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LARGE-SCALE BIOTIC SURVEY IN MITARAKA, FRENCH GUIANA

Edited by Julien TOUROULT

Dipterological survey in Mitaraka Massif (French Guiana) reveals megadiverse dolichopodid fauna with an unprecedented species richness in *Paraclius* Loew, 1864 (Diptera: Dolichopodidae)

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Couverture / *Cover* :
Coloured pan traps in river bed forest, a sampling method for Diptera employed at Mitaraka (French Guiana) (photo Marc Pollet). In medaillion, *Pelastoneurus* sp. lateral view (photo Florence Trus).

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Dipterological survey in Mitaraka Massif (French Guiana) reveals megadiverse dolichopodid fauna with an unprecedented species richness in *Paraclius* Loew, 1864 (Diptera: Dolichopodidae)

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ABSTRACT

During the "Our Planet Reviewed" French Guiana 2014-2015 expedition, Diptera were collected in seven habitat types over an approximately 1 km^2 area in the Mitaraka Mountains of southwestern French Guiana. Sixteen collecting methods were used, seven of which yielded multiple samples containing Dolichopodidae. The survey produced a total of 4918 specimens of Dolichopodidae, belonging to 244 morphospecies, 31 genera including four new ones, and 10 recognized subfamilies. This is the highest dolichopodid species richness thus far recorded from a single location anywhere in the world. Three taxa could be identified to species level and all represent first records for French

Guiana. *Paraclius* Loew, 1864, *Chrysotus* Meigen, 1824 and *Medetera* Fischer von Waldheim, 1819 were the most speciose genera. *Paraclius* represented by 50 species, exhibited an unprecedented species richness, mainly in the palm swamps. The three most productive methods in terms of numbers of specimens collected (68% of all specimens obtained using the three methods combined), SLAM traps, sweep nets, and a 6 m long Malaise trap, each yielded between 78 and 90 species, with approximately half of the species from each trap type unique to that method. Both blue, white or yellow pan traps, on the contrary, captured less than 20 species, and overall yellow traps were clearly the least efficient. Pan trap yields, however, were severely affected by repeated heavy rainfall. The highest species richness was recorded around the drop zone and in the base camp, on river banks and in river bank forests, with 40 to 60% of species unique to one of these habitat types. Forty-five species were collected on 'savanes roches', and 14 species on inselbergs, with four species shared by both types of rocky outcrops and uniquely found on them.

KEY WORDS
Dolichopodidae,
Diptera,
Mitaraka,
tropical lowland rainforest,
savane roche,
inselberg,
biodiversity,
pan traps.

RÉSUMÉ
L'inventaire diptérologique du massif du Mitaraka (Guyane) révèle une faune mégadiverse de dolichopodides, avec une richesse spécifique sans précédent du genre Paraclius *Loew, 1864 (Diptera: Dolichopodidae).*
Pendant l'expédition "La Planète revisitée" Guyane 2014-2015 les diptères ont été collectés dans sept biotopes du massif du Mitaraka, au sud-ouest de la Guyane. Seize méthodes de collecte ont été utilisées dont sept se sont montrées efficaces pour récolter des dolichopodides. L'inventaire faunistique a produit un total de 4918 dolichopodides répartis en 244 morpho-espèces, 31 genres – dont quatre nouveaux – et dix sous-familles connues. Il s'agit de la richesse spécifique la plus élevée en dolichopodides jamais enregistrée dans le monde pour une seule localité. Trois taxons ont été identifiés à l'espèce et signalés pour la première fois de Guyane. *Paraclius* Loew, 1864, *Chrysotus* Meigen, 1824 et *Medetera* Fischer von Waldheim, 1819 constituent les genres les plus diversifiés. *Paraclius*, avec 50 espèces, présente une richesse spécifique sans précédent, surtout dans les forêts de bas-fonds. Les trois méthodes les plus productives en termes de nombre de spécimens collectés (68% de tous les spécimens collectés l'ont été par ces trois méthodes), filets fauchoirs, pièges SLAM et un piège Malaise de 6 m, ont chacune capturé entre 78 et 90 espèces, dont environ la moitié spécifique à chacune d'elle. Au contraire, les assiettes bleues, blanches et jaunes ont capturé chacune moins de 20 espèces. En général, les assiettes jaunes se sont révélées les moins efficaces. Les rendements des assiettes ont été cependant sévèrement affectés par les pluies intenses et répétées. La plus haute richesse spécifique a été enregistrée autour de la « drop zone » et du camp de base, les berges des rivières et dans les forêts de bas-fonds, 40 à 60 % des espèces étant uniques à l'un de ces biotopes. Quarante-cinq espèces ont été capturées sur les savanes roches et 14 sur les inselbergs, dont quatre communes à ces deux types de zones rocheuses et trouvées uniquement sur celles-ci.

MOTS CLÉS
Dolichopodidae,
Diptera,
Mitaraka,
forêts tropicales de plaine,
savane roche,
inselberg,
biodiversité,
assiettes colorées.

INTRODUCTION

With over 7500 described species worldwide (Bickel 2009), globally long-legged flies (Diptera: Dolichopodidae) currently represent the fourth largest dipteran family, after Limoniidae Speiser, 1909, Tachinidae Bigot, 1853 and Asilidae Kirby & Spence, 1817 (Pape *et al.* 2009). The family consists of 17 subfamilies, including the basal Microphorinae Collin, 1960 and Parathalassiinae Chvála, 1986, and 15 other subfamilies, generally referred to as Dolichopodidae Latreille, 1809 *s. str.* (Pollet & Brooks 2008). Although long-legged flies occur in nearly every terrestrial and semi-aquatic habitat type, most species prefer humid to moist conditions. As a result, the highest species richness and numbers are found in rainforests, marshes and on banks of various waterbodies (Pollet 2000). As many species exhibit a pronounced habitat affinity, the family as such serves well as bio-indicator in e.g. site quality assessments, in particular of humid biotopes (Pollet & Grootaert 1999; Pollet 2009). Apart from the plant mining larvae of *Thrypticus* Gerstäcker, 1864 (Dyte 1959; Bickel & Hernandez 2004), in general both adults and larvae are predatory and feed on small invertebrates (Ulrich 2004).

Yang *et al.* (2006) listed nearly 1300 species for the Neotropical realm, which is – surprisingly – over 100 species fewer than reported from the Palaearctic region. It is obvious that this is only a fraction of the extant Neotropical fauna, which is confirmed by the permanent stream of new species described from this part of the world (Bickel 2006, 2007, 2015; Brooks & Cumming 2008, 2009; Brooks *et al.* 2010; Capellari 2013a, b, 2015a, b; Capellari & Amorim 2009, 2010, 2011, 2014; Naglis 2011; Runyon 2015; Grichanov 2017). And many more Neotropical species await to be discovered or described (e.g. Bickel 2009; Pollet 2010; Pollet & Arias 2014). At present, only four dolichopodid species are recorded from French Guiana: *Cheiromyia brevitarsis* Brooks *in* Brooks *et al.,* 2010, *C. palmaticornis* (Parent, 1930), *Condylostylus acceptus* Parent, 1933, and *C. pectinator* Parent, 1930.

During the Mitaraka 2015 large-scale biotic survey (Pollet *et al.* 2014; Pascal *et al.* 2015), an unprecedented number of dolichopodid species was detected, most of which are still undescribed. In the present paper, we present the overall results, and discuss the productivity and efficiency of seven collecting methods used during the general invertebrate survey, the distribution of the dolichopodid communities over the investigated sites and habitat types, and add first records of a number of genera and species for French Guiana.

Material and methods

General framework and sampling period

The material studied here was collected during the international biotic survey "Our Planet Reviewed" ("La Planète revisitée") French Guiana 2014-2015, also known as the "Mitaraka 2015 survey". This was the 5th edition of a large-scale biodiversity survey undertaken by the Muséum national d'Histoire naturelle (MNHN) and the NGO Pro-Natura international (both in France). Both organizations jointly run the "Our Planet Reviewed" program which aims to rehabilitate taxonomical work that focuses on the largely neglected components of global biodiversity, i.e., invertebrates (both marine and terrestrial). Basic arthropod taxonomy and species discovery were at the heart of the survey, although forest ecology and biodiversity distribution modelling were also part of the project. From 22 February till 11 March 2015, a first team of 32 researchers explored the area, including 12 invertebrate experts. During a second period (11-27 March), a second equal-sized team took over and a third smaller team returned to the site from 12 to 20 August 2015. MP was the only Diptera worker who participated in the Mitaraka 2015 expedition, and was also responsible for the sorting and dissemination of all dipteran samples and fractions (Touroult *et al.* 2018; papers on Diptera in the same series). Next to continuous trapping methods (mainly pan traps), he also actively collected with sweep nets, and hereby focused primarily on Dolichopodidae. Most specimens that were actively collected were searched for and detected visually, in particular, on low vegetation in the palm swamps, but also on tree trunks, fallen logs, wet rocks, sandy river banks and on vegetation overhanging the Alama River.

Study site and habitat types

The expedition was conducted in the Mitaraka Mountains, a largely unknown and uninhabited area in the southwesternmost corner of French Guiana, directly bordering Suriname and Brazil (Fig. 1). It is part of the Tumuc-Humac mountain chain, extending east in the Brazilian state of Amapá and west in southern Suriname. Seven habitat types were sampled: minor ('savanes roches', SAV) and major rocky outcrops ('inselbergs', INS), slopes ('pentes', SL), hill tops ('plateaux', TOP), surroundings of a man-made clearing (drop zone for helicopters and neighbouring base camp, DZ+BC), river banks (RB), and river bank forests or palm swamps ('bas-fonds', RBF) (see also Table 5). The area studied consisted primarily of tropical lowland rainforest with scattered 'savanes roches' (*c.* 390-470 m a.s.l.) and 'inselbergs' (*c.* 540-570 m a.s.l.), isolated partly bare rock formations that stand out above the forest plains (Fig. 2). The investigated 'savanes roches' at Mitaraka featured dense layers of *Pitcairnia* sp., scattered shrubs and exposed rocks, often with seeps (Fig. 2A, B). Both inselbergs included in this survey, i.e. Sommet-en-Cloche (Fig. 2C, D) and Borne 1 (Fig. 2E, F) had more extensive open rocky surfaces that were wet in the morning but dried up extremely fast during the day. Inselbergs thus experience humidity and temperature extremes on a daily basis, and are generally rather windy as well. Only Borne 1 showed extensive permanent seeps (Fig. 2E, F). The rainforest landscape itself is composed of numerous small hills (*c.* 360-430 m a.s.l.) (Fig. 3A, B) with rather steep slopes which raise between 35-75 m above small valleys which hold river bank forests or palm swamps (*c.* 260-310 m a.s.l.) (Fig. 3C, D) and streams (Fig. 3E). Altogether 37 sampling sites were explored (Table 1).

