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Species Distribution and Conservation Status of Dragonflies and Damselflies (*Odonata*) in Antananarivo City, Madagascar

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Dragonflies are iconic freshwater and excellent indicators of freshwater ecosystems' environmental health and quality. The knowledge of Madagascar's *Odonata* is not advanced, and inventories are needed to increase the information on the distribution and conservation of these species. Here, we assessed the *Odonata* fauna occurring in Antananarivo City. Through opportunistic observations

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from October 2020 to September 2021 in 13 pond areas, we recorded 32 species of *Odonata* (22 Anisoptera and 10 Zygoptera). Endemic species represent a high proportion of the samples (69.70%). Few exotic species have been recorded (15.15%) and do not represent a real threat to the native species. Based on the International Union on Conservation of Nature criteria, most of the species are classified as a Least Concern (81.82%). River and the lake represent the main breeding sites for these species. The rice fields surrounding the Capital are excellent for breeding but contain fewer species. Interaction predator-prey should be initiated to assess Odonata's role in controlling malaria vectors such as *Anopheles arabiensis.*

Keywords: Wetland; dragonflies; urban development; breeding site.

1. INTRODUCTION

Several studies have been conducted to assess Madagascar's fauna and flora community for decades [1-3]. The bulk of research carried out in the Island are focused on plants and vertebrates, but few studies have been undertaken on invertebrates, especially dragonflies [4-8]. Studies of insects have focused mainly on the taxa that have economic and medical concerns [9] and those associated with forest conservation [10-12]. Despite their essential role in the ecosystem as important bio-indicators [13] and natural pest managers, dragonflies are considered to provide economic value [14]. In Madagascar, the taxa have been neglected, thus driving a significant gap on the knowledge of their ecology, conservation, and taxonomy [8,15]. However, Madagascar harbors a high diversity of dragonflies with high endemism. Due to the lack of data related to Madagascar's *Odonata*, more studies are needed in all aspects of *Odonata* ecology [5, 8, 16]. Here, we assess the first diversity of dragonflies and damselflies within Antananarivo City. We undertook a simulation of the seasonal trends and the potential effect of habitat quality on the species' richness.

2. METHODS

2.1 Study Area and Methodology

The study was conducted in 13 potential habitats of adult dragonflies and damselflies within Antananarivo City, Madagascar (Fig. 1). The primary habitats visited were water pools, lake, rivers, rice paddies, and three wetland protected areas (Mandroseza, Tsarasaotra, and Tsimbazaza). It is essential to note that Lake Tsarasoatra has been a Ramsar site since 2005. From October 2020 to September 2021, we

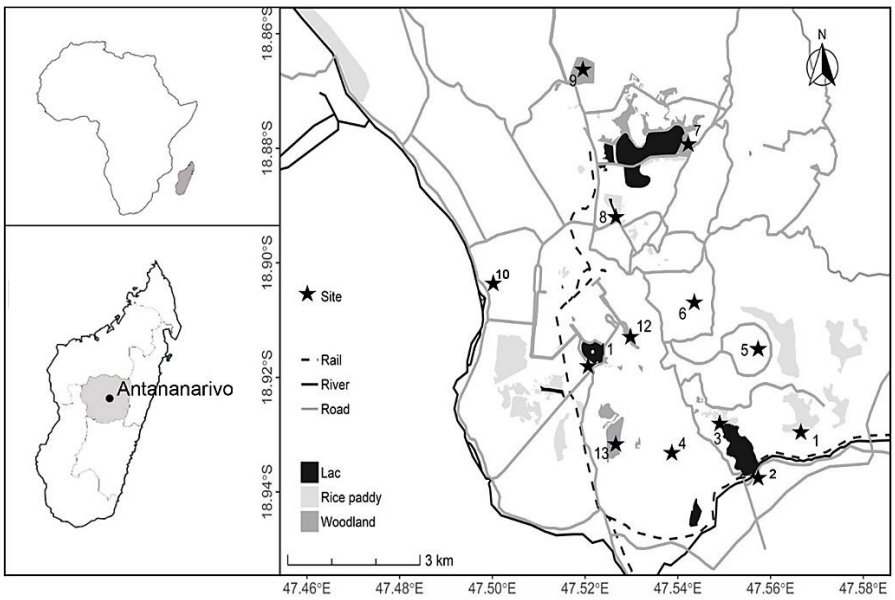

Fig. 1. Antananarivo city with the different points of the record. 1: Ikopa, 2- Mandroseza, 3-Andohanimandroseza, 4-Manakambahiny, 5-Ankatso, 6-Avaradoha, 7-Masay, 8-Manjakaray, 9-Tsarasaotra (Park), 10-Andohatapenaka, 11-Anosy, 12-Ambanidia, 13-Tsimbazaza (Park).

