African Invertebrates 58(2): 55–82 (2017)
doi: 10.3897/AfrInvertebr.58.21083
http://africaninvertebrates.pensoft.net

RESEARCH ARTICLE

African Invertebrates
A journal of biodiversity research

Edible insects of Northern Angola

Thea Lautenschläger[1], Christoph Neinhuis[1], Mawunu Monizi[2], José Lau Mandombe[2], Anke Förster[3], Thomas Henle[3], Matthias Nuss[4]

1 *Department of Biology, Institute of Botany, Faculty of Science, Technische Universität Dresden, 01062 Dresden, Germany* **2** *University of Kimpa Vita, Province of Uíge, Rua Henrique Freitas No. 1, Bairro Popular, Uíge, Angola* **3** *Department of Chemistry and Food Chemistry, Institute of Food Chemistry, Faculty of Science, Technische Universität Dresden, 01062 Dresden, Germany* **4** *Senckenberg Museum of Zoology, Königsbrücker Landstr. 159, 01109 Dresden, Germany*

Corresponding author: *Thea Lautenschläger* (thea.lautenschlaeger@tu-dresden.de)

Academic editor: *P. Stoev* | Received 28 September 2017 | Accepted 21 November 2017 | Published 8 December 2017

http://zoobank.org/09BAF5C2-259E-447D-A083-C1056C9735E8

Citation: Lautenschläger T, Neinhuis C, Monizi M, Mandombe JL, Förster A, Henle T, Nuss M (2017) Edible insects of Northern Angola. African Invertebrates 58(2): 55–82. https://doi.org/10.3897/AfrInvertebr.58.21083

Abstract

From 2013–2017, we accompanied and interviewed local people harvesting edible insects in the Northern Angolan province of Uíge. Insect and host plant samples were collected for species identification and nutritive analyses. Additionally, live caterpillars were taken to feed and keep until pupation and eclosion of the imago, necessary for morphological species identification. Altogether, 18 insect species eaten by humans were recorded. Twenty four edible insect species were formerly known from the country, four of which are confirmed in this study and 14 species additionally recorded. *Sciatta inconcisa* Walker, 1869 (Erebidae) and *Gastroplakaeis rubroanalis* Wichgraf, 1913 (Lasiocampidae) are reported for the very first time as human dietary foods. All 18 species are illustrated and DNA-Barcodes are provided to enable re-identification of species. Though much effort has been undertaken for the identification of the 18 species, only 14 species have been identified at species level and another four only at family level. The scientific names are listed along with the vernacular names. A nutritional analysis is provided for nine species most of which are consumed in the villages, but some are also traded, for which a market study has been conducted. Information is also given on traditional collection and preparation as well as cultural aspects of edible insects in Northern Angola.

Keywords

Edible insects, DNA-barcoding, nutritional values, market study, Uíge province

Introduction

The consumption of insects by humans is commonly found in the Americas, Africa, Asia and Australia (DeFoliart 1999, Huis 2003, Durst et al. 2010, Gahukar 2011, Mitsuhashi 2017). About 2,140 species of edible insects have been scientifically identified worldwide so far, but many more that are used by humans still need to be identified (Mitsuhashi 2017).

The number of insect species consumed by people in Africa ranges from 250 (Huis 2003) to more than 470 (Kelemu et al. 2015, Jongema 2017).

However, until the present time, only 24 species of edible insects have been recorded from Angola, 19 of which are identified at species and five at genus level. These records are scattered over publications from a period of more than a hundred years (Wellman 1908, Bergier 1941, Santos Oliveira et al. 1976, Silow 1983, Hunter 1984, DeFoliart 2002, Malaisse and Lognay 2003, Malaisse 2005, Kelemu et al. 2015, Mitsuhashi 2017).