Fig. 1. — Map of French Guiana with Mitaraka region indicated by white box in southwesternmost corner of this part of South America.

Collecting methods

During the survey, invertebrate sampling was carried out with 16 different methods near the base camp, on the drop zone and, in particular, along four trails of about 3.5 km each that started from the base camp in four different directions (Fig. 4). During the first period (22 February-11 March 2015) over 31 different collecting methods were applied,

Table 1. — Overview of invertebrate samples and summarized data on Dolichopodidae obtained per collecting method at Mitaraka sampling sites. Sample site codes are explained in Material and methods. Collecting methods: **BPT**, blue pan traps; **BT**, butterfly trap; **DT**, dung trap; **EM**, emergence trap; **FIT**, flight intercept trap; **HC**, collection by hand; **LT**, light trap; **LT/SW**, sweep net collection at light trap; **MT** (6 m), 6 m long Malaise trap; **PGL**, gemlight polytrap automatic light trap; **PVB**, blue polytrap automatic light trap; **PVP**, pink polytrap automatic light trap; **SLAM**, quadrate Malaise trap; **SW**, sweep net; **WPT**, white pan trap; **YPT**, yellow pan trap; "–" implies that no samples were examined by MP.

Sampling site code	MT (6 m)	SW	SLAM	YPT	FIT	WPT	BPT	EM	HC	DT	LT/SW	PVB	BT	PGL	PVP	LT	Total no. samples
between MIT-C-RBF and MIT-C-RBF2	–	6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6
between MIT-C-SL and MIT-C-RBF	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5
between MIT-DZ-RBF and MIT-A-RBF	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
between MIT-E-Sommet-en-Cloche-low and MIT-E-swamp	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
MIT-A	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
MIT-A-RBF/RBF2	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2
MIT-A-RBF1	–	4	–	2	–	2	2	–	–	–	–	–	–	–	–	–	10
MIT-A-RBF2	–	2	4	–	–	–	2	–	–	–	–	–	–	–	–	–	8
MIT-A-RBF2 and nr MIT-A-RBF2	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
MIT-A-SL	–	1	–	2	–	2	2	–	–	–	–	–	–	–	–	–	7
MIT-A-TOP	–	1	–	2	–	2	2	–	–	–	–	–	–	–	–	–	7
MIT-BC	–	9	–	–	–	–	–	–	–	–	1	–	–	–	–	–	10
MIT-C-Borne 1	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	1
MIT-C-Borne 1 - seep	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2
MIT-C-RBF1	–	10	–	2	–	2	2	–	–	–	–	–	–	–	–	–	16
MIT-C-RBF2	–	14	–	2	–	–	2	–	–	–	–	–	–	–	–	–	18
MIT-C-RBF2 (SLAM1)	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	5
MIT-C-RBF2 (SLAM2)	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	5
MIT-C-savane roche	–	6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6
MIT-C-SL (MIT08)	–	–	–	2	–	2	2	–	–	–	–	–	–	–	–	–	6
MIT-C-TOP (MIT07)	–	1	–	2	–	2	2	–	–	–	–	–	–	–	–	–	7
MIT-D-RBF	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
MIT-DZ	–	2	1	–	4	–	–	–	1	1	–	–	1	–	–	11	21
MIT-DZ1	–	–	4	2	–	2	2	–	–	–	–	–		–	–	–	10
MIT-DZ2	–	–	4	2	–	2	2	–	–	–	–	–	–	–	–	–	10
MIT-DZ-Alama	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3
MIT-DZ-RBF	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2
MIT-DZ-RBF1	–	–	–	2	–	–	2	–	–	–	–	–	–	–	–	–	4
MIT-DZ-RBF2	–	1	–	2	–	–	2	–	–	–	–	–	–	–	–	–	5
MIT-E-savane roche 1	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2
MIT-E-savane roche 2	1	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3
MIT-E-Sommet-en-Cloche-high	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2
MIT-E-Sommet-en-Cloche-low	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3
MIT-E-swamp	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4
nr MIT-A-RBF1	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4
nr MIT-A-RBF2	–	2	–	–	–	–	–	–	2	–	–	–	–	–	–	–	4
nr MIT-C-Borne 1 - tree	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
no info on sampling site	–	2	6	–	4	–	–	1	–	–	–	1	1	2	2	–	19
Total no. samples	5	94	30	22	8	16	24	1	3	1	1	1	2	2	2	11	223
No. samples with Dolichopodidae	5	71	27	22	7	16	22	1	1	–	–	–	–	–	–	–	172
No. (morpho)species	78	84	90	19	49	12	13	3	1	–	–	–	–	–	–	–	244
No. identified specimens	952	519	213	225	150	63	58	7	3	–	–	–	–	–	–	–	2190
No. collected specimens (including females)	1362	1090	878	571	394	378	230	12	3	–	–	–	–	–	–	–	4918
Standardized (rarefied or extrapolated) species richness for 200 individuals (+/-95% Confidence Interval) [different letters indicate significant differences]	21.4 ±4.6 [c]	50.4 ±8.4 [b]	85.9 ±14.6 [a]	18.1 ±5.5 [c]	57.0 ±9.1 [b]	27.3 ±17.4 [c]	23.6 ±14.8 [c]	–	–	–	–	–	–	–	–	–	

with a total of 401 traps operational within a perimeter of 1 km² (Touroult *et al.* 2018). This array consisted primarily of Charax butterfly traps (n = 50), square Malaise traps (SLAM) (n = 32) (Fig. 5A), a 6 m long Malaise trap (Fig. 5B), Flight Intercept Traps (FIT, n = 13) (Fig. 5C), and coloured pan traps (n = 280) (Fig. 5D-F). Nine of these trap types yielded dolichopodid specimens (Table 1). Two methods (EM: emergence trap and HC: collection by hand) only gathered a very low number of specimens (12 or less) and were discarded from the analyses. For more information on SLAMs, FITs and the 6 m long Malaise trap utilized at Mitaraka, see Touroult *et al.* (2018).

From February 24 till March 10, 2015 (first period), MP employed pan traps and sweep nets to collect Dolichopodidae. The pan traps used are coloured lightweight bowls (www.partypro.com) with a 1 cm flat upper rim (inner diameter: 15 cm, depth: 4 cm) (Fig. 5E). Along two trails (A, C), three habitat types (hill top, slope and palm swamp) were selected to install a full pan trap set of 10 blue, 10 white and 10 yellow pan traps. One additional full set

FIG. 2. — Minor and major rocky outcrops in Mitaraka area: **A**, 'savane roche' with *Pitcairnia* sp. vegetation (site MIT-E-savane roche 2); **B**, Dr Rémy Pignoux on 'savane roche' with wet rocks (site MIT-C-savane roche); **C**, inselberg Sommet-en-Cloche; **D**, inselberg Sommet-en-Cloche, wet rocks; **E**, inselberg Borne 1, general view; **F**, inselberg Borne 1, with permanent seeps. Photos: Marc Pollet, except for C, Xavier Desmier.

was installed in the forest edge of the drop zone, whereas sets of 10 blue and 10 yellow pan traps were in operation in three additional palm swamps (trails A, C, and near the drop zone). Finally, one last set of 10 blue pan traps was employed in another palm swamp after the discovery of a new sciapodine genus at this site during the first days of the expedition. Installation of the first pan trap sets was carried out during 24-27 February. Traps were filled with

Table 2. — Pan trap sampling scheme applied at Mitaraka. Sample site codes are explained in Material and methods. Number of trapping days are given as total number, and number of days per separate sampling periods in parentheses. Abbreviations: **BPT**, blue; **WPT**, white; **YPT**, yellow pan traps; * applicable for yellow pan traps only.

Sampling site code	Habitat type	Latitude	Longitude	Altitude (m)	Full sampling period	No. trapping days	BPT	WPT	YPT
MIT-A-TOP	hill top ('plateau')	02°14'19.8"N	54°27'11.3"W	361	25.II-8.III.2015	11 (6, 5)	10	10	10
MIT-A-SL	hill slope ('pente')	02°14'17.8"N	54°27'08.2"W	352	25.II-8.III.2015	11 (6, 5)	10	10	10
MIT-A-RBF1	river bed forest/palm swamp ('bas-fond')	02°14'11.4"N	54°27'07.0"W	306	27.II-8.III.2015	9 (5, 4)	10	10	10
MIT-A-RBF2	riverbank	02°14'12.5"N	54°27'08.1"W	287	27.II-10.III.2015	11 (5, 6)	10	–	–
MIT-C-TOP	hill top ('plateau')	02°13'59.1"N	54°26'37.9"W	433	24.II-8.III.2015	12 (6, 6)	10	10	10
MIT-C-SL	hill slope ('pente')	02°14'07.7"N	54°26'41.5"W	373	24.II-8.III.2015	12 (6, 6)	10	10	10
MIT-C-RBF1	river bed forest/palm swamp ('bas-fond')	02°14'10.8"N	54°26'49.5"W	258	24.II-8.III.2015	12 (3, 9)	10	10	10
MIT-C-RBF2	river bed forest/palm swamp ('bas-fond')	02°14'03.4"N	54°26'53.0"W	299	27.II-10.III.2015	11 (6, 5; 7, 4*)	10	–	10
MIT-DZ1	hill top ('plateau')	02°14'01.4"N	54°27'00.2"W	304	26.II-8.III.2015	10 (4, 6)	5	5	5
MIT-DZ2	hill top ('plateau')	02°14'02.6"N	54°27'01.7"W	296	26.II-10.III.2015	12 (4, 8)	5	5	5
MIT-DZ-RBF1	riverbank	02°14'03.6"N	54°27'02.3"W	270	26.II-10.III.2015	12 (4, 8)	10	–	10
MIT-DZ-RBF2	river bed forest/palm swamp ('bas-fond')	02°13'59.3"N	54°27'00.3"W	283	28.II-10.III.2015	10 (5, 5)	10	–	10

Table 3. — Overview of sites at Mitaraka where samples were collected by sweep net. Sample site codes are explained in the Text.