visited one to three areas every month between 8.00 to 18.00 and under the ideal observation climates (sunny and not very windy). Each visit was conducted for approximately two hours, depending on the size of the site. A butterfly sweep net was used to take samples, and, in the meantime, a camera EOS CANON 60D – 100 mm lens was used. During each visit, we strolled to take pictures of observed species of adult dragonflies and damselflies and take samples of the species observed for species identification in the laboratory. For familiar and common species, we noted their presence during each observation. We identified the photographed species from previous work on *Odonata* on the Island to the species level [8].

Establishing whether the species is native or not is very important for this study. We use the International Union for Conservation of Nature IUCN to determine the conservation status of the observed species.

2.2 Statistical Analysis

We conducted all analyses on R 4.0.1 using the R package iNEXT. We drew the species richness and rarefaction curves using the Chao1 index with a 95% confidence interval of both Anisoptera and Zygoptera [17]. We performed a quadratic polynomial regression to estimate seasonal trends of the species richness in Antananarivo City.

3. RESULTS

3.1 Species Richness and Diversity

We recorded 32 species of *Odonata* from the 13 different observation sites in Antananarivo City (Annexe 1). For Anisoptera, we recorded 22 species belonging to 16 genera and grouped in two families in which the family of Libellulidae was the most diversified (81.8%), followed by the Aeshnidae (9.1%). For Zygoptera, most species belong to Coenagrionidae (73.91%) followed by Lestecidae (21.73%). When extrapolating the sampling effort, we observed 21±4 species of Anisoptera (Fig. 2A). The families of Macromiidae and Cordulidae were the least diverse (4.5 %) (Fig. 2B). In general, for the *Odonata*, most of the species collected belong to three families represented by Libellulidae (55.92%) followed by Coenagrionidae (22.37%) and Aeshnidae (7.89%). The estimated species was similar to the observed species in

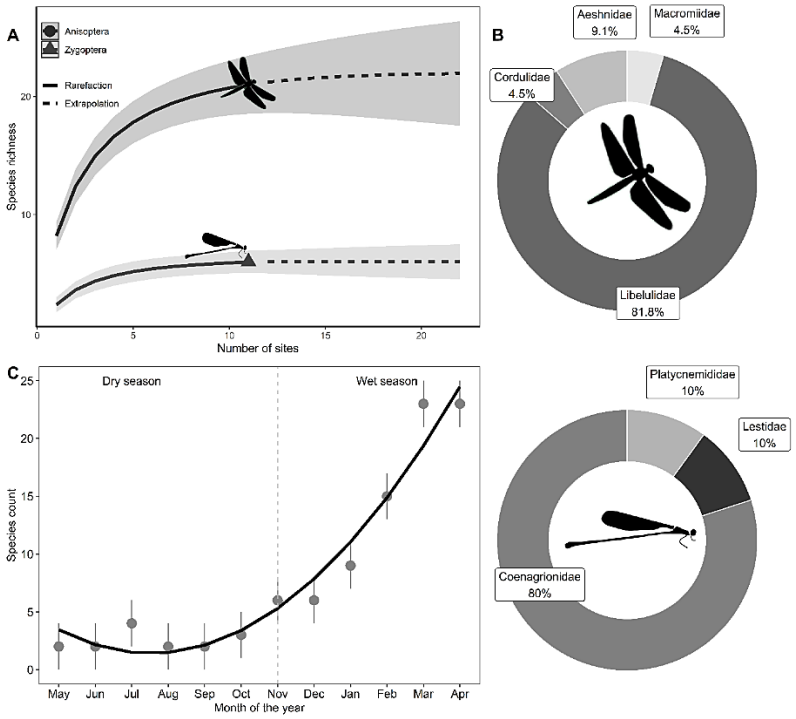

Fig. 2. Rarefaction curve with interpolation and extrapolation of the species richness (A). The proportion of the species in each suborder family Anisoptera and Zygoptera (B). Seasonal trend in the species number (during the dry season: May-October, and wet season: November-April (C)

the field. Thus, most of the species that occur in the City are in the Fig. 2A. The main difference in the distribution pattern is the type of habitat that those species lived in. Some species occurred only in lakes and rivers, such as *Acisoma attenboroughi, Ceriagrion aff glabrum, Syncordulia sp* and *Trithemis hecate.* In general, lake represented the primary habitat colonized by most of the dragonflies collected (36.59 %) followed by the river (24.39%), the rice field (23.17%), and the swamp (15.85%) (Annexe 1). Results from the species richness show a nonlinear pattern through the year in the Capital Antananarivo (Fig. 2C). Fitted with the polynomial quadratic regression, the species richness increased from the beginning of the rainy season. It reached the maximum in March and April, coinciding with the end of this season ($R2=0.96$, $F2, 9=91.86$, $p=0.001$).

