

Distribution and conservation of the Neotropical rattlesnake, *Crotalus durissus* (Squamata: Viperidae), in French Guiana: citizen science and local communities come to the rescue

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Abstract. The South American Rattlesnake, *Crotalus durissus durissus*, is a typical savannah habitat snake that only rarely occurs in forested areas. Its populations are generally fragmented and widely separated, which has been recognised for a long time in French Guiana. Our recent fieldwork, community surveys, and data gathered from social media and other online platforms allowed us to review and extend the distribution of this snake in French Guiana. It was previously considered to be composed of two populations widely separated by more than 100 km. Contrary to previous accounts, our data show that the distribution of the species is most likely continuous from Montsinéry in the east to Mana and Saint Laurent du Maroni in the west. Conservation concerns are numerous but habitat destruction following human expansion along the narrow coastal border is the primary concern and seriously threatens this species.

Key words. South American Rattlesnake, distribution, citizen science, social media, social network, community survey, savannah, habitat destruction, urbanisation, road kill

Introduction

French Guiana is largely composed of tropical rainforest (about 95% of the area) with few open habitats that are restricted to the coastal fringe. The later comprised savannahs, swamps, farming lands and urbanised areas. Savannahs are thus one of the less common ecosystems, representing only 0.3% of French Guiana landscapes (Chaix et al., 2002; De Pracontal and Entraygues, 2009).

Crotalus durissus Linnaeus, 1758 occurs in every country on the South American mainland from Venezuela to Argentina, except for Chile and Ecuador. In Brazil it is common in open areas such as savannahs (Colli et al., 2002; Tozetti et al., 2009; Nogueira et al., 2019) but is absent from the Amazonian rainforests,

resulting in a wide and highly discontinuous spatial distribution, particularly fragmented in its northern part (Campbell and Lamar, 1989; Campbell et al., 2004; David et al., 2018). Despite many populations being separated from each other, recent genetic studies have shown that most South American populations of *C. durissus* are phylogenetically closely related (Wüster et al., 2005; Quijada-Mascareñas et al., 2007). The majority of the published observations are originally from Brazil, principally because it is the largest country of South America (Carvalho Siqueira et al., 2017) but also because the extended Brazilian savannah, namely Cerrado, is a large biome and a favourable ecological niche for this species (Campbell et al., 2004), including the Cerrado forest formation (Benício, 2018). The species is medically important and responsible for human envenomation (De Haro, 2012; Rodrigues et al., 2016; Mutricy et al., 2018; Santos et al., 2019).

Most rattlesnake populations of the Guiana Shield (French Guiana, Suriname, Guyana), previously considered as *C. durissus dryinas*, are now regarded as belonging to only one subspecies, *C. durissus durissus* (see Campbell et al., 2004). In French Guiana, only that subspecies occurs (Fig. 1) and it is generally considered as restricted to the coastal savannahs (Mutricy et al., 2018; Dewynter et al., 2021). Here we provide the largest summary of observations for *C. durissus* in French Guiana. Before our investigations,

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the distribution of the species in French Guiana was considered to be limited to two well-separated coastal populations (Faune-Guyane.fr). We describe the fine scale spatial distribution of *C. durissus* in French Guiana, based on the results of a study conducted from 2020 to 2021 using observations made by people living in communities along the coastline. During the last decades, inclusion of the public in research has been very relevant and helpful in many ways, for example: monitoring sea turtles in Mozambique (Williams et al., 2015), producing an inventory of the herpetofauna of Oaxaca in Mexico (Simón-Salvador et al., 2021), establishing trophic interactions (Maritz and Maritz, 2021) or even following the colonisation of an invasive gecko (Auguste and Fifi, 2020), among others. We also include some novel information about reproductive biology in that area.



Figure 1. *Crotalus d. durissus* from Bois-Diable – Forêt, Kourou, French Guiana (May 2021). Photo by Vincent Prémel.

