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Unpublished population data of *Dendrobates azureus* Hoogmoed 1969 obtained in 1968 and 1970, and its historical and current taxonomic status

Marinus S. Hoogmoed

Museu Paraense Emílio Goeldi, Caixa Postal 399, 66017–970 Belém, Pará, BRAZIL

***Abstract.*—During a herpetological inventory in the Sipaliwini area in southern Suriname in 1968, and again during a second expedition to the area in 1970, anecdotal population data on *Dendrobates azureus* Hoogmoed, 1969 were obtained. As of now, some 50 years later, these data have not been published, yet they may be useful for the evaluation of the status of this taxon at the present time and the evolution of its populations over the period since 1968. Visits to the Sipaliwini savanna to observe or collect this taxon over the past 50 years have been few and far between. An overview of the population data available in the publications about these visits is provided.**

Keywords. *Dendrobates tinctorius*, isolated populations, Sipaliwini savanna, Suriname, conservation, threats.

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Introduction

During a herpetological inventory of the Sipaliwini area in 1968 Hoogmoed (1969a,b, 1971a,b, 1972) discovered a blue Dendrobatid frog in forest islands in the Sipaliwini savanna, near the Vier Gebroeders Mountain close to the Suriname-Brazilian border, that he named *Dendrobates azureus*. In the description (Hoogmoed 1969b), a number of ecological and behavioral data were provided, but data that give an impression about the abundance of the population were not presented, because they were not collected in a systematic way, but rather anecdotally. The author paid a second visit to the Sipaliwini area and the habitat of *D. azureus* in 1970 (Hoogmoed 1971a,b, 1972) and more data were obtained on the abundance of the frog in the type locality (forest island on West slope Vier Gebroeders Mountain) and some other forest islands nearby, and about forest island occupation by this taxon. These population data are available in the author's field books (archived in the former Rijksmuseum van Natuurlijke Historie, now Naturalis Biodiversity Center in Leiden [RMNH], in the Netherlands) and in his private diary notes, and they can provide basic data about the population status of the taxon at the time of its discovery. This taxon is considered vulnerable [VU: D2] (Stuart et al. 2006), and as a member of the genus *Dendrobates* it is on CITES Appendix II, so in Suriname it officially cannot be traded (Hoogmoed 2013). However, since it still has been subject to illegal capture and export of specimens, it seems timely to publish the basic population data of this taxon, even though they were collected anecdotally.

Polder (1974), based on his observations of the taxon in captivity, expressed some doubt on the specific status of *D. azureus*, but this had no direct consequences as Silverstone (1975) considered it a species. Wollenberg et al. (2006), followed by Wollenberg (2007), on the basis of morphological data and genetic analysis, synonymized *D. azureus* with *D. tinctorius* (Cuvier, 1797). This assessment was supported by Noonan and Gaucher (2006), who found that specimens of *D. azureus* (from the type locality or near to it, see below, Noonan, pers. comm.) shared the same haplotype with two "nearby" (from the continuous rainforest, see below, Noonan, pers. comm.) populations of *D. tinctorius* and concluded that this signified the two taxa were identical. Grant et al. (2006) still treated *D. azureus* as a species but on the basis of molecular results were inclined to follow the synonymy suggested by Wollenberg et al. (2006). Gaucher and McCulloch (2010) and Frost (2018) accepted the synonymization and considered *D. azureus* a synonym of *D. tinctorius*. Ouboter and Jairam (2012) considered *D. azureus* a subspecies of *D. tinctorius*, without providing arguments, but this was not accepted by Frost (2018), who treated *D. tinctorius* as monotypic.

However, Avila-Pires et al. (2010) and Hoogmoed (2013) did not accept the synonymization by Wollenberg et al. (2006) and pointed out that this publication suffered several shortcomings. Here I add to those critiques the