Scientific research on this topic is scarce for Angola even though there is reason to presume that consumption is comparably common in adjacent countries. Much more data has been compiled from regions adjacent to northern Angola. Gomez et al. (1961) reported more than 65 insect species consumed in today`s Democratic Republic of the Congo. For the neighbouring province Kwango, caterpillars of more than 30 species are consumed (Leleup and Daems 1969). In Bas-Congo, Latham (2005) gathered information over a period of more than two decades for 36 ethno-species representing 42 morpho-species, 17 of which were identified at species level, 9 at genus level and 16 remain scientifically unidentified. To the east, Malaisse and Parent (1980) found caterpillars of 35 species eaten by humans in the province Katanga (former Shaba). Similarly, more than 60 species of insects are eaten by humans in Zambia (DeFoliart 1999). The Bisa people regard the caterpillars of eight saturniid species as highly valuable and still use traditional and sustainable methods to some extent for harvesting the caterpillars (Mbata et al. 2002, Mbata and Chidumayo 2003).

Due to the available data from adjacent regions, it is to be expected that many more insect species are eaten by humans in Northern Angola than previously recorded in scientific literature. Decades of war have hindered the exploration of this area. The most compelling argument in favour of insects as food is their nutritional value, especially since they are rich in protein, vitamins and minerals, iron and B-vitamins (Santos Oliveira et al. 1976, Bukkens 1997, Xiaoming et al. 2010, Belluco et al. 2013, Rumpold and Schlüter 2013, Grande et al. 2017). As in other regions of the world, insects are consumed as emergency food, as a staple food or as delicacies. However, about 85–90% of the rural population in Angola depend entirely on subsistence farming, hunting and gathering of natural resources such as insects (FAOstat 2017). Harvesting insects is an important source for protein, since large wild animals have been significantly exploited during the war.

In the following, we present the data for a first survey of the consumption and trading of edible insects in Northern Angola and provide information on their nutritive, as well as their commercial, values.

Materials and methods

Study area

Our survey was conducted in the Province Uíge between 6 and 8 degrees latitude south and 14 and 17 degrees longitude, bordered to the north and east by the Democratic Republic of Congo, to the south by the provinces of Malanje, Cuanza Norte and Bengo and to the west by the province of Zaire (Fig. 1). According to the Köppen climate classification, the province has a tropical wet or dry or savannah climate Aw (Peel et al. 2007, Briggs and Smithson 1986). This so-called Guineo-Congolian rainforest climate is characterised by a rainy season which lasts more than six months, accompanied by relative humidity above 80% and dense fogs, locally called *Cacimbo* (Marquardsen and Stahl 1928). A precise description of the region was defined by White (1983) who classified Angola north, between the Guineo-Congolian and the Zambesian Regions, calling it the Guinea-Congolia/Zambesia regional transition zone. According to that classification, this zone is characterised by a high complexity since elements of both formations are present. Edaphic conditions and the associated diverse topography strongly influence the formation of the distinctive vegetation mosaic patterns. Barbosa (1970) differentiated the area into six vegetation zones, shown in Fig. 1 (Lautenschläger and Neinhuis 2014).

Large areas are heavily disturbed anthropogenically and elements of Zambezian flora have greatly increased in abundance following destruction of the original vegetation leaving secondary grass- and woodland (White 1983). The reasons for this are, on the one hand, logging that concentrates on *Milicia excelsa* or species of *Entandrophragma*, which have been historically exploited and therefore are under increasing pressure (Romeiras et al. 2014) and, on the other hand, uncontrolled fires caused by the increasing agricultural activities of local people (Göhre et al. 2016).

The province Uíge comprises 16 municipalities, covering an area of 58,698 km^2 housing over 1.4 million inhabitants (CENSO 2014), the majority of whom belong to the Kikongo speaking Bakongo ethnic group. As this Bantu-group is also present in the adjacent northern countries of the Democratic Republic of Congo, Republic of Congo and Gabon, cultural overlaps in the use of natural resources are evident.

Sampling and preservation of vouchers

Field surveys in Uíge Province were performed during six trips in November 2013, January-February 2014 and February 2015, July 2015, November 2016 and February 2017. One trip to the Calandula falls in Malanje Province completed the survey in February 2017.