Materials and Methods

Obtaining data from a species with low frequency of occurrence, such as *Crotalus durissus*, was the most challenging part of this study. For this note we compiled as much observations as possible, using both grey and scientific literature but also databases as iNaturalist, HerpMapper or VerNet. Most of these sources do not contain relevant observation for our study area. We thus focused our research on two main sources, the geolocated observations reported in the French database “Faune-Guyane”, and we conduct an investigation among all the native community on the coastal fringe of French Guiana. Finally, we also used data available from both citizen science and social media to obtain observations

from throughout French Guiana (see details of sources in Results).

We used this source of information to obtain a better knowledge of the distribution of *C. durissus* in French Guiana through time and space. Observations of *C. durissus* were mainly based on opportunistic encounters, during our surveys in the savannahs, or by hunters or farmers, but also with people that we met in front of grocery stores (city agent, young people etc.). By word of mouth, a few people known to have seen the rattlesnake were contacted afterwards by telephone. The photos used for identification are conserved by one of us (VP) in a personal database, on Faune-Guyane and Facebook.

Despite its small size (83,846 km²), French Guiana is a territory of great richness and diversity. Thus, as mentioned above, we also decided to take this opportunity to lead investigation among native human communities (Saramaca, Bushinengue, Creole and Kal’ina). We focused our investigations on three axes, (1) direct or telephone interviews of the inhabitants, (2) posters in grocery stores in towns and villages, and finally (3) through communication on the social network to collect a maximum of data and reach as much people as possible. All those communities play an important role in the knowledge and the conservation of the biodiversity (through medicinal plants, folklore, tales and legends etc.). We conducted around 100 surveys from all over French Guiana. More than the social aspect, citizen science is also an effective alternative conservation tool to collect data and engage the public (Cooper et al., 2007; Dickinson et al., 2010, 2012; Newman et al., 2017), even more so with elusive species as the rattlesnake *C. durissus*. Its use is particularly efficient for rapidly collecting observations of ephemeral ecological interactions with low spatial and temporal predictability such as feeding ecology or reproduction events (Maritz and Maritz, 2021). Moreover, most of French Guiana’s herpetologists are living in two towns, Cayenne and Kourou, and their observations are centred on those cities. Faune-Guyane.fr is the biggest database of this French department with nearly one million wildlife data in January 2022. Of the 22 municipalities in the database, Kourou is the 1st (154,557 observations), Mana is 7th (61,996), Sinnamary is 11th (41,200), and Iracoubo is 18th (12,633). There is an obvious lack of data from areas extending more in the West from Kourou to Saint Laurent du Maroni (Fig. 2). Our investigation was in this way, even more relevant given the large source of new information we obtained by other means from such unexplored areas.

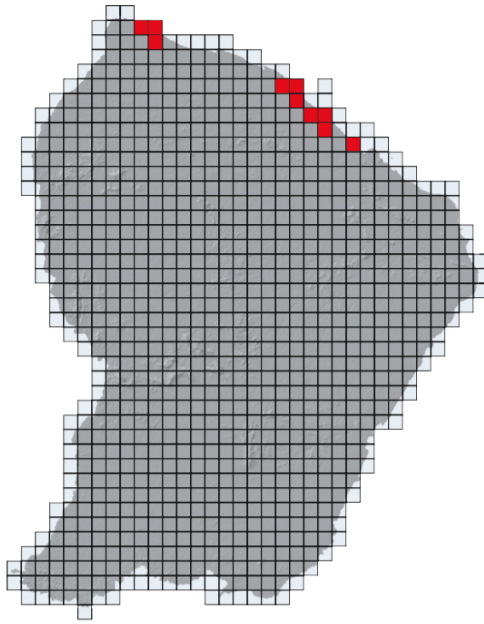


Figure 2. Geographical distribution of *C. durissus* in French Guiana before our study (source: Faune-Guyane.fr). Each square of 10x10 km (100 km²) correspond to at least one observation location.