SW sampling site no.	Sampling site code	Latitude	Longitude	Altitude (m)	Collector	No. samples
1	between MIT-C-RBF1 and MIT-C-RBF2	02°14'08.5"N	54°26'51.0"W	–	Marc Pollet	6
2	between MIT-C-SL and MIT-C-RBF1	02°14'11.7"N	54°26'49.5"W	315	Marc Pollet	5
3	MIT-A	02°14'9.71"N	54°27'6.40"W	–	Marc Pollet	1
4	MIT-A-RBF1	02°14'11.4"N	54°27'07.0"W	306	Marc Pollet	4
5	MIT-A-RBF2	02°14'12.5"N	54°27'08.1"W	287	Marc Pollet	7
6	MIT-A-SL	02°14'17.8"N	54°27'08.2"W	352	Marc Pollet	1
7	MIT-A-TOP	02°14'19.8"N	54°27'11.3"W	361	Marc Pollet	1
8	MIT-BC	02°14'02.0"N	54°26'59.8"W	266	Marc Pollet	9
9	MIT-C-Borne 1 - seep	02°12'26.2"N	54°26'12.3"W	536	Marc Pollet	2
10	nr MIT-C-Borne 1 - tree	02°13'07.8"N	54°26'05.6"W	473	Marc Pollet	1
11	MIT-C-RBF1	02°14'10.8"N	54°26'49.5"W	258	Marc Pollet	10
12	MIT-C-RBF2	02°14'03.4"N	54°26'53.0"W	299	Marc Pollet	14
13	MIT-C-savane roche	02°14'19.4"N	54°26'05.8"W	389	Marc Pollet	6
14	MIT-C-TOP	02°13'59.1"N	54°26'37.9"W	433	Marc Pollet	1
15	MIT-D-RBF	02°13'58.8"N	54°27'07.5"W	317	Marc Pollet	1
16	MIT-DZ	02°14'01.8"N	54°27'01.0"W	306	multiple people	2
17	MIT-DZ-Alama	02°14'03.4"N	54°27'02.5"W	265	Marc Pollet	3
18	MIT-DZ-RBF1	02°14'03.6"N	54°27'02.3"W	270	Marc Pollet	3
19	MIT-DZ-RBF2	02°13'59.3"N	54°27'00.3"W	283	Marc Pollet	1
20	MIT-E-savane roche 1	02°13'58.3"N	54°27'39.3"W	411	Marc Pollet	2
21	MIT-E-savane roche 2	02°13'59.8"N	54°27'46.5"W	471	Marc Pollet	2
22	MIT-E-Sommet-en-Cloche-high	02°13'43.2"N	54°27'57.1"W	566	Marc Pollet	2
23	MIT-E-Sommet-en-Cloche-low	02°13'44.4"N	54°27'57.9"W	499	Marc Pollet	3
24	MIT-E-swamp	02°13'51.9"N	54°28'00.2"W	445	Marc Pollet	5
–	different sites nr base camp and along trails	–	–	–	Julien Touroult	1
–	different sites nr base camp and along trails	–	–	–	Marc Pollet, Julien Touroult and others	1
Total no. samples						94

a 10% formaline solution and detergent to lower surface tension. However, due to heavy rainfall and even flooding of the MIT-C-RBF1 site, servicing of the traps was conducted earlier than originally anticipated (2-6 March), even on 27 February in MIT-C-RBF1, and traps were refilled this time with a salt water solution with detergent. During servicing, yields were sieved, pooled per trap colour and site, carefully transferred to a Whirlpack® to which a label and 96% ethanol were added (Fig. 5F). Between 8 and 10 March 2015, all traps were serviced a second time and finally removed (see Table 2).

Processing of the material

A total of 223 invertebrate samples (often pooled yields of different traps of the same type from a certain site) were examined, including 94 sweep net samples, and 30 and 62 samples collected by SLAMs and coloured pan traps (24 blue, 16 white and 22 yellow traps), respectively (Table 1). The

Fig. 3. — Tropical lowland rainforest in Mitaraka area: **A**, hilly aspect of Mitaraka lowland rainforest, viewed from top of inselberg; **B**, hill top (site MIT-C-TOP); **C**, river bank forest / palm swamp (site MIT-C-RBF); **D**, river bank forest / palm swamp (site MIT-C-RBF2); **E**, bank of river Alama near drop zone (site nr MIT-DZ-RBF). Photos: Marc Pollet, except for A, Xavier Desmier.

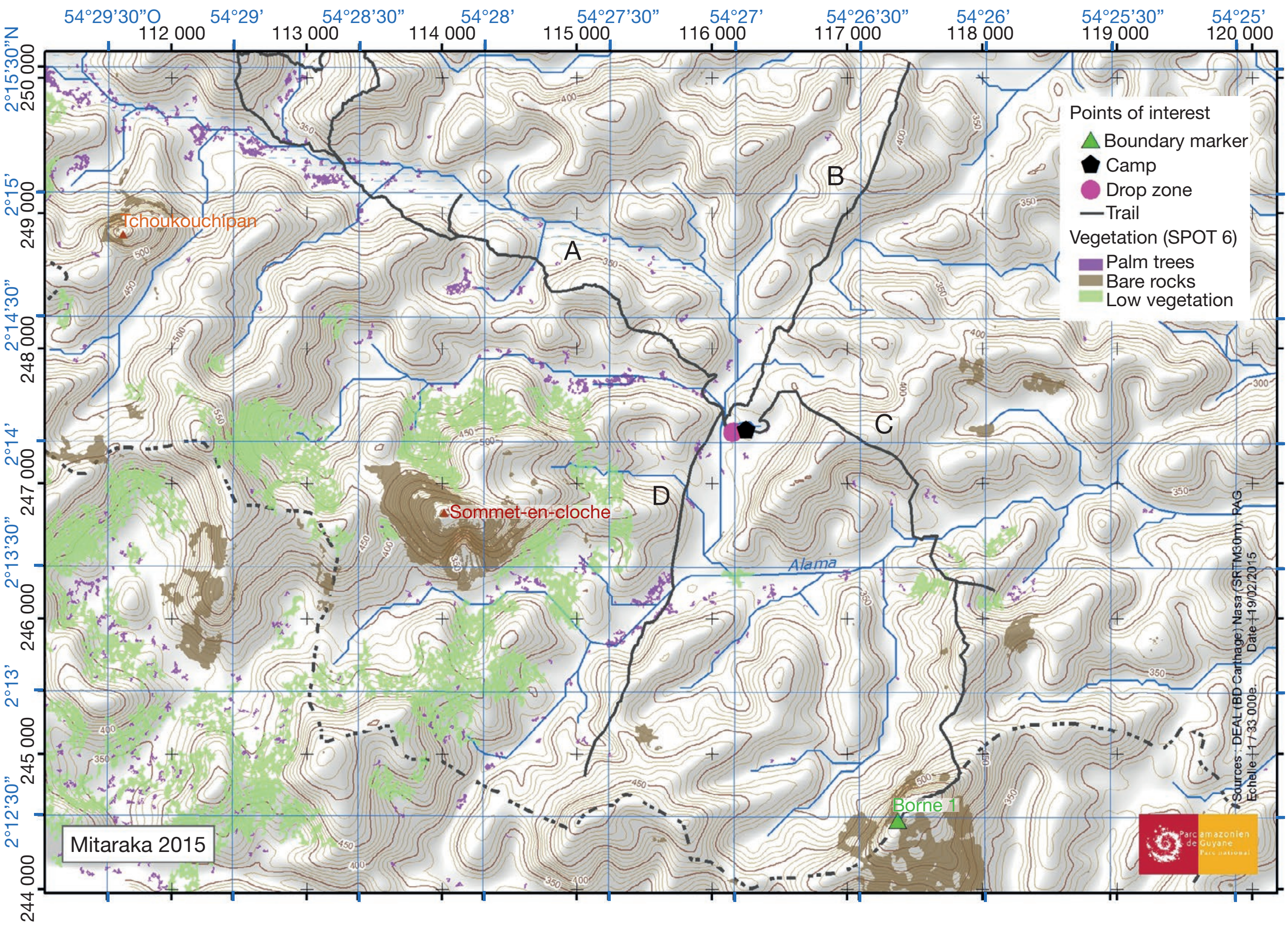

FIG. 4. – Mitaraka site map with four trails indicated (map: Maël Dewynter).

sweep net samples were collected on at least 24 identified sites (Table 3). The majority of these samples (n = 44) were gathered in swamp forests, 11 in/near the base camp and drop zone, 10 on the 'savanes roches' and seven on the two inselbergs (Fig. 6).

Non-pan trap samples were sorted to insect orders and families at the SEAG (Société entomologique Antilles Guyane) offices (http://insectafgseag.myspecies.info/fr), while pan trap samples were treated similarly at MP's home lab. Dipteran subsamples of the following families and superfamilies were subsequently disseminated among experts worldwide: Agromyzidae Macquart, 1851; Asilidae; Bibionidae Fleming, 1821; Bombyliidae Westwood, 1838; Calliphoridae Townsend, 1915; Ceratopogonidae Grassi, 1900; Chloropidae Verrall, 1888; Conopidae Stephens, 1829; Drosophilidae Loew, 1862; Dolichopodidae and other Empidoidea Séguy, 1951; Lauxaniidae Bezzi, 1914; Lygistorrhinidae Hendel, 1936; Micropezidae Loew, 1861; Muscidae Kirby & Spence, 1815; Mycetophiloidea Malloch, 1917; Psychodidae Bigot, 1854; Ropalomeridae Curran, 1934; Scatopsidae Enderlein, 1911; Sciomyzidae Macquart, 1846; Sepsidae Walker, 1833; Sphaeroceridae Macquart, 1835; Stratiomyiidae Giebel, 1856; Syrphidae Samouelle, 1819; Tabanidae Samouelle, 1819; Tachinidae; Tephritoidea Hendel, 1916 and Tipuloidea Coquillett, 1901. The dolichopodid genus *Enlinia* Aldrich, 1933 was treated by Justin Runyon (see Runyon & Pollet 2018) and the remaining Dolichopodidae by MP. See Touroult *et al.* (2018) for a scheme of the whole process. During the first phase of the identification, specimens were assigned to morphospecies which were briefly described using 12 standard morphological features (incl. antenna, face, palpus, body and wing size, etc.). In most cases this was only possible for males as species diversity proved considerable in certain genera. Moreover 109 or 45% of all species were represented by singletons (see further), which largely prohibited the assignment of females to morphospecies. In a second phase, morphospecies diagnoses were compared to descriptions of known species, species groups or genera that have been revised recently (e.g. Naglis 2000, 2001, 2003; Brooks *et al.* 2010; Bickel 2015). At present, this process has been accomplished for only a few genera (e.g. *Cheiromyia* Dyte, 1980, *Neurigona* Rondani, 1856, *Systenus* Loew, 1857), whereas new species are only described in *Enlinia* (see Runyon & Pollet 2018). All collected material (except for *Enlinia*) is stored in 70% alcohol solution and is temporarily residing in MP's private collection.