Correspondence. *marinus@museu-goeldi.br*

use of tissue samples of captive bred material of dubious origin (although stated to be from the type locality) and the fact that among dendrobatid breeders *D. azureus* has been confused with, and interbred with, a blue morph of *D. tinctorius* that occurs in southern Guyana, northwestern Pará in Brazil (south to Porto Trombetas) and possibly in extreme southwestern Suriname (in a contested area between Suriname and Guyana). See Avila-Pires et al (2010: Fig. 23) and Lötters et al. (2007: Fig. 707) for color pictures of this blue *D. tinctorius* morph. Hoogmoed (1969, 2013: Fig. 4), Eisenberg (2004), and Lötters et al. (2007: Fig. 708 [as *D. tinctorius*]) provide pictures of *D. azureus*. Noonan and Gaucher (2006) mention specimens of *D. tinctorius* and *D. azureus* from slightly different localities (Table 1) and their samples of *D. azureus* are from the area of Vier Gebroeders Mountain (see Noonan, pers. comm., below as well). In Wollenberg et al. (2008) it seems that the blue morph of *D. tinctorius* has incorrectly been considered as *D. azureus* (see Fig. 4 Haplotype 2, the second figure from above and the lower figure; no *D. azureus* can be found in this figure). Unfortunately, only the fancy names of hobbyists have been used for the "Sipaliwini" material and no vouchers have been indicated.

In order to remove any doubt regarding which population I am discussing, and avoid upsetting the present accepted nomenclature, below I use the name *Dendrobates* "*azureus*" in the sense of the population of *D. tinctorius* described in 1969 as *D. azureus* and only known from isolated forest islands in the Sipaliwini savanna in southern Suriname.

History of (the herpetological) exploration of the Sipaliwini Savanna and inventories of *D. "azureus"* populations

1935–1938: Border expedition (van Lynden 1939) to establish the border between Suriname and Brazil (= watershed). Although Van Lynden stayed on the Sipaliwini savanna for an extended period (4 October 1935 to 10 March 1936), and made general observations about animals (mostly mammals and birds), he did not mention "blue frogs," so we may conclude he did not observe them, or that he did not deem them worthy of mentioning. His camp III (on the western base of Vier Gebroeders Mountain, from where he wrote his diary on 12 October 1935) actually was close to the later type locality of *D.* "*azureus*," but it was probably in the savanna itself, not in the forest island. The map published by van Lynden (1939) unfortunately does not show the location of the forest islands.

1961: During Operation Grasshopper, the Sipaliwini airstrip was constructed on a small savanna about 3.5 km west of the western border of the Sipaliwini savanna. Apparently, the forest islands in the savanna were not visited.

1968: Hoogmoed (1969a,b) discovered populations of *D.* "*azureus*" in four forest islands in the middle of the Sipaliwini savanna near the Vier Gebroeders Mountain

Fig. 1. *Dendrobates* "*azureus*" (= *tinctorius*).

when making a herpetological inventory of the area in 1968 (22 August to 7 October), concentrating on the area between Sipaliwini airstrip and Vier Gebroeders Mountain. He collected a total of 37 specimens and two tadpoles of *D.* "*azureus*" (Table 1), which were all preserved and form the type material of the description of *D. azureus* Hoogmoed, 1969. The location and shape of the forest islands as shown in Hoogmoed (1969b: Fig. 3) were taken from a topographical map (Centraal Bureau Luchtkartering, Paramaribo, Suriname) of the area based on aerial photographs.

1968–1969: After Hoogmoed's departure from the area, the Sipaliwini expedition (Hoogmoed 1969a) continued working in the Sipaliwini savanna and the participants (botanists and a geologist) moved N of the Vier Gebroeders area to the Morro Grande Mountain area. Hoogmoed (1969b: Fig. 3) marked four northern forest islands as possible localities for *D.* "*azureus*" because the botanist J.P. Schulz reported having seen "blue frogs" there. Considering later observations (see Gagliardo 2004 a,b; Fouquet et al. 2015), these might well have been *D. tinctorius* with a yellow semicircular mark on the snout.

1970: Between 13 January and 13 February Hoogmoed again visited the Sipaliwini savanna, this time concentrating on the part south of the Vier Gebroeders Mountain and the Brazilian border. During this trip one specimen of *D.* "*azureus*" was collected and preserved, and 10 additional specimens were collected at the type locality and transported alive to the Netherlands, where they were bred in captivity by Polder (1973a–c, 1974).

1981: According to Wevers (2007), a "group of Dutchmen" brought live *D.* "*azureus*" from the Sipaliwini savanna (most likely an illegal operation), making no mention of the names of participants, numbers of frogs brought back, or from which forest island(s).

1988: An illegal import of *D.* "*azureus*" (apparently three specimens) was confiscated in the Netherlands and transferred to Blijdorp Zoo, Rotterdam (Wevers 2007).