In this kind of investigation, the most difficult task is to know the reliability of the information. Indeed, for untrained observers in French Guiana, *C. durissus* can easily be confused with other viperid snakes like *Bothrops atrox* (Linnaeus, 1758) or *Bothrops oligobalius* Dal Vechio, Prates, Grazziotin, Graboski & Rodrigues, 2021. During the interviews we conducted, only few persons were able to show us pertinent evidence of the presence of the Neotropical rattlesnake (photographs, rattle or specimen in alcohol) (Fig. 3). However other proof lead us to be almost certain (or not) about species' identification. Being the only species having a rattle, there is no confusion possible with any other snake once the presence of that organ was ascertained, even with non-venomous snakes shaking their tail as a defensive behaviour. Second, during our oral investigation, as a precaution, we systematically excluded people who told us of regularly seeing rattlesnakes, a fact which is highly improbable according to the scarcity of encounters. Without photographs or other proof, we considered such doubtful multiple reports as confusions with other species.

In order to obtain a maximum of new distribution data, we also searched on social media and platforms that

host photographs (Facebook, Flickr, Skyrock). Indeed, in the last decade, the growth of social media has opened a new way to gather opportunistic data (Durso et al., 2021). There is no doubt that the use of social media is a new way to easily obtain internet biological data (Marshall and Strine, 2019; Kalki and Weiss, 2020; Iankoshvili and Tarkhnishvili, 2021; Maritz and Maritz, 2021). Such data have to be verified and cannot be accepted without critical analysis. It is however relevant to highlight that without a gateway between the biologist community and social media, most of the data would be lost. In fact, during our study, most of the photos collected from the social media were found on Facebook and most if not all were destined to be lost or at best unused. Although many people assume that posting something on Facebook or Instagram creates a permanent record, this is not true. We encourage people to post georeferenced and timestamped photos of plants and animals on iNaturalist, HerpMapper, Faune-Guyane, or other such curated platforms.



Figure 3. A detached rattle as can be sometimes found in the field can be considered as a serious proof of the presence of *Crotalus d. durissus*. Bois-Diable – Forêt, Kourou, French Guiana (May 2021). Photo by Thibaut Ferrieux.

Results

Summary of observations. In this study, considering 1978 to October 2021, we gathered a total of 100 museum deposited specimens, direct observations or presence indices (rattle) of the Neotropical rattlesnake compiled of 90 verified records. We classified these observations into 7 sources and for each we indicate the percentage of data: (1) our own investigations (42%), (2) Faune-Guyane (41%), (3) observations by colleagues (8%), (4) social network (6%), (5) Gasc and Rodriguez (1980) publication (1%), (6) data from national collections [MNHN, Muséum national d'Histoire naturelle, Paris] (1%) and (7) data from ZNIEFF [Zone naturelle d'intérêt écologique, faunistique et floristique] (1%). Until now, 45 of all reports (50% of all records) were previously documented in databases, thus half of the data in this study (mainly provided by our own investigation) are new and unpublished (Fig. 4). Investigation among native communities provides us useful additional information about the distribution of this species and

clearly allowed us to fill the data gap mentioned above.

Distribution. Our results showed that *C. durissus* also occurs in forest, savanna mosaics and sandy coastal habitats in French Guiana. Before our investigations, the total extent of occurrence in French Guiana was estimated to be less than 5,000 km². It extends over 5 main areas located between the cities of Montsinéry and Sinnamary, and several sandy coastal habitats of Mana in the western part of French Guiana (MNHN, UICN France and Biotope, 2018). Our new dataset strongly expands the known distribution of *C. durissus* in French Guiana from Mana and Saint Laurent du Maroni to Montsinéry (Fig. 4).