FIG. 5. — Sampling methods for Diptera employed at Mitaraka: **A**, quadrate Malaise trap (SLAM) in operation on drop zone; **B**, 6 m long Malaise trap installed over Alama River; **C**, flight Intercept Trap (FIT) in rain forest at Mitaraka; **D**, coloured pan traps in river bed forest (MIT-A-RBF); **E**, yellow pan trap at hill top (MIT-C-TOP) with yield of 6 days; **F**, senior author during pan trap servicing procedure. Photos: A, D, E, Marc Pollet; B, C, Julien Touroult; F, Xavier Desmier.

Fig. 6. — Diptera pan trap and sweep net sampling sites at Mitaraka. Yellow line marks the approximate border between French Guiana (north) and Brazil (south). Brown areas are rocky outcrops ('savanes roches' and inselbergs). For explation of sampling site codes, see Text and Tables 2, 3.

Data management

All survey related metadata, e.g. locations, sampling sites and samples, as well as taxonomic information on species and the ultimate identification data, are stored in a relational Microsoft® Access database NEOTROPICS (Pollet, pers. database). In this database, a Mitaraka sampling site is defined by a unique combination of latitude, longitude and altitude, and identified by a description and a code of the format [MIT]-[trail/zone]-[habitat type]([number]) e.g. "MIT-A-SL" = "slope along trail A in Mitaraka" or "MIT-DZ-RBF2" = "river bank forest no. 2 near drop zone in Mitaraka". Also, a code for life zone ("tropical lowland rainforest" for all Mitaraka sampling sites) and for habitat type (e.g. slope ('pente'), hill top ('plateau')) is assigned to each sampling site (see e.g. Table 2). A sample, on the other hand, is defined as a unique combination of sampling site, sampling date or period, collecting method, and collector's name. An identification record, finally, contains information on the (morpho)species name, number of males and females, possible teneral (freshly emerged) specimens, status (e.g. new species, doubtful identification, etc.), and the identifier, together with the sample code.

Data processing

In this paper, both productivity and efficiency estimates were made. In our interpretation, productivity refers to the actual number of species and specimens collected, whereas efficiency as calculated with rarefaction analysis is expressed as the estimated number of species for a given number of collected specimens. In order to estimate the number of species per habitat type (Fig. 13), we fitted a generalized linear mixed effects model that predicts the number of different species caught as a function of habitat type conditional on a random effect of collecting method and a random effect of sampling site. We assumed a Poisson distribution for the response variable. A Bayesian approach was used to fit the model with the aid of the *brms* package (Bürkner 2017), which is an interface to the Stan statistical programming language. The model was fitted with the No-U Turn algorithm using four chains with each 1000 warmup samples and 1000 post-warmup samples.

We calculated a sample-based rarefaction curve based on the formula in Heck *et al.* (1975) and Hurlbert (1971). The curve (Fig. 16) gives the expected species richness in random subsamples from the community and uses the average number of individuals per sample to calculate the corresponding number of specimens in a random subsample. Calculations were conducted with the function *specaccum* in package vegan (Oksanen *et al.* 2017) with R statistical software (R Core Team 2017).

In a second approach, species rarefaction curves were plotted on the abundance data matrices using EstimateS 9.1.0 software (Colwell 2016) with 100 randomizations of the sampling order without replacement. An interpolation or extrapolation to a common number of individuals (200) was also performed by the same procedure as well as the Chao1 estimator of species

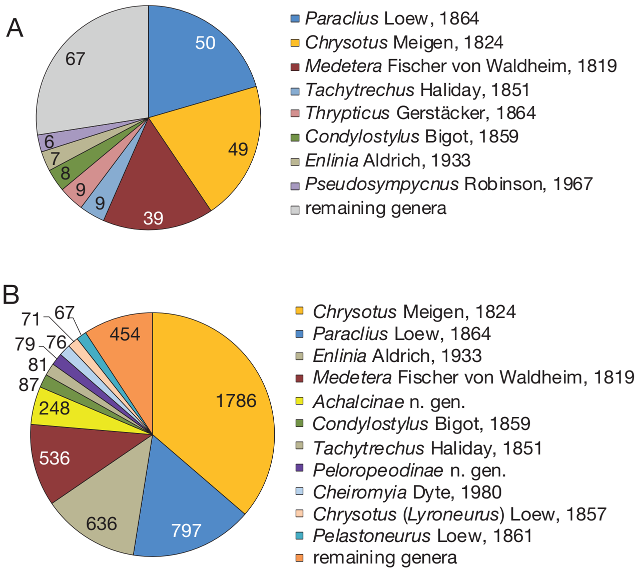

FIG. 7. — Generic composition of Dolichopodidae (Diptera) at Mitaraka: **A**, number of species per genus (indicated); **B**, abundances of dolichopodid species per genus (combined number of specimens indicated).

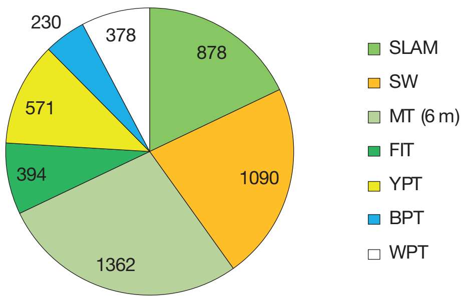

FIG. 9. — Total number of Dolichopodidae (Diptera) specimens per collecting method at Mitaraka. For explanation of collecting method abbreviations, see Table 1.

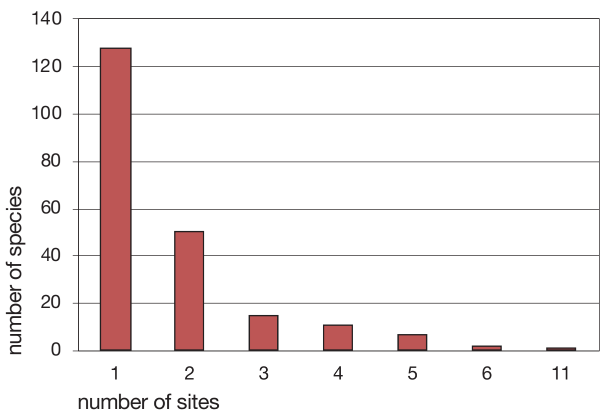

FIG. 11. — Distribution pattern of Dolichopodidae (Diptera) species over Mitaraka sampling sites.

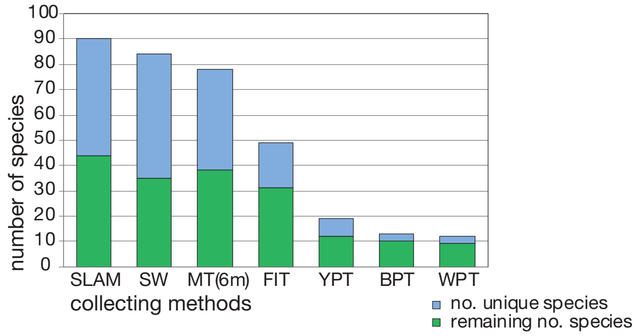

FIG. 8. — Total number of Dolichopodidae (Diptera) species per collecting method at Mitaraka. For explanation of collecting method abbreviations, see Table 1. Unique species refer to species that were collected with one single method.

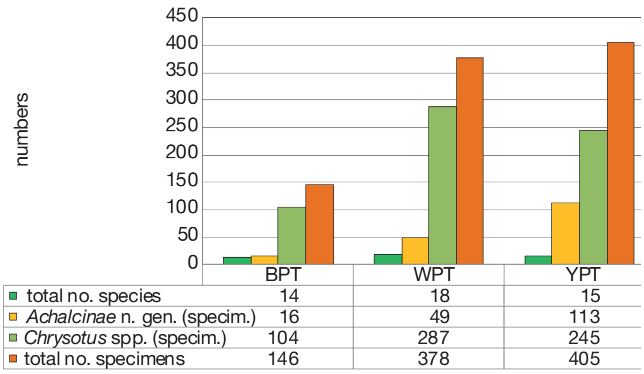

FIG. 10. — Comparison of Dolichopodidae (Diptera) yields among pan trap types across seven different sites at Mitaraka. Abbreviations: **BPT**, blue; **WPT**, white; **YPT**, yellow pan traps.

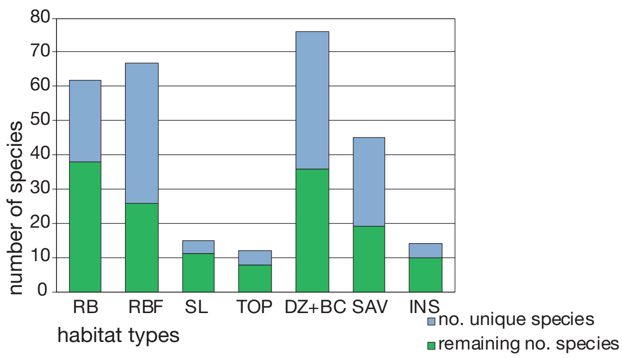

FIG. 12. — Distribution pattern of Dolichopodidae (Diptera) species over Mitaraka habitat types. Habitat types: **RB**, river bank; **RBF**, river bank forest; **SL**, slope; **TOP**, hill top; **DZ+BC**, drop zone + base camp; **SAV**, 'savane roche'; **INS**, inselberg. Unique species refer to species that were only collected in one single habitat type; other species were found in at least two habitat types.

richness. The curves (Fig. 17) give the expected species richness in random subsamples from the community and uses the average number of individuals per sample to calculate the corresponding number of species in a random subsample. Non-overlap of 95% confidence intervals constructed from unconditional variance estimators was used as a conservative criterion of statistical difference (Colwell 2016).