1996: Cover (1996, 1997) reported on an expedition in June 1996 (sponsored by the National Aquarium in Baltimore, USA) to attempt a population survey of *D.*

Table 1. Detailed data for specimens of *D.* "*azureus*" collected/observed by M.S. Hoogmoed in 1968 and 1970. Number of specimens accounts for both collected and observed specimens, numbers between brackets in the first column refer to the numbers of forest islands as used in the text. The asterisk (*) indicates that 10 specimens were observed in about 10 minutes.

Forest island (see text)	Date	Number of specimens	Time spent in field	Person-minutes spent in field	Number person-minutes per specimen
1968					
1	10 Sep	1 (RMNH 13838)	18:15 h	-	-
1	11 Sep	11 (RMNH 13837)	10:30–12:30 h	120	10.9
1	13 Sep	15	15:00–15:30 h	30	2
1	30 Sep	1 (+ 2 tadpoles) (RMNH 13842)	10:15 h	-	-
1	1 Oct	10 (RMNH 13843)	11:00–11:30 h	30	3
1	**Mean or total**	**38**		**180**	**4.7**
2	19 Sep	5 (RMNH 13839)	10:00–11:30 h	90	18
3	20 Sep	0	-	120	-
3	23 Sep	10 (6 coll, RMNH 13840)	10:00–11:00 h	60	10*
3	**Mean or total**	**10**		**180**	**18**
4	27 Sep	3 (RMNH 13841)	10:30–12:00 h	90	30
1970					
1	6 Feb	1 (RMNH 42487)	13:15 h	-	-
1	7 Feb	25	08:00–12:00 h (2 persons)	480	19.2
Total 1968 + 1970					
		82 (38 preserved, 10 live for ex situ breeding colony)	**11 days**	**920**	**10.1**

"*azureus*." Three staff members of the NAIB and three field workers of Conservation International Suriname participated. Fifty-four adults and two juveniles were observed during a limited number of days. They surveyed six forest islands and found specimens in three of them "two on the slopes of Vier Gebroeders and one in a valley floor forest just north of the mountains" (Cover 1997; Eiben 2005). Most likely Cover referred to forest island nos. 1 and 4 on the slopes of Vier Gebroeders Mountain and to forest island no. 2 north of that mountain (see below). No material was collected, and the position of the other three forest islands was not mentioned.

1997: Gagliardo (2004a,b) reported on a new expedition (14 August–19 September 1997) by Cover and three other zoo curators in order to collect specimens to establish a breeding population in the USA. "Nearly 60 specimens" and an unknown number of tadpoles were observed in two forest islands that were not the type locality. Furthermore, three pairs of *D. tinctorius* (with a yellow semi-circular mark on the snout) were collected (and finally exported) in a forest island northeast of the Sipaliwini airstrip. One day before departure from the savanna permission was obtained to collect and export 20 specimens of *D.* "*azureus*," so they had to be collected at a rush and were meant to establish an ex-situ breeding population (Eiben 2005). No mention was made of which forest island(s) these specimens were collected from or how much time it took to collect them.

2003: B.P. Noonan (pers. comm.; Eiben 2005) visited the area of the Vier Gebroeders Mountain from 23–26 May 2003. He flew in using Mamija airstrip (= "Myers' airstrip" in Hoogmoed (1969) and in the present text, Wapaisana Anotato on Google Earth) on the border of Suriname and Brazil, SE of the Vier Gebroeders Mountain, and he left via Sipaliwini airstrip, W of the savanna. He was not allowed to collect specimens of *D.* "*azureus*," but was allowed to make toe clips from 10 specimens for molecular studies (Noonan and Gaucher 2006). He found three specimens on 24 May, four specimens on 25 May, and another three on 26 May. No

data on time spent finding specimens are available, but Noonan writes: "….my experience was that neither of these populations was terribly dense. While I did not keep detailed notes on abundance, I am comfortable saying that I did not observe more than one individual per hour of searching (on average)." Noonan also collected tissue from three *Dendrobates* specimens found in the continuous rainforest NE of the airstrip Sipaliwini, about 100 m from the savanna edge, that were identified as *D. tinctorius* (Noonan and Gaucher 2006).

2007: According to Wevers (2007) several frog fanciers visited the Sipaliwini savanna and "observed respectively 9, 15 [probably Wevers himself] and 20 specimens (mostly the same specimens)." Wevers (2007) visited the Sipaliwini savanna for five days in February and during those days observed 15 specimens and four larvae. He at least visited the type locality on the western slope of the Vier Gebroeders Mountain and the forest island on the northeastern slope from where he reported juvenile specimens. He reported that his guide who lived on Mamija airstrip (= "Myers' airstrip") on the frontier of Suriname and Brazil, never had seen more than 25 *D.* "*azureus*" in one day. Based on his own observations (five days and a limited number of forest islands visited) and information from his Indian guides, he estimated the size of the total wild population to be between 1,000 and 1,500 specimens, but this does not seem to be a very reliable figure.