Period of activity. Before our data compilation, most of the observations were made at the end of the afternoon around sunset (between 17.00 to 19.00 h). This time slot can be easily explained not by a biological trait inherent to the species but as an artifact due to a prospecting bias related to observers. Indeed, before May 2021, all the observations of *C. durissus* were fortuitous and not

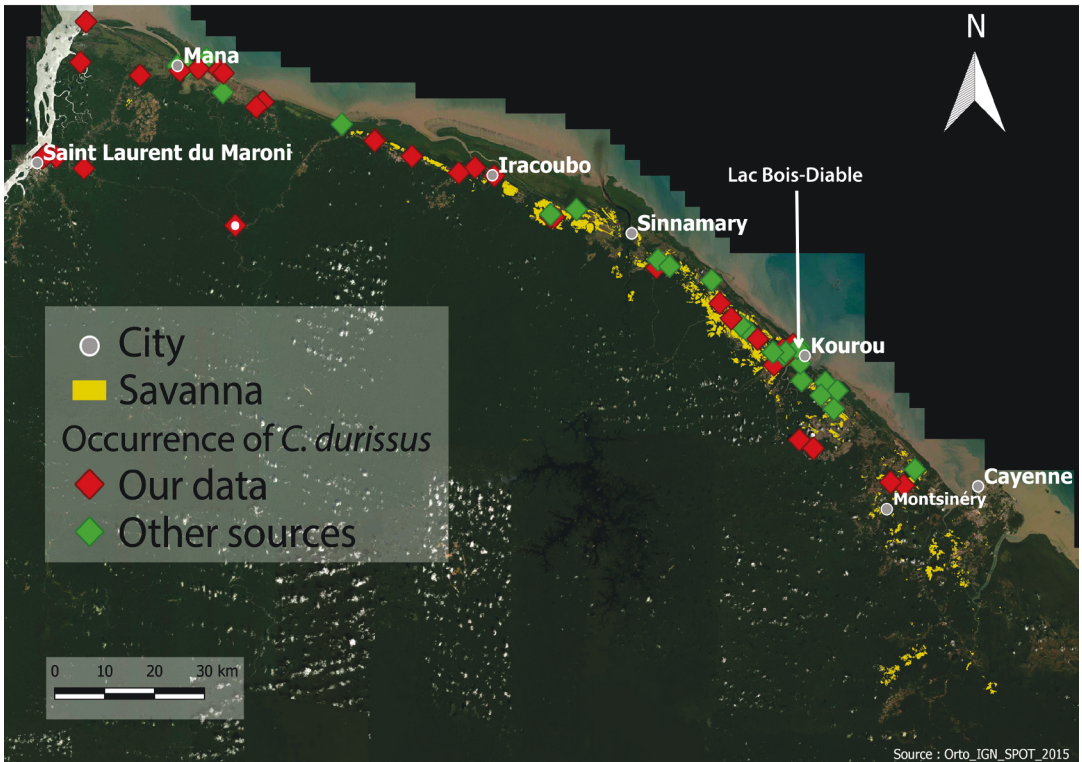


Figure 4. Geographical distribution of *Crotalus d. durissus* in French Guiana according to all data including our new unpublished observations. The forest locality of Mana NI discussed in the first lines of our conclusion is materialised here by a red diamond with a white dot in its centre.

obtained by active search for the species. People told us they were made after work, during leisure activities. However, since May 2021 (when *C. durissus* was found during active searching) observations indicated that this species can be found at any time of the day, with an observation peak during sunny days. Surveys were carried out during cloudy and rainy days without results (Vincent Prémel, pers. obs.). Our active searching observations also provide interesting data on activity period and movement. During May 2021, which is clearly the peak annual activity month, observations of distinct individuals were made at very close time intervals in the same area (Fig. 5). After photographic identification of all the observed specimens, we noticed that they belong to distinct individuals: 8 May, 2 specimens; 26, 28 and 29 May, different individuals (all distinct from those of 8 May).