RESULTS

Overall species richness

A total of 4918 dolichopodid specimens were collected and examined, 2190 of which were identified to morphospecies level. Indeed, 55.5% (n = 2728) of the specimens, nearly always females, could only be diagnosed onto generic level. The collected specimens belonged to 10 recognized subfamilies, 31 genera and 244 morphospecies (see Table 4). The estimated species richness calculated on pooled samples was 391 ± 38.4 (standard deviation). Thus far, just four species could be identified as known species: *Cheiromyia brevitarsis*, *C. pennaticornis* (Parent, 1931) (previously recorded from Bolivia and Brazil) (Brooks *et al.* 2010), *Neurigona brevitibia* Naglis, 2003 (Venezuela, Peru, Brazil) (Naglis 2003) and *Neotonnoiria maculipennis* (Van Duzee, 1929) (Peru, Brazil, Panama, Costa Rica) (Naglis 2001). The latter three represent first records for French Guiana. In addition, apart from *Cheiromyia* and *Condylostylus* Bigot, 1859, all genera listed in Table 4 are recorded for the first time from French Guiana. Four new genera were discovered, with one each in Achalcinae, Peloropeodinae, Sciapodinae and in a possibly new dolichopodid subfamily. None of the subfamilies showed a high generic diversity, with Peloropeodinae being the richest with five genera. In terms of species richness, however, three genera clearly stood out by an extraordinary high number of species: *Paraclius* (Dolichopodinae) with 50, *Chrysotus* (Diaphorinae) with 49, and *Medetera* (Medeterinae) with 39 species (Fig. 7A). Together these three genera accounted for 56.6% of the observed dolichopodid species richness. In contrast, six genera were represented by a single species. In terms of abundances, 109 and 78 species were collected as singletons or doubletons, respectively, representing 76.6% of all species observed. Five *Paraclius*, 4 *Chrysotus* and 2 *Enlinia* species were among the 15 species with 20 specimens or more. In fact, with 553 specimens one of these *Enlinia* species proved the most numerous dolichopodid species in the samples (see Runyon & Pollet 2018). *Chrysotus* species (including the unidentified female fraction) comprised 36.3% of all specimens, whereas *Paraclius*, *Enlinia* and *Medetera* represented 16.2%, 12.9 and 10.9% of the total yields, respectively. As a result, over ¾ of all specimens in the samples belonged to these four genera (Fig. 7B).

Overall yields and efficiency of collecting methods

Overall, 172 of the 223 (77%) examined invertebrate samples contained Dolichopodidae, with specimens in all five Malaise trap (6 m) samples, 16 white and 22 yellow pan trap samples. Other traps, including most of the light or baited traps, did not produce any specimen (Table 1). The highest number of species were collected by SLAM (n = 90), sweep net (n = 84) and the 6 m long Malaise trap (n = 78) (Fig. 8). FITs also produced 49 species, but none of the coloured pan trap types yielded more than 20 species, despite the large number of traps employed (Table 1). Overall, the 6 m long Malaise trap collected most specimens, followed by SLAM (Fig. 9). Over 1000 specimens were actively collected on sight by sweep net. Again, pan traps produced surprisingly low numbers. The sweep net method, the Malaise trap and the SLAMs each yielded 40 or more species that were uniquely collected with this single method (hereafter called *unique* species). For each of these methods, the unique species accounted for over half of the total species, however, the species composition greatly differed among the methods. Though a comparable generic richness among these unique species was observed among the collecting methods, this fraction was dominated by *Paraclius* (22 of 49 unique species) in the sweep net samples, whereas *Medetera* and *Chrysotus* were among the most diverse lineages in the unique species fraction of the Malaise trap and SLAM samples. *Enlinia* (five species) and *Trypticus* (seven species) proved quite diverse only in the Malaise trap samples. And despite the low yield of the coloured pan traps, these devices still collected a few species that did not show up in the samples of any other collecting method.

The analysis of yields of separate species over the different collecting methods was strongly biased by an uneven application of these methods over the different sites and the wide range in number of samples taken e.g. the 6 m long Malaise trap was only used at two sites and produced 5 samples contrary to the sweep net collection (Table 1). Nevertheless, a rarefaction analysis revealed that SLAMs were the most effective method of obtaining new species (i.e. highest number of new species for a given number of specimens), followed by FITs and sweep net collecting (see standardized richness for 200 specimens, Table 1). Surprisingly, the 6 m Malaise trap and pan traps scored comparably, and the blue traps accumulated better – though not significantly – than the yellow traps (Table 1).

Certain sites were investigated in a standardized way that did allow comparison. In this respect, results of three types of pan traps (40 blue, 20 white, and 30 yellow pan traps) from two river bank forests along both trails A and C were compared with 30 (all timed) sweep net samples collected in the same sites during the same time period. As shown before, sweep net collecting proved superior to pan traps, with a total of 46 species against only eight, five and three in the yellow, white and blue traps, respectively. Of the species with five or more specimens in the combined samples, 15 of the 19 species were only collected by sweep net, including nine *Paraclius* species, and three species were both found in the sweep net and pan trap samples. Species 'sp. *GF-001*' in the new Achalcinae genus was the exception to the rule as it only showed up in the pan traps. And this pattern was confirmed in a second species of this undescribed genus over all

Table 4. — Overview of the Dolichopodidae (Diptera) collected at Mitaraka. No. specimens (**id.**) include only specimens identified to (morpho)species level.

Subfamily	**Genus**	**No. species**	**No. specimens (id.)**	**No. specimens (total)**
Achalcinae	new genus	4	245	248
Achalcinae	*Xanthina* Aldrich, 1902	4	5	24
Diaphorinae	*Chrysotus* Meigen, 1824	49	471	1786
Diaphorinae	*Chrysotus* (*Lyroneurus*) Loew, 1857	2	6	71
Diaphorinae	*Diaphorus* Meigen, 1824	5	29	29
Dolichopodinae	*Cheiromyia* Dyte, 1980	3	30	76
Dolichopodinae	*Paraclius* Loew, 1864	50	368	797
Dolichopodinae	*Pelastoneurus* Loew, 1861	5	27	67
Dolichopodinae	*Tachytrechus* Haliday, 1851	9	74	81
Enliniinae	*Enlinia* Aldrich, 1933	7	621	636
incertae sedis	*Argyra* Macquart, 1834	1	1	1
incertae sedis	new genus	2	21	21
incertae sedis	*Symbolia* Becker, 1922	4	27	49
Medeterinae	*Medetera* Fischer von Waldheim, 1819	39	98	536
Medeterinae	*Systenus* Loew, 1857	1	9	9
Medeterinae	*Thrypticus* Gerstäcker, 1864	9	16	42
Neurigoninae	*Coeloglutus* Aldrich, 1896	2	11	12
Neurigoninae	*Neotonnoiria* Robinson, 1970	3	15	31
Neurigoninae	*Neurigona* Rondani, 1856	4	6	26
Neurigoninae	*Viridigona* Naglis, 2003	5	8	19
Peloropeodinae	*Discopygiella* Robinson, 1965	1	11	12
Peloropeodinae	*Dominicomyia* Robinson, 1975	1	3	6
Peloropeodinae	*Micromorphus* Mik, 1878	1	5	12
Peloropeodinae	new genus	5	25	79
Peloropeodinae	*Peloropeodes* Wheeler, 1890	3	18	36
Sciapodinae	*Amblypsilopus* Bigot, 1888	1	2	21
Sciapodinae	*Condylostylus* Bigot, 1859	8	13	87
Sciapodinae	new genus	3	5	40
Stolidosomatinae	*Pseudosympycnus* Robinson, 1967	6	11	22
Stolidosomatinae	*Stolidosoma* Becker, 1922	4	4	23
Sympycninae	*Sympycnus* Loew, 1857	3	5	19
Total number		244	2190	4918

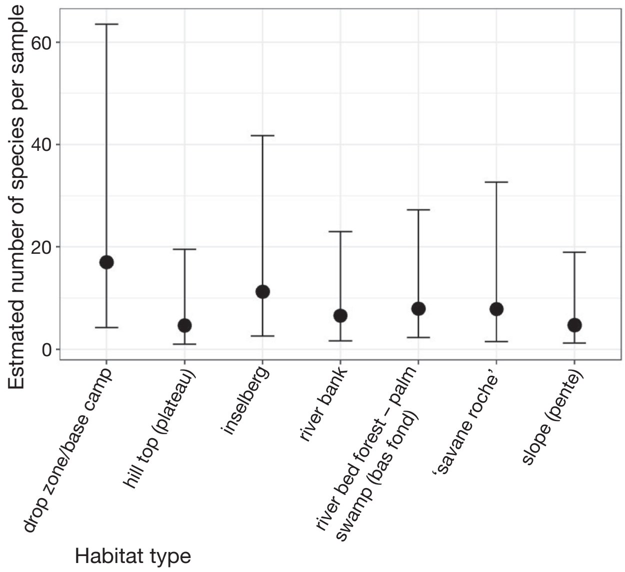

Fig. 13. — Estimated number (+ 95% CI) of species per habitat type.

Table 5. — Overview of samples and species of Dolichopodidae per Mitaraka habitat type. Abbreviations: **RB**, river bank; **RBF**, river bank forest (swamp forest, 'bas-fond'); **SL**, slope ('pente'); **TOP**, hill top ('plateau'); **DZ+BC**, drop zone + base camp; **SAV**, minor rocky outcrop ('savane roche'); **INS**, major rocky outcrop ('inselberg').

Mitaraka habitat types	**RB**	**RBF**	**SL**	**TOP**	**DZ+BC**	**SAV**	**INS**
No. samples	14	75	25	16	49	11	8
No. species	62	67	15	12	76	45	14
No. unique species	24	41	4	4	40	26	4
% unique species	38.7	61.2	26.7	33.3	52.6	57.8	28.6
No. specimens	674	1081	197	498	602	778	207

Table 6. — Overview of results on Dolichopodidae from Palaearctic and Neotropical surveys compared to those obtained at Mitaraka. Collecting methods: **BPT**, blue pan traps; **EM**, emergence traps; **FIT**, flight intercept traps; **HC**, collecting by hand; **LT**, light traps; **MT**, Malaise traps; **PiT**, pitfall traps; **RPT**, red pan traps; **SW**, sweep net collecting; **WPT**, white pan traps; **YPT**, yellow pan traps. Abbreviation: **NR**, Nature Reserve.