2014: Fouquet et al. (2015) visited the Sipaliwini area between 15 and 28 April, but did not visit the forest islands where *D.* "*azureus*" occurs. They reported *D. tinctorius* (with a yellow semi-circular mark on the snout) from a mountain 10 km N of Sipaliwini airstrip in the area of continuous rainforest.

By no means is this overview intended to be an exhaustive listing of all visits to the *D.* "*azureus*" habitat or nearby areas. It is known that Suriname scientists with a license to study the frogs and personnel of the Forestry Service flew into Sipaliwini airstrip, but were not allowed to travel from there to the Vier Gebroeders Mountain and they were confined to the airstrip. Some scientist may have paid unregistered (and unpublished) visits to the area. Illegal collectors (animal dealers) and terrarium keepers apparently have visited the area at least several times, but because of the nature of these trips, they have not been documented publicly. It also is possible that native and Brazilian Indian collectors have provided animal dealers with specimens that may have left Suriname directly or via Brazil. No numerical data are available, but Suriname animal dealers exporting reptiles and amphibians to the USA and Europe have long-standing commercial contacts (since the early 1970's) with the Indians of the villages of Alalapadu and Kwamalasemutu.

Material and Methods

During the 1968 herpetological inventory of the Sipaliwini savanna in southern Suriname (Hoogmoed 1969a,b), five forest islands near the Vier Gebroeders Mountain were searched. In 1970, Hoogmoed surveyed five forest islands in the southern part of the savanna. During the fieldwork in the area around Vier Gebroeders Mountain no formal population surveys were made, but notes were kept about how many specimens were observed/collected during the time spent along transects in the forest islands. Frogs were observed/collected while traversing forest islands following creek beds, either downhill or ascending the creek, generally searching an area of five m at each side of the stream. The time period during which frogs were collected was noted, and based on this the abundance was expressed in specimens per person-minutes. In 1968 observations/collections were made by one person, and in 1970 by two people. All specimens were either simply observed, or collected by hand. Specimens collected were killed with MS222, fixed and preserved in 70% ethanol (thus, no formaldehyde was used and the type specimens could still be used for DNA analysis). Live specimens were transported in plastic bags with leaf litter, and termites were provided as food.

Data on specimens collected in 1968 were provided by Hoogmoed (1969b) in general terms. The coordinates of forest islands where *D.* "*azureus*" was found were calculated in 1968 on the basis of a topographic map of the area, but they now can be provided more precisely, based on localization with Google maps. Only slight differences can be noticed.

In 1968, the area of the Sipaliwini savanna where *D.* "*azureus*" was obtained was visited between 11 September and 1 October, a total of 21 days. During this period, several forest islands on and near the Vier Gebroeders Mountain (as well as the intervening savanna area) were searched for herpetofauna. Coordinates for the center of the forest islands are given as in Hoogmoed (1969b) and corrected according to Google Earth 2018, datum W84. Forest islands inhabited by *D.* "*azureus*" are indicated with asterisks (*).

1. *Forest island W flank Vier Gebroeders Mountain (Base Bivouac), type locality of *D. azureus*, 2°N, 55°58'W (corrected to 2°00'21.24"N, 55°58'10.85"W)
2. *Forest island (J-shaped [the eastern narrow extension is not rainforest but gallery forest of *Mauritia* palms]) 1.5 km NE of Vier Gebroeders Mountain, 2°01'N, 55°57.30"W (corrected to 2°00'59.30"N, 55°57'26.03"W)
3. *Forest-island 2 km (note this distance differs from that in the description of *D. azureus*) N of Vier Gebroeders Mountain, long and narrow, directed W–E, 2°01'N, 55°58'W (corrected to 2°01'25.78"N, 55°57'34.22"W)
4. *Forest island on NE slope Vier Gebroeders Mountain, 2ºN, 55°57'30"W (corrected to: 2°00'24.92"N, 55°57'22.03"W)
5. Forest island (small) on N slope Vier Gebroeders Mountain (Google Earth 2°00'52.49"N, 55°58'04.71"W)