Reproduction. The reproductive cycle of *C. durissus* in Brazil has been well documented (e.g., Almeida Santos and Salomão, 2002; Barros et al., 2012; Almeida Santos et al., 2021). In southeastern Brazil, spermatogenic activity begins in spring (September to November) when sperm is stored by the male until mating occurs in autumn (March to May). Spermatogenesis and fertilisation are dissociated in time (Almeida Santos and Salomão, 2002; Almeida Santos et al., 2004). However,

spermatogenesis is also known to proceed at any time from April to February depending on weather conditions (Belluomini et al., 1966; Saint Girons, 1982). In French Guiana, we documented one direct observation of mating made in Organabo (Irakumpapi) in May 2006 (A. Auguste, pers. obs.). In May 2021, two individuals were seen a few meters from each other but no mating was observed (T. Ferrieux, pers. obs.). In other parts of Brazil, the activity peak of *C. durissus* occurs between April and May (Almeida-Santos and Salomão, 1997) with a mating period occurring between April and June (Almeida Santos and Salomão, 2002). In French Guiana, all our observations supported these months as activity peaks which are likely related to mate-seeking.

Habitat occupied. It is relevant to give an indication of the species' distribution in each habitat. Considering the literature and all our available observations from French Guiana, savannah is by far the predominant habitat for the species (52% of all observations).

The IUCN red list (MNHN, UICN France and Biotope, 2018) provides a first indication on the type of habitats occupied by rattlesnakes in French Guiana. According to our most recent investigations, this species occurs in forest/savannah mosaics and sandy coastal habitat. Its distribution is much more continuous than previously thought, mostly along the narrow coastal fringe.

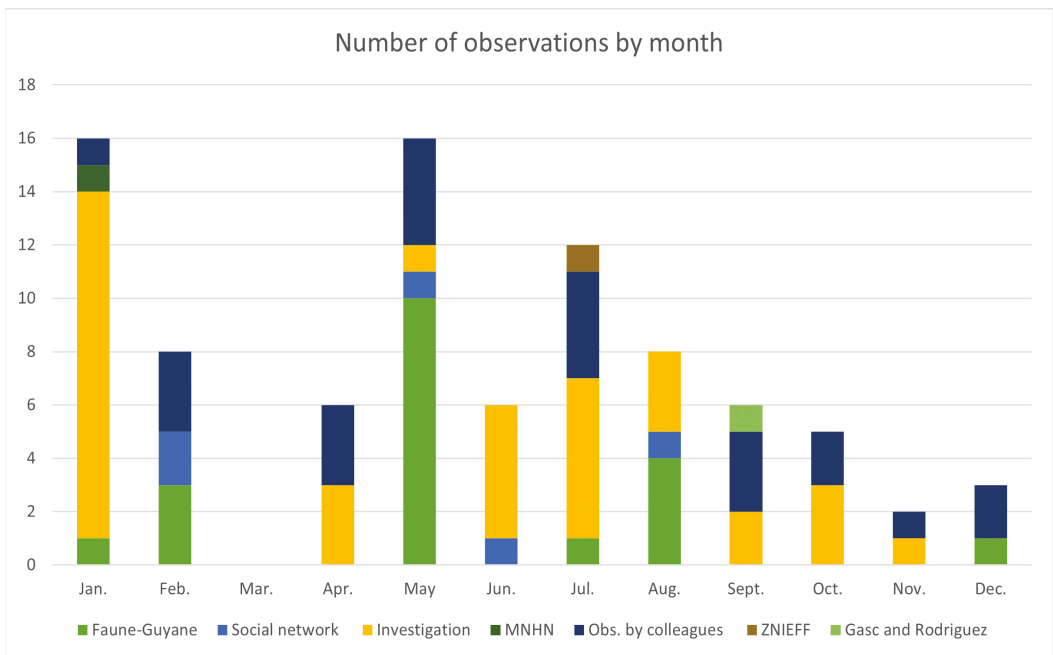


Figure 5. Monthly observation frequency of *Crotalus d. durissus* in French Guiana according to our seven data sources.