Locality, study area	**Main sampling year(s)**	**Collecting methods**	**No. specimens**	**No. species**	**Reference**
Palaearctic					
Wijnendalebos, Torhout-Ichtegem (Belgium)	1986	MT, BPT, RPT, WPT, PiT	16143	60	Pollet & Grootaert 1987
Mandelhoek NR, Ingelmunster (Belgium)	1987-1988	MT, BPT, RPT, WPT, SW	10659	80	Pollet & Grootaert 1992
Meetjeslandse Krekengebied (Belgium)	1990	WPT	8964	73	Pollet 1992
Ossemeersen-Bourgoyen, Gent (Belgium)	1993	WPT	14963	70	Pollet 2001
Bos t'Ename NR, Ename (Belgium)	2015	MT, BPT, WPT, YPT, HC, SW, a.o.	91468	131	Pollet *et al.* 2016
Neotropics					
Podocarpus National Park (Ecuador)	2009	MT, BPT, RPT, WPT, YPT, SW	3252	199	Pollet 2010
National Parks along Andes (Central Chile)	2013	MT, BPT, WPT, YPT, SW	8247	111	Pollet & Arias 2014
Zurquí (Costa Rica)	2013	MT, EM, FIT, HC, LT, a.o.	8346	177	Borkent *et al.* 2017
Mitaraka (French Guiana)	2015	See Table 3	4918	244	present paper

sites: 246 of the 248 specimens of this genus were collected by pan traps, with 72.6% of the yields found in yellow pan traps. Further, results of pan traps of three colours were compared based on identical pan trap sets at seven sites (with a total of 70 traps of each colour over all sites) (Fig. 10). The three pan trap colours showed a comparable low species richness, but blue pan traps collected considerably less specimens than white and yellow ones. Two of the most abundant species groups exhibited a different behaviour, with the Achalcinae new genus showing a distinct preference for yellow pan traps whereas *Chrysotus* species (including females) were slightly more abundant in the white pan traps. However, particular species within these groups appeared to behave differently from the others, e.g. *Chrysotus* sp. *GF-017* was only collected in blue pan traps, even in fair numbers, in contrast to most other congeners. The comparison of the yields of 100 blue and yellow pan traps at 10 different sites revealed a similar colour preference in some species: four of the 12 species with more than five specimens were only collected in yellow pan traps, and five species were more abundant in this pan type. Aside from *Chrysotus* sp. *GF-017*, *Stolidosoma* Becker, 1922 was the only genus that was found in larger numbers in blue pan traps.

Species distributions among sampling sites

In order to analyse the distribution of the different species in the Mitaraka area, identification data were clustered per sampling site, resulting in more than 29 different sites. Sites where sampling was very poor, i.e., with less than 10 examined dolichopodid specimens, were excluded from the analysis. The final matrix encompassed 24 sites and 214 (morpho) species and unidentified specimens. Nearly 130 species (59.8%) were encountered in one single sampling site, and an additional 50 species (23.4%) in merely two sites. This implies that less than 17% of the species was collected in three or more sites (Fig. 11). Specimens of one species, sp. *GF-001* in the Achalcinae new genus, were retrieved from 11 sampling sites and can be considered as the by far most widespread of all collected Dolichopodidae in Mitaraka. It reached its highest numbers in non-flooded palm forests, on slopes, hill tops and in forested areas near the drop zone, but seemingly avoided rocky outcrops. A related species, sp. *GF-003* of the Achalcinae new genus, showed a similar pattern. Among the 36 species recorded from three and more sites, 11 and seven species belonged to *Paraclius* and *Chrysotus*, respectively.

Species richness and habitat types

Despite the strong bias by different collecting methods and various number of samples gathered, sampling results over the different habitat types in the Mitaraka area do provide some indications on habitat preferences and distribution range of species and species groups. For this analysis, samples were clustered according to the habitat type of the sites where they were collected (see Material and methods). In this comparison, seven different habitat types with eight samples or more were distinguished, arranged by increasing altitude and openness: river bank, river bank forest, slope, hill top, drop zone + base camp, and minor ('savane roche') and major rocky outcrop ('inselberg') (see Table 5, Fig. 12). The drop zone + base camp, river bank forests and river bank each harboured more than 60 species, with unique species to each of these particular habitat types ranging from 38.7% (river bank) to 61.2% (river bank forest). The three investigated 'savanes roches' produced a combined 45 species, with nearly 60% unique to this habitat type. The lowest number of species was established on the slopes, hill tops and inselbergs, though sampling efforts between the two former and last habitat type differed substantially. 'Savanes roches' and inselbergs also shared 11 species, four of which were only observed on these rocky outcrops, and two species of *Tachytrechus* Haliday, 1851 were encountered there even in fair numbers. Statistically, however, no significant differences were found in the estimated species richness of the habitat types (see Fig. 13), though the analysis also revealed highest scores in the drop zone + base camp.

Ecological characterization and notes on behaviour

On the basis of both field observations and subsequent analysis of the identification data, the larger dolichopodid lineages at Mitaraka are briefly discussed here, including the number of species collected during the Mitaraka 2015 survey and the wing length range among these species, registered during morphospecies characterization. Known genera are ordered per subfamily, and representative photos of selected taxa are provided in Figure 14 and 15.

Family Diaphorinae Schiner, 1864

Genus Chrysotus Meigen, 1824
(Fig. 14A, B)

Diversity. — 49 species (1.0-2.6 mm)

Morphology, ecology and distribution

Overall very small to rather small, mostly metallic species. Together with *Paraclius*, by far the most speciose genus in Mitaraka. Different lineages were recognized, one of which comprises species with an enlarged antennal postpedicel and a distinct spur on the apex of the mid coxa anteriorly (Fig. 14B). At least 25% of the unidentified female specimens could be assigned to this species group. Most *Chrysotus* species were retrieved from the SLAM and 6 m long Malaise trap (n = 26 and 23, respectively). Representatives of this genus were found at 22 of the 24 sampling sites, with highest species richness (identified species) on one of the minor rocky outcrops and near the drop zone. The genus was also collected on each of the 'savanes roches' and inselbergs. Some species appeared confined to these sunny open habitats like *Chrysotus* sp. *GF-010* (Fig. 14A), recorded from both inselbergs (Sommet-en-Cloche and Borne 1), and the closely related *Chrysotus* sp. *GF-044* (only found on Borne 1).

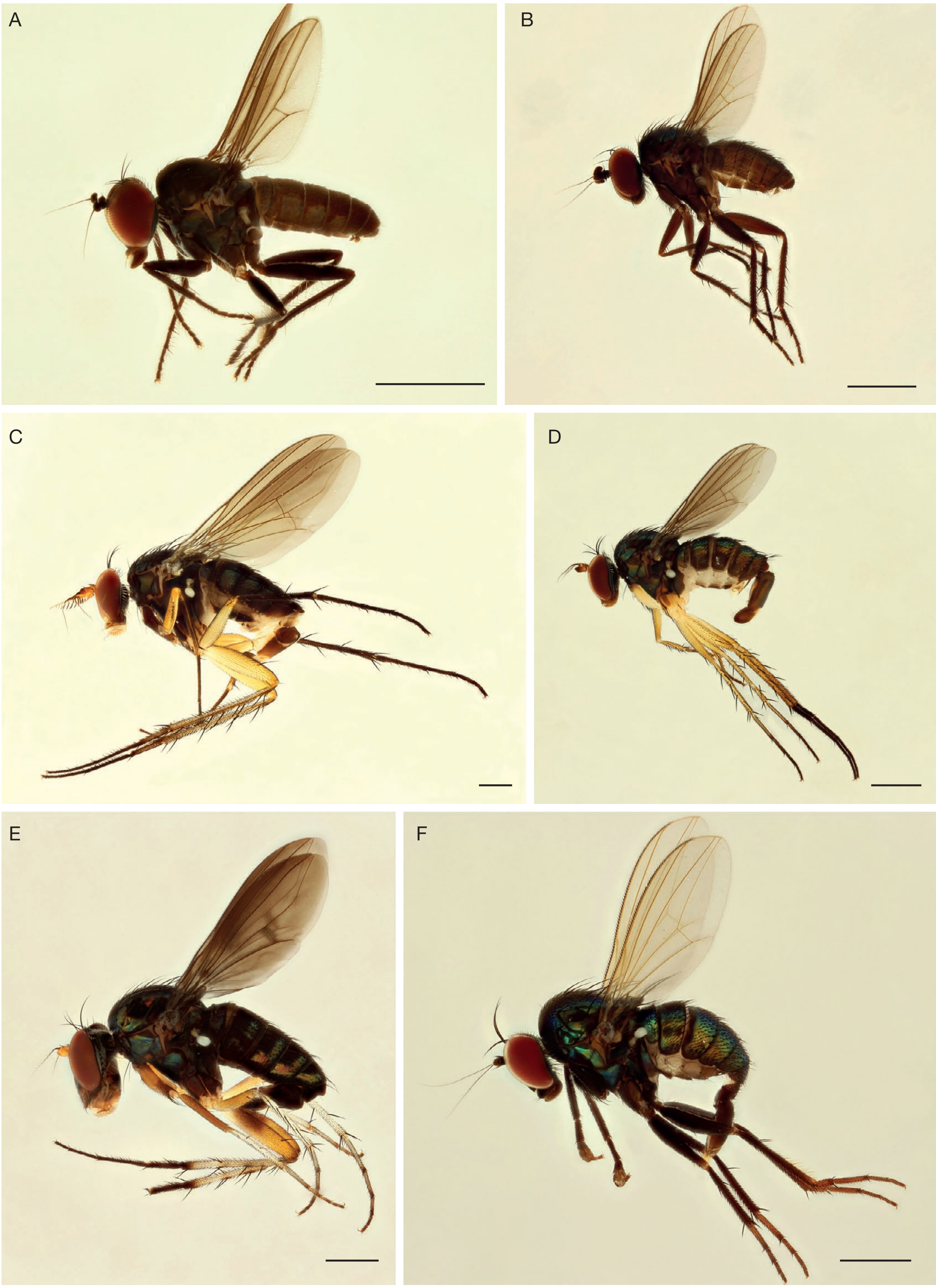

Fig. 14. — Photos of selected Mitaraka Dolichopodidae: **A**, *Chrysotus* sp. *GF-010*, ♂; **B**, *Chrysotus* sp. *GF-021*, ♂; **C**, *Cheiromyia pennaticornis* (Parent, 1931), ♂; **D**, *Paraclius* sp. *GF-005*, ♂; **E**, *Pelastoneurus* sp. *GF-002*, ♂; **F**, *Medetera* sp. *GF-001*, ♂. Photos: Florence Trus.