In 1970, the Sipaliwini savanna was visited again (13 January–13 February), this time mostly in a part further south from the area visited in 1968, with a stay of only

two days in forest island no. 1 (see above). During this period the following forest islands, that turned out not to be inhabited by *D.* "*azureus*," were searched (coordinates based on Google Earth 2018):

6. Small forest island on northernmost part of Lange Dijk, 2°00'09.36"N, 55°55'58.78"W, Suriname, 27 January 1970
7. Small forest island on ridge of Lange Dijk, 1°59'28.01"N, 55°55'15.81"W, Brazil, 27 January 1970
8. Elongate forest island on SW slope Lange Dijk, 1°59'18.74"N, 55°55'20.73"W, Brazil, 27 January 1970
9. Westernmost small forest island of two, E of Myers' farm, about 8 km WSW of Vier Gebroeders Mountain W flank, 1°59'09.10"N, 56°02'35.11"W, Suriname, 4 February 1970
10. Easternmost (630 m E of and twice as large as no. 9) forest island, E. of Myers' farm, about 8 km WSW of Vier Gebroeders Mountain W flank, 1°59'11.78"N, 56°02'13.63"W, Suriname, 4 February 1970.

Results

Forest Islands

The shapes and sizes of eight forest islands in 1968 were based on a topographical map and aerial photographs that formed the basis for Figure 3 in Hoogmoed (1969b). These were all compared with Google Earth images of 31 December 1969 and 17 November 2004 (the most recent freely available large-scale images on the Internet), and all the forest islands still exist and no notable changes in shape or size were observed. Cover (1997) noted that concern had been expressed that the anthropogenic fires which ravage the savanna yearly might damage the forest islands. In 1970, Hoogmoed observed that savanna fire had destroyed the narrow band of forest between the 1968 Vier Gebroeders Bivouac (type locality) and the savanna on the SW edge of the campground, but also that the forest island interior, probably because it is rather moist, had not suffered any damage. *D.* "*azureus*" was still regularly present in the former, open camp ground. Gagliardi (2004a,b) stated that the fires did enter the forest islands, but he did not mention the extent of damage. Wevers (2007) wrote that fire had gnawed at the edges of the forest islands and expressed fear that in an El Niño year fire might reach the interior of the forest islands and thus threaten their integrity. Cover (1997), however, reported that the fires apparently did not damage the forest islands, but thought that they might be the reason that the forest islands did not expand into the savanna. These last observations are confirmed by Hoogmoed's 1970 observations (Hoogmoed 1972) and by the Google Earth images of 2004. The *Map for Environment* (2018) shows that there has been only limited tree loss in the Sipaliwini savanna between 2000 and 2014, although tree loss near Sipaliwini airstrip has been significant. The forest islands themselves do not show any noticeable changes.

The most recent Google Earth images (2004) show that in the Brazilian part of the savanna (Paru savanna) south and east of the Sipaliwini savanna there are six large forest islands that would be worth investigating for the presence of *D.* "*azureus*." However, as this area is a Brazilian Indian Territory, conducting biological research there is very difficult, because of the need for special permits and its remoteness. Just south of the Paru savanna in Brazil is another, isolated, more or less oval savanna with a large, elongate forest island in the middle (160 km SSW of Sipaliwini airstrip). This forest island was inventoried by Avila-Pires et al. (2010: ESEC Grão Pará Centro) and they did not find any *Dendrobates* species there.

Population Data

11 September–1 October 1968. For this period of 21 days spent in Vier Gebroeders Bivouac, general herpetological collecting was conducted in the savanna and forest islands on and near Vier Gebroeders Mountain. Only some parts of the days were spent in forest islands searching for *D.* "*azureus*."

Apart from the four forest islands where specimens were observed and collected, one small forest island on the N slope of Vier Gebroeders Mountain was searched for *D.* "*azureus*," but no specimens were found. The four northernmost forest islands in Hoogmoed's (1969) map were not visited during this time. Data on time spent observing/collecting *D.* "*azureus*" and population density are summarized in Table 1.

Between 1968 and 1970. The population density of *D.* "*azureus*" in forest island no. 1 on the W slope of the Vier Gebroeders Mountain seems to have diminished considerably (remembering that 23 specimens and two tadpoles were removed in 1968, which might have had a negative influence on the population), *viz*. one specimen per 4.7 person-minutes in 1968 (one observer only), versus one specimen per 19.2 person-minutes in 1970 (two observers).