In French Guiana, forests seem also to be occupied by the Neotropical rattlesnake which must be given special attention. Forest habitat was already known to be occupied by the species in Brazil (Marques et al., 2001; Bastos et al., 2005; Benício, 2018). This can be explained first because forest is a habitat where many small mammals (*Marmosops* sp.) and lizards (*Ameiva ameiva*, *Kentropyx* sp. etc.) occur, which constitute most frequent prey items for *C. durissus*. Savannas in French Guiana are mainly composed of an herbaceous layer, without shrubs. Savannas are (or used to be) burned each year to maintain the herbaceous layer, thus forest could play the role of a temporary refuge habitat during and shortly after burning for those primarily open habitat snakes. Forest can also be considered as a refuge to protect snakes from visual predators, but also from intense heat during the dry season when vegetal cover is reduced through burning.

We provide an aerial photograph from the locality “Bois-Diable – Forêt” where seven individuals were found (Fig. 6). This small area covers around 5500 m² at the border of Kourou city (750 m from the first habitations and 3 km from the city centre) and is mostly used by birders. As show in Figure 6, this open area is very narrow, surrounded by a forest and a lake on the south. At a larger scale, this area is surrounded in the south by the city of Kourou, in the west by wetland, in the east by the sea coast and, in the north by savannas. At present we can provide no hypothesis to explain the number of observations made in such a small area. However, the proximity of the dwelling and the recurring

presence of birders is a factor that significantly increases the possibility of encounters.

Discussion

It is not easy to draw conclusions from our new dataset obtained mostly from fortuitous observations but when such data are numerous as in our case, they can at least allow comparisons with other better studied countries, for example, Brazil. Such a comparison can allow the establishment of trends and formulation of some hypothesis that can be later tested in the field. As for many other snakes, our data suggest an increase of movements during reproduction (active mate-searching) and also a weather-dependent activity peak relating to basking opportunity. Despite concentrating their terrestrial activity on the soil surface, rattlesnakes avoid open exposed microhabitats, being most frequently observed under shrubs and low bushy vegetation (Fig. 7). These vegetation formations probably offer simultaneously hunting opportunities at night, thermoregulation during the day, and a constant protection against predation (Tozetti and Martins, 2008).

Loss of habitat and IUCN status. Recent studies have shown that in French Guiana savannas (and low-vegetated habitats) have lost 1626 hectares (or 5.6% of their area) since 2001. The strong human pressure (agriculture combined with growing urbanisation, mostly located in coastal areas which are those occupied by savannas) is the main threat for these habitats (Debarros, 2010). Colonisation of the savannah by invasive plant species such as *Acacia mangium*, which most likely occurred as early as the 1980’s, is another threat that should not be underestimated. Indeed, the rapid colonisation of such invasive species leads to rapid conversion of savannah habitat into forest that is detrimental to the rattlesnake’s biology. Lastly, two direct threats are also identified for *C. durissus*. First are roads, known to be responsible for high snake mortality (Fig. 8); our data does not show particularly high mortality mainly because the species is rare throughout the territory. Nevertheless, savannah fragmentation by roads will have a real negative impact for this species in the near future. The second threat is direct destruction by man related to fear of snakes (MNHN, UICN France and Biotope, 2018; de Resende Assis et al., 2020). Finally, as mentioned above, 52% of the snake observations have been made in savannas, even if it is indisputably its preferred habitat this means that the other half of the observations were made in non-savannas habitats. The ecotone from beach to savannas is totally unexplored



Figure 6. Habitat of *Crotalus d. durissus* in low forest vegetation at Bois-Diable – Forêt, Kourou (May 2021). Photo by Thibaut Ferrieux.