3.2 Species Composition

Of the 32 recorded species, the rate of endemic species is 69.70%, and they all have a large distribution across the main Island and Malagasy region (Annexe 1). No invasive species were recorded, but five exotic species and four undescribed species were sampled. According to IUCN classification (2023), all species are classified as Least Concerned (81.82%), Data Deficient (30.3%), and with an unidentified species (3.03%).

4. DISCUSSION

4.1 Species Richness and Endemicity

Madagascar is home of over 227 species of *Odonata*, with 190 described species [18]. This study revealed a subset of the *Odonata* occurring in Antananarivo. Here, 32 species represent the overview of *Odonata*'s illustrated diversity in an urban area. The data recorded during this study represented around 14.53% of Madagascar's *Odonata* diversity. The endemic species mainly inhabit forests and have a low tolerance to habitat change [8]. However, a significant number of endemic species were recorded during this survey, and they are widespread across the Island (23 species). For example, *Orthetrum azureum* or *Acisoma attenboroughi* found in open rivers and tolerant to various anthropogenic habitats such as rice paddies. We noticed that Zygoptera was less diverse and less abundant than Anisoptera. The Zygoptera group is quite sensitive to water pollution in the City. Most recorded species belong to the genus suitable for modified landscapes, such as *Ceriagrion* and *Ischnura*. Most Malagasy endemic species are globally associated with the forest ecosystem (*Nesolestes, Pseudagrion, Malgassophebia, Neothydemis*), but these species were not sampled during this study. This primary study provided the first species distribution of dragonflies and damselflies in anthropogenic landscapes. In general, most Malagasy insect species are associated with the forest ecosystem. This is the case for ants [19], butterflies [20], and diving beetles [12]. Our study demonstrates the importance of conserving wetlands as breeding sites and the open surrounding habitat for the adult stage of *Odonata*.

4.2 Conservation Implications

As small animals, restricted habitats contain specialized, rare species, but higher species richness is found in habitats with good water quality. For example, these habitats include waterfall spray zones and wet trickles along rock faces and swamps. These habitats are not present in the Antananarivo Capital. This is the first published data on the *Odonata* diversity of Antananarivo City in urban areas published during the past decade. Our research fills the gap on the ecology of *Odonata*, particularly their distribution and the resilience of some species in anthropogenic areas. The Ramsar site at Tsarasaotra played an important role as a breeding site for the species inhabiting the downtown. Streams surrounding the town played the same function for the species living at the boundaries. In contrast, the rice fields and swamps surrounding the City contain fewer species. Species composition in lakes and rivers differed from that in rice fields and swamps. Furthermore, anthropogenic activities reduce the habitat of native species. Antananarivo City dominates by valley. Demographic pressure, many valley floors and swamps transformed into a *rice field.* Wetlands, frequently utilized for backfilling and construction over the past decade, have been significantly impacted by human activities. Additionally, local farmers use pesticides that contaminate the rice fields, affecting the water quality. Instead of having an alternative habitat other than the lake and river, the rice field didn't play the same role as a *Odonata* breeding site. As habitat quality changes, *Odonata* also exhibit changes in their diversity, abundance and distribution due to their sensibility. Due to the lack of time, we only have

data on the incidence of *Odonata*. It's crucial to emphasize the integral role played by *Odonata*'s larval and adult stages, serving as a formidable predator of mosquito. *Odonata* larvae are highly effective in reducing the abundance of various mosquito species [21]. This approach should be initiated for Antananarivo City to assess the dynamic of predatory prey and relative impact on malaria cases and arbovirus disease. At Antananarivo, rice fields remained the principal breeding sites for the potential vector of malaria *Anopheles arabiensis* [22]. In the past, lack of funding or partnership was the primary reason Malagasy scientists do not initiate this kind of research [23]. This primary should be used as a milestone to start the investigation in this field.