In 1970 an additional 11 specimens were removed from this same forest island, one for the RMNH collection, and ten live specimens to establish an ex-situ breeding colony in the Netherlands.

It should be mentioned that specimens were not evenly distributed throughout the forest islands. They might be absent in certain stretches and be numerous in other parts (generally near creeks and/or in areas with large boulders).

No comparative data for the other forest-islands are available for the period 1968–1970. Cover (1996, 1997) does not provide data in a comparable way, but he apparently collected data in three of the forest islands mentioned by Hoogmoed (1969), but unfortunately the locations of these have not been published. Noonan (pers. comm. 2017) reported that he did not see more than one specimen per hour. Already in 1968, the population den-

sity in the other forest islands seemed to be less (one specimen per 18–30 person-minutes) than in the largest forest island (no. 1) on the W slope of Vier Gebroeders Mountain (one specimen per 4.7 person-minutes). This could be related to the size of the forest islands, but this is just an impression that is not based on firm facts. Also, we have to take into account that more time was spent in forest island no 1, because it was the location of the camp (both in 1968 and 1970).

Collections in 1968 were made during the second part of September, during the dry season, and those in 1970 were made in early February, during the beginning of the wet season—when rainfall is about twice that in the dry season, and about half that of May and June, the wettest months (see Hoogmoed 1969).

Conclusions

At the time of the discovery of *D.* "*azureus*" in 1968 it was clear that not all forest islands inhabited by this taxon had populations of the same density. Since 1968, although several expeditions have visited the distribution area of *D.* "*azureus*" in the Sipaliwini savanna, no data on population densities have been published that could be directly compared with those presented here. However, the anecdotal data available (see the **History of … inventories of *D.* "*azureus*" populations** section above) give the strong impression that the numbers of *D.* "*azureus*" in its restricted habitat have considerably diminished since 1968. This impression should be confirmed by systematic population studies that might serve in situ and ex situ management programs for this unique population of brilliant blue poison frogs. At the moment we do not even have an idea about the size of the population in the wild, but it might run only into the hundreds. Eiben (2005) and Stuart et al. (2008) described the successful ex situ breeding program in the National Aquarium in Baltimore (Maryland, USA) based on 20 specimens collected in 1997 (see above) and some additional exchanged specimens. This program should be continued and fortified with the help of the Suriname authorities and several nature conservation interest groups, such as WWF, The Nature Conservancy, and Conservation International, that are already active in Suriname.

Although the habitat of this taxon is completely within a Suriname Nature Reserve, the area is easily accessible from Brazil and the border is not patrolled. Illegal visits by collectors cannot be ignored, and should be taken into account when making an in situ management plan. Stuart et al. (2008: 228) optimistically assumed that interest in wild collected specimens would diminish with successful breeding in captivity, but this is a naïve assumption (e.g., IUCN 2015).

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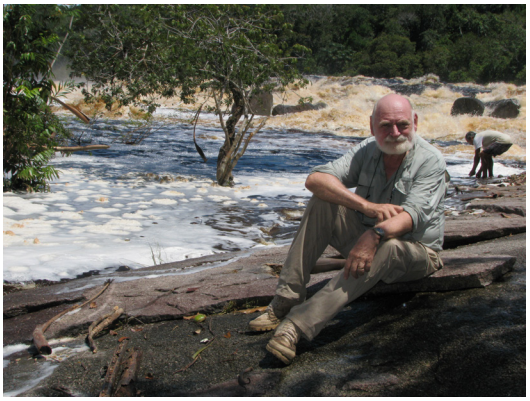

Marinus Steven Hoogmoed was curator of Herpetology at the Dutch National Museum of Natural History (RMNH) in Leiden from 1966 to 2004, and Head of its Department of Vertebrates from 1991 to 2001. Marinus obtained his doctorate degree in Mathematics and Natural Sciences at Leiden University, Netherlands, in 1973 based on a monograph of the lizards and amphisbaenians of Suriname. He worked mainly on systematics, taxonomy, and biogeography of Amazonian and Guianan herpetofauna; and he has done fieldwork in all Amazonian countries, except Guyana. Marinus spent a total of three years in the field in Suriname. After his retirement, Marinus continued his research in the Amazon area as a volunteer at the Museu Paraense Emilio Goeldi (MPEG) in Belém, Pará, Brazil, where he is still active. Between 1975 and 2004 he was involved in CITES as a representative of the Netherlands, and between 2000 and 2002 Marinus was chair of the Animals Committee of CITES.