Figure 7. Aerial view of the Locality “Lac Bois-Diable – Forêt”, surrounded by forest and a lake, where several specimens have been observed. Photo by Vincent Prémel.

in French Guiana mainly because of inaccessibility but also because mangroves and swampy ecosystems are difficult to prospect. Moreover, because of the sediments carried by the Amazon river, coastal dynamics are very important, resulting in a strong erosion or accretion phenomena leading to a total disappearance of some beaches or, on the contrary, the rapid development of large areas of coastal mangroves. Under these conditions, we considered the fundamental niche of the species to be much wider than previously thought. This hypothesis is supported by the western French Guiana population of *C. durissus* in Mana, where it occurs in a wetland (former rice field) rather than in savannah, so local adaptation to alternative habitats seems to be a solid hypothesis. However further studies must be undertaken to better define the wider ecological niche of the species and to verify if this is unique to French Guiana.

In accordance with our dataset and the IUCN criteria (EN B(1+2)ab(iii)), the French Guiana rattlesnake population was classified as “Endangered” (http://www.guyane.developpement-durable.gouv.fr/IMG/pdf/fascicule_liste-rouge-faune-verteebree-de-guyane.pdf), although the species is classified as of “Least Concern” on the World Red List. Population trends in French Guiana are unknown (MNHN, UICN France and Biotope,

2018), but strong urbanisation, demographic explosion and high human pressure, causes savannahs to be the species’ habitat most threatened with degradation. In that context we highly recommend all observers to be careful and to note all further observations and encounters with *Crotalus durissus* in French Guiana before submission to Faune-Guyane, iNaturalist or other such data sources (i.e. not Facebook). This will allow the development of a better understanding of its population trends and range modifications through time.

Conclusion. Our investigations provide an updated overview and better understanding of the spatial distribution of *C. durissus* along the French Guiana coastline to which the species is restricted. One of four data points is geographically clearly out of the coastal fringe, at Mana N1, pk 212, Saut Sabbat bridge, 5.38333°N, -53.66667°W (Fig. 4). It could be considered as dubious but we decided to keep it in our database first because its scarcity allowed us to consider it as background noise regarding the whole data set. Secondly, because the habitat where that extra-limital observation took place, a dominant sandy forest soil, seems to be as suitable as coastal forest where the species often occurs. *C. durissus* is known to have a discontinuous distribution throughout South America and occurrence of widely separated populations was generally accepted for



Figure 8. In French Guiana like in other parts of its distribution area, large individual of *Crotalus d. durissus* are sometimes found dead on road (La Malmanoury, Sinnamary; July 2017). Photo by Thomas Deradj.

French Guiana (Fig. 2). Until now two populations in French Guiana were regarded as widely geographically separated: the western population of Mana separated by approximately 100 km from the eastern populations of Sinnamary and Kourou (Fig. 2). However, as can be observed from our survey of native communities and from our own prospections, a significant distribution extension for the species clearly appears (Fig. 4). Our distribution for the species comprised numerous new localities and thus extends the coastal extension of the species, filling numerous gaps between populations. Contrary to previous accounts, our data showed that the distribution of the species is globally continuous from Mana and Saint Laurent du Maroni to Montsinéry (Fig. 4).

The increasing observation effort during the last decade allowed us to better understand the distribution and ecology of this little-known venomous snake species. Data on this species is still lacking and further studies should be conducted to continue and complete the present work. Indeed, our data summarises all the information and observations available to us on the distribution of *C. durissus* in French Guiana. However, it is important to note that all these observations are non-standardised data. They came from individual observation made possible mostly through survey of local communities and observations deposited on open databases such as Faune-Guyane.fr, as well as from other sources such as social networks, which are becoming a rich and growing source of information. No protocol was established to render the data more robust but their utility is evident. Our study showed that much data provided on social media are lost (unreported observations orally collected), go non-documented (observation without pictures or voucher collection) or are under-utilised (observations posted e.g. on Facebook but not used by scientists). They also highlight the importance of citizen contributions for a better understanding of species distribution, behaviour and biology, particularly for species with low detectability such as *C. durissus*. In the near future, in the frame of an official conservation scheme and with a view to obtain uniform and standardised exploitable data, a protocol or long-term continuation of observations has to be established. This will allow effective conservation of the threatened *C. durissus*. Only with such actions will the persistence of the species be assured for future generations in French Guiana.

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