Family Dolichopodinae Latreille, 1809

Genus Cheiromyia Dyte, 1980
(Fig. 14C)

Diversity. — 3 species (4.2-5.0 mm).

Morphology, ecology and distribution
Rather large species with males that can easily be recognized by the antler-shaped postpedicel. *Cheiromyia pennaticornis* (Fig. 14C) was the only species in this genus that was encountered in numbers; only one male of *C. brevitarsis* and four specimens of *C. fuscipennis* Pollet & Brooks, 2018 (Brooks *et al.* 2018) are available. Apart from eight specimens collected in yellow pan traps, all other specimens were collected by sweep net. This genus seems to be entirely confined to swamps. *Cheiromyia pennaticornis* was exclusively encountered in rather dark, flooded river bank forests (palm swamps), and all specimens but one were collected in two sites of this habitat type along trail C. This species occurred mainly on leaves of rather low broad-leaved shrubs or herbs in half dark conditions and appeared very alert and surprisingly hard to collect with a sweep net. In fact, during sweep net collection attempts this species often escaped by diving to the soil and/or – unnoticed – flying away from the collector through the vegetation.

Genus *Paraclius* Loew, 1864
(Fig. 14D)

Diversity. — 50 species (2.0-4.4 mm).

Morphology, ecology and distribution
Apparently the most speciose genus in Mitaraka with small to rather large species (Fig. 14D). There is a considerable size variation, and males can be separated by the colour and shape of the postpedicel, the leg colour, the shape of the hypandrium and cercus (hypopygial appendages), and Male Secondary Sexual Characters (MSSCs) that are found in the femur, tibia and tarsus. Thirty species and 75% of all specimens were collected only by sweep net, and FITs were the only other productive collecting method (14 sp., 108 specimens). This genus was encountered at 21 sampling sites but the highest species diversity was definitely reached in palm swamps and the forested area around the drop zone. One species, *Paraclius* sp. GF-017, was nearly entirely found on low vegetation at the bottom of rocky outcrops. Contrary to *Cheiromyia pennaticornis*, in palm swamps *Paraclius* species were also found higher up in the shrubs and both in well-lit (insolated) and darker conditions. This genus also appeared much easier to collect using a sweep net.

Genus *Pelastoneurus* Loew, 1861
(Fig. 14E)

Diversity. — 5 species (2.9-5.5 mm).

Morphology, ecology and distribution
Rather small to large species, with a characteristic bulging clypeus and a strongly plumose antennal (arista-like) stylus (Fig. 14E). Sixty of the 67 *Pelastoneurus* specimens were collected by sweep net, all but three specimens exclusively in swamp forests. Contrary to *Cheiromyia pennaticornis*, *Pelastoneurus* species seemed to prefer well-lit places where they were encountered mostly on low leaves of broad-leaved shrubs and herbs, and on leaf litter. As with *C. pennaticornis*, representatives of this genus, and the larger species in particular, appeared very agile and hard to collect with a net.

Genus *Tachytrechus* Haliday, 1851
(Fig. 15B)

Diversity. — 9 species (3.5-4.5 mm).

Morphology, ecology and distribution
Rather large, metallic species with males often featuring modified fore tibiae or tarsi. Similar to the other Dolichopodinae, most of the *Tachytrechus* species (seven spp.) and specimens (n = 61) were gathered by sweep net, whereas FITs produced six species (with only 12 specimens). This genus was collected at 11 sampling sites, including four of the six rocky outcrops. *Tachytrechus* species show an entirely different ecological profile than the other Mitaraka Dolichopodinae, and are generally not found in the centre of the palm swamps but rather occupy low vegetation overhanging running water (streams), fallen logs and wet rocks. Two species, *Tachytrechus* sp. *GF-003* and *T.* sp. *GF-005* (Fig. 15B), were only collected on bare rocks of 'savanes roches' and inselbergs, the latter species in large numbers.

Family Enliniinae Robinson, 1970

Genus Enlinia Aldrich, 1933

Diversity. — 7 species (0.8-1.5 mm).

Morphology, ecology and distribution
See Runyon & Pollet (2018).

Family Medeterinae Aldrich, 1905

Genus Medetera Fischer von Waldheim, 1819
(Figs 14F; 15A)

Diversity. — 39 species (1.0-3.6 mm).

Morphology, ecology and distribution
The third most speciose genus in Mitaraka, comprised of very small to rather large, generally dark species, often with metallic green to blue body. SLAMs yielded 25 species and nearly 75% of all specimens, whereas the 6 m long Malaise trap, sweep nets and FITs produced 12, eight and six spe-

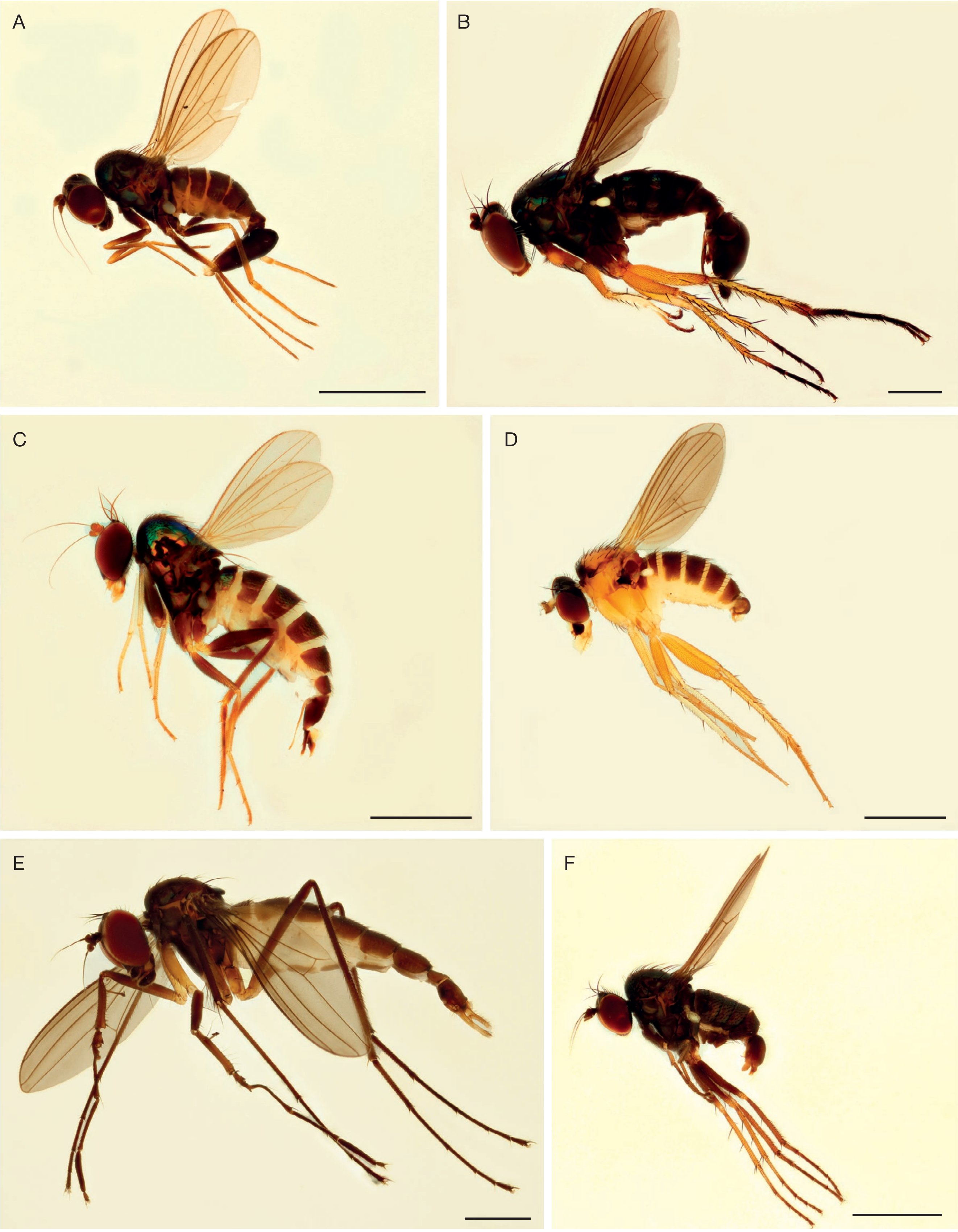

FIG. 15. — Photos of selected Mitaraka Dolichopodidae: **A**, *Medetera* sp. *GF-005*, ♂; **B**, *Tachytrechus* sp. *GF-005*, ♂; **C**, *Thrypticus* sp. *GF-004*, ♂; **D**, species sp. *GF-001* of Achalcinae new genus, ♂; **E**, species sp. *GF-001* of incertae sedis, ♂; **F**, species sp. *GF-002* of Peloropeodinae new genus, ♂. Photos: Florence Trus, except for E, Camille Locatelli.

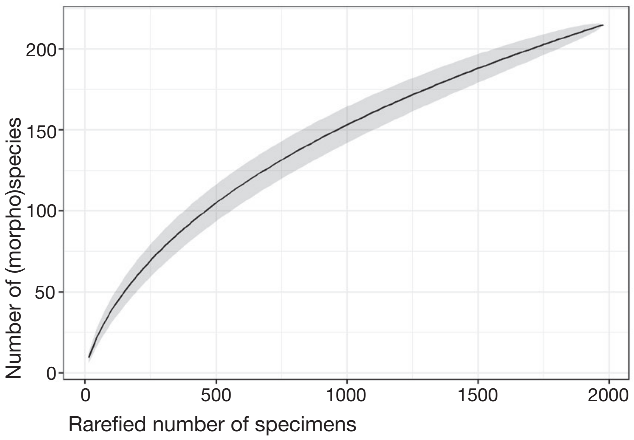

Fig. 16. — Rarefaction curve on Dolichopodidae identified to (morpho)species level collected by combined various methods at Mitaraka.

cies respectively, but in much lower numbers. Two lineages seemed well represented: the first was previously considered a separate genus, *Saccopheronta* Becker, 1914, and comprises larger species often with modified fore tarsi that are found both on tree trunks and broad-leaved vegetation (Fig. 14F). The second lineage is composed of minute, rather dull species with an often remarkably large hypopygium (Fig. 15A) and most probably restricted to tree trunks. *Medetera* was collected at 11 sites, with most species near the drop zone (n = 12), while six species were recorded from three other sites where either SLAMs or the 6 m long Malaise trap had been in operation.