Globally, wetlands play a key role in supporting biodiversity and housing a population of birds [24]. For the *Odonata* fauna, the loss of ponds and high pollution levels are significant threats in urban zones. Indeed, some protected lakes or wetlands around the City, such as Mandroseza, Tsimbazaza, and Tsarasaotra, are crucial as breeding sites and should preserve the remaining diversity. Tsarasaotra, a RAMSAR site, harbors a few endemic species, such as *Acisoma attenboroughi* and *Proplatycnemis malgassica*. However, this site is contaminated with high levels of nitrate associated with low pH [25]. The aquatic stage of *Odonata* is susceptible to these conditions, and it is not excluded that many species of dragonflies and other taxonomic groups have not survived as a result. This paper aims to raise awareness among decision-makers to enhance the protection of the wetland in the Capital and preserve the remaining few endemic species. Nevertheless, their survival requires close study. The current situation of Madagascar as a developing country makes it difficult to preserve the habitats from human needs. At this stage, it is challenging to determine the accurate number of *Odonata* that perished or were lost before being inventoried. This primary data can be used as a reference to evaluate the diversity of *Odonata* in the City. Generally, all *Odonata* collected are cosmopolitan and have a high plasticity to habitat change. Research on waterbirds and benthic invertebrates in 37 wetlands Malagasy sites demonstrates that this current trend in Madagascar affects the faune negatively [26]. Other studies on dragonflies and other taxa highlighted this evidence [27-29]. Large-scale restoration of degraded wetlands is required to conserve Madagascar's freshwater biodiversity long-term.

4.3 Study Limitation

This current study is limited to a simple assessment for one year. The capture-recapture technique was not used to estimate the relative abundance of each species. Still, it highlights that additional studies should be carried out to assess the response of the diversity of *Odonata* to habitat changes, interaction predator-prey on mosquito vector disease, and pesticide effects on the *Odonata* breeding site in Antananarivo.

5. CONCLUSION

This paper provided the first data on the distribution of dragonflies and damselflies in Antananarivo City for the past two decades. It reveals the preferred habitats of *Odonata*. An important number of endemic species were collected. Further research is required to promote the conservation of these sites to reduce the impact of urban expansion on *Odonata* biodiversity.

CONFLICT OF INTEREST STATEMENT

All authors performed the conception of the protocol and the statistical analysis and wrote the manuscript. All authors read and approved the final manuscript. The corresponding author confirms on behalf of all authors that no involvement might raise the question of bias in the work reported or in the conclusions, implications, or opinions stated.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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ANNEXE 1. Checklist of the 32 species recorded in Antananarivo city with the UICN status. DD: Data Deficient; LC: Least Concern; En: Endemic; Indet: Indeterminate

Family	Species	Swamp	Lake	Rice field	River	Endemicity	IUCN
Aeshnidae	*Anax tumorifer*	-	1	1	1	En	LC
	Anax imperator	1	1	1	1	En	LC
Coenagrionidae	*Pseudagrion punctum*	-	1	-	1	En	LC
	Ceriagrion glabrum	1	1	1	1	En	LC
	Azuragrion kauderni	1	1	1	1	En	LC
	Ceriagrion aff glabrum	-	1	-	-	Exotic	LC
	Agriocnemis exilis	1	1	-	-	Exotic	Not evaluate
	Ischnura senegalensis	-	1	1	1	Exotic	Not evaluate
	Pseudagrion sp1	-	1	-	-	Indet	Not evaluate
	Pseudagrion sp2	-	1	-	1	Indet	Not evaluate
Corduliidae	*Syncordulia sp*	-	1	-	-	indet	Not evaluate
Lestecidae	*Lestes ochraceus*	1	1	1	1	En	LC
Libellulidae	*Crocothemis erythraea*	1	1	1	1	Cosmo	LC
	Acisoma attenboroughi	-	1	-	-	En	LC
	Neodythemis hildebrandti	1	1	-	-	En	LC
	Trithemis selika	-	1	1	-	En	LC
	Thermorthemis madagascariensis	-	-	1	-	En	LC
	Trithemis persephone	-	1	-	1	En	LC
	Tholymis tillarga	-	1	1	-	En	LC
	Trithemis annulata	-	1	1	1	En	LC
	Brachythemis leucosticta	-	1	-	-	En	LC
	Neodythemis trinervulata	-	1	1	1	En	**DD**
	Urothemis edwardsii	-	1	1	1	En	LC
	Orthetrum stemmale	1	1	1	-	En	LC
	Orthetrum azureum	1	1	1	1	En	LC
	Palpopleura vestita	1	1	1	1	En	LC
	Pantala flavescens	1	1	1	1	En	LC
	Diplacodes lefebvrii					En	LC
	Trithemis hecate	-	-	-	1	Exotic	LC
	Tramea basilaris	-	1	-	1	Exotic	LC
Macromiidae	*Phyllomacromia trifasciata*	1	1	1	1	indet	LC
Platycnemididae	*Proplatycnemis malgassica*	-	1	-	-	En	LC