure 4). Our collection efficiency was around 83%, which can be explained by two factors related to the sampling methodology. First, in relation to the study area, the collections were concentrated in the eastern portion of the Conservation Unit, in the municipality of Alagoa, due to logistical reasons. Thus, collections in other locations could help in recording more species, as discussed in other studies conducted in the same area for other insect taxa (SOUZA et al. 2015, 2018). Second, there might be a need for a greater number of sampling hours in spring and summer, periods in which are more likely to observe an increase in odonatan populations, with a higher chance of recording adults (DUTRA 2011). Therefore, it is recommended to conduct

more odonatan collections in underexplored areas within this Conservation Unit.

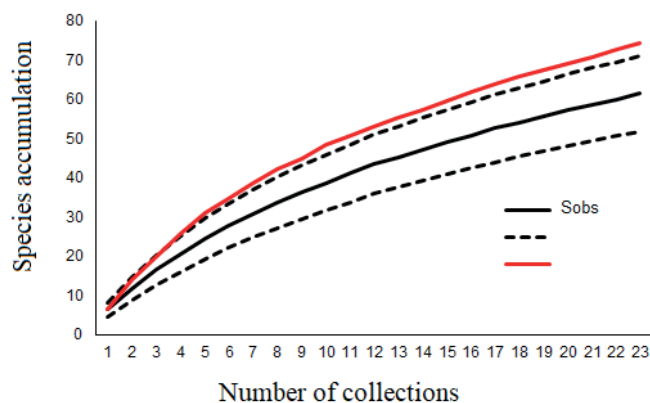


Figure 4. Number of recorded Odonata species in PESP (solid black line) and estimated richness using the Bootstrap estimator (red line) with a 95% confidence interval.

With the results presented here, we have demonstrated that the importance of inventories has been reaffirmed, both for understanding the distribution of species and for their conservation. Regarding distribution and taxonomy, we have provided new records for the state of Minas Gerais, expanding the areas of species occurrence and documenting taxa rarely sampled in inventories, many of which have not been collected since the 20th century. In terms of conservation, the data presented here represent advancements that can contribute to future assessments of the threatened status of these species, offering evidence of their presence within a Conservation Unit.

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