Genus *Thrypticus* Gerstäcker, 1864 (Fig. 15C)

Diversity. — 9 species (1.1-2.1 mm).

Morphology, ecology and distribution

As mentioned before, larval stages of this genus of minute to rather small species live as leafminers in plants, while adult flies are most often found in dense herb vegetation. Nearly all specimens were retrieved from samples collected by SLAMs and the 6 m large Malaise traps. *Thrypticus* was recorded from only seven sites and the fair numbers at two of them are entirely due to the use of the Malaise trap.

New genera

Four new genera were also discovered at Mitaraka, three of which were previously known to MP from species from several Central and South American countries, and are currently in the process of description. Species *GF-001* of the Achalcinae new genus (Fig. 15D) belongs to a megadiverse exclusively Neotropical lineage that is most speciose at higher altitudes (e.g. Costa Rica) (Pollet 2005). In tropical lowland rainforests, only a few species seem to occur. Contrary to most other Dolichopodidae but characteristic for this genus are the pale body colour, the specific colour pattern on the mesonotal dorsum, and the postpedicel with an anterior and posterior face that feature different colours. This genus was encountered at half of the Mitaraka sampling sites, and – contrary to almost all other Dolichopodidae – was most abundant on the slopes and hill tops, and in the drier palm swamps; it was entirely lacking from the rocky outcrops. A monograph on this lineage is being prepared by MP.

The new genus in Sciapodinae with three species found at Mitaraka has been recognized for over 10 years by MP and Dan Bickel (Australian Museum Sydney, Australia) who will dedicate a separate paper on this genus and the near 20 new species thus far discovered in Central and South America. Compared to most other Sciapodinae, this genus includes rather small and extremely slender species (wing size approx. 3 mm). Males have an extremely elongated fore tarsus.

Two new Mitaraka species were assigned to a new genus and possibly a new subfamily. MP has previously detected other species of the same lineage in Ecuador, Nicaragua, Costa Rica and Colombia. One of the two Mitaraka species was represented by females only; the male of the other species (Fig. 15E) features distinct MSSCs in fore and mid leg. Sixteen of the 20 specimens were collected with the 6 m long Malaise trap over the Alama River. This species group will further be treated in a separate paper.

The fourth new genus (Fig. 15F) belongs in Peloropeodinae and represents a taxon that has not been collected before, and is, at present, only known from Mitaraka. Five different species were recorded, and over ⅘ of the 84 specimens were retrieved from FITs and the 6 m Malaise trap. Ten specimens were collected near the river Alama where they were found both on sandy banks and on low vegetation hanging over the stream. Overall, most specimens were collected near the drop zone and on the river bank, although one species was only found on 'savane roche 2'. A separate paper will be dedicated to the description of this genus.

DISCUSSION

Beyond any doubt, with a total of 244 observed species and undoubtedly more among the unidentified female fraction, the dolichopodid species richness established at Mitaraka can be considered exceptional. Not only is this only a part of the extant dolichopodid fauna as is suggested in Figure 16 – the estimated number of species was calculated at 391 – , but it is also considerably higher than the species richness thus far recorded at a single site anywhere in the world. At low altitudes in Europe, dolichopodid faunas of even protected areas seldom reach one hundred species (Table 6). In 2015, over 130 species were recorded from one single forest area (Bos t'Ename, Belgium) but this was mainly due to a massive sampling campaign and exceptional weather conditions, which produced a total yield of over 91 000 specimens (Pollet *et al.* 2016). Previous reports on entire Neotropical dolichopodid faunas are rare, and suggest an overall highest species richness with up to nearly 200 species in southern Ecuador. However, results are very hard to

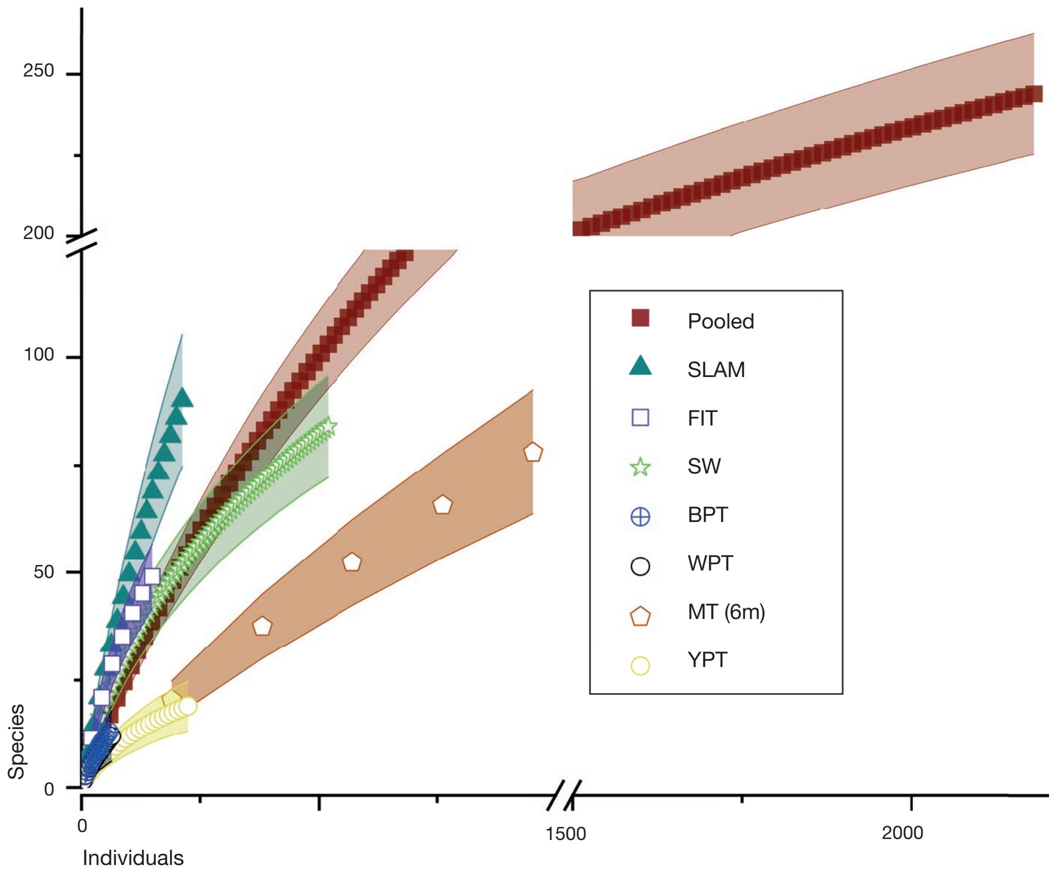

FIG. 17. — Rarefaction curves on Dolichopodidae identified to (morpho)species level collected by various collecting methods at Mitaraka.

compare. The Chilean survey (Table 6) encompassed 17 sites along an approx. 1000 km long transect that were investigated during high summer (January 2013), whereas different sites at 1000 m, 2000 m and 3000 m a.s.l. in Podocarpus National Park (Ecuador) were sampled during less than one month. The dipterological survey at Zurquí, a forested area at about 1600 m a.s.l. in NE Costa Rica, lasted for one entire year and comprised a wide array of different collecting techniques and even blitz visits (Borkent *et al.* 2017). But none of these assessments comes close to the Mitaraka dolichopodid richness.

The generic composition of the Mitaraka fauna also differs greatly from that of the other Neotropical sites, and especially lineages that are highly diverse at higher altitudes such as several achalcine genera and *Sympycnus* Loew, 1857 are poorly represented at Mitaraka. And whereas *Medetera* and especially *Chrysotus* are encountered in high diversities in other parts of the Neotropics as well, the species diversity of *Paraclius* at Mitaraka is truly unprecedented. The surveys in Ecuador, Costa Rica and Chile as listed in Table 6 yielded no more than nine, three and one species of *Paraclius*, respectively. It is still unclear how this huge species richness can be explained, but seemingly many species in this genus prefer the damp and half dark conditions that are offered by the 'bas-fonds' or palm swamps. They share these swamps with *Cheiromyia* and *Pelastoneurus*, two other dolichopodine genera that are far less diverse and abundant than *Paraclius*, but nonetheless, characteristic of this habitat type. A study of the phylogenetic relationship among those *Paraclius* species, together with a detailed ecological and behavioural field study, would most probably shed more light on this exceptional species group.

Since the mid 1980s MP has been applying several types of coloured pan traps to collect Dolichopodidae, both in the Palaearctic and the Neotropics, and each survey produced fairly to extremely high numbers of specimens (e.g. Pollet & Grootaert 1987; Pollet *et al.* 2016). During the Mitaraka survey, however, it proved unsuccessful largely due to the heavy rainfall and the occasional subsequent flooding of the sampling sites. The 280 pan traps yielded a mere 1179 specimens of 40 species, or about four dolichopodid flies per trap, whereas yields should normally run into the hundreds per trap over two weeks sampling time. In this respect, a single yellow pan trap on the bank of a forest pond in the Vallei van het Merkske (Belgium) produced several hundreds of specimens in less than one hour (Wind & Pollet 2017). Fortunately, other collecting techniques were also employed at Mitaraka, the 6 m Malaise trap, sweep nets, SLAMs and FITs being the most productive with 90, 84, 78 and 49 species, respectively (Fig. 17), while the latter three were also the most efficient (Table 1). It is, however, impossible to assess what these techniques might yield in other tropical lowland rainforest sites around the Neotropics, but it is very likely that they might disclose a yet unknown part of the Diptera fauna in general, and the dolichopodid fauna in particular.

Acknowledgements

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