Edible insects were sampled in collaboration with people from the villages in order to learn where and when to find the insects that are used as human food. Along with the sampling, semi-constructed interviews with local collectors took place to detect

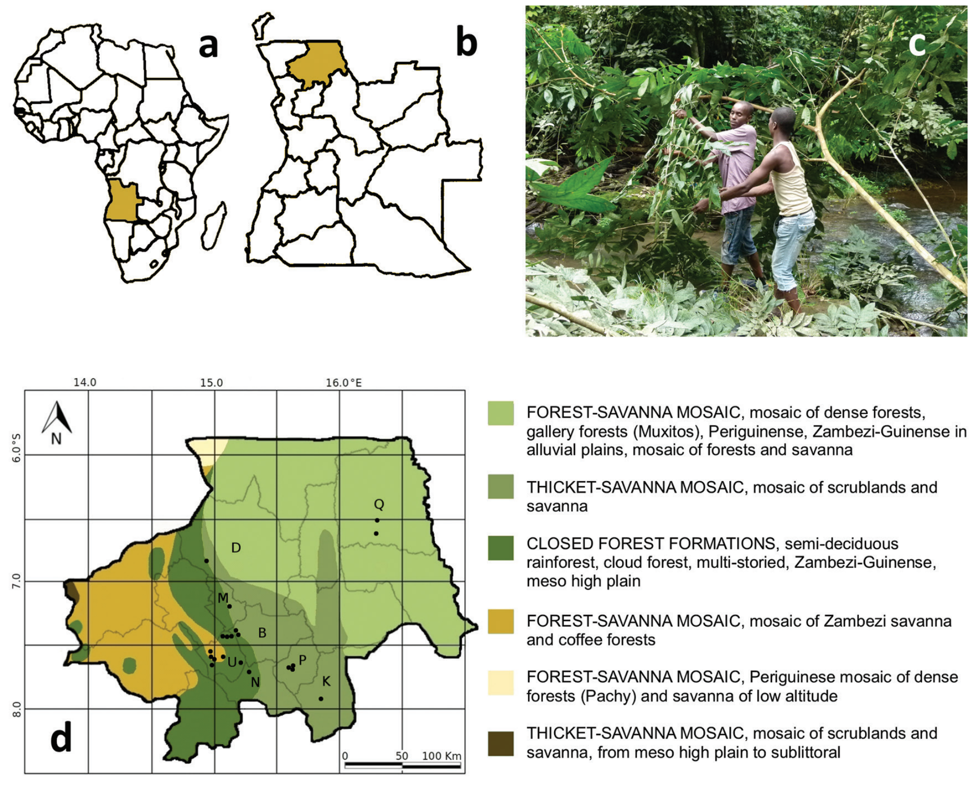

Figure 1. Study area. **a** Location of Angola in Africa **b** Province of Uíge in Angola **c** Collectors of caterpillars cutting a host tree to collect larvae **d** Sample points of edible insects including several species according to Table 2. Vegetation zones according to Barbosa (1970).

larvae as well as their host plants, the local Kikongo names, preparation and possibly even its commercialisation. Seventeen villages in eight different municipalities Uíge, Puri, Mucaba, Bungo, Negage, Damba, Kangola and Quimbele, were therefore visited to collect larvae from forest and savannah.

Since most of the edible insects are moth larvae and taxonomy of the moths is mainly based on imagoes, larvae were taken alive and fed with their natural plants until pupation. Pupae were placed in an incubator until eclosion of the imagoes. Additionally, moths were attracted by artificial light to analyse the phenology of the species and to enable molecular identification of larvae by comparison with the imagoes.

One part of each sample was stored in absolute ethanol for later morphological and molecular identification while the other part was deep frozen for nutritional analyses. Moths were killed with cyanide and quickly dried in paper envelopes for later morphological and molecular identification. Voucher specimens are preserved at the Senckenberg Museum of Zoology Dresden on behalf of TU Dresden due to its having appropriate facilities.

Plants were photographed and voucher specimens collected, dried and stored at the Herbarium Dresdense, Technische Universität Dresden, Germany.

In a Memorandum of Understanding between the Instituto Nacional da Biodiversidade e Áreas de Conservação (INBAC), Angola and the Technische Universität Dresden, Germany, signed in 2014, it was agreed that, as soon as appropriate conditions to store the insect and herbarium vouchers had been established, duplicates would be returned to Angola. Collection and export permits were issued by the Ministry of Environment Angola and the Province Government of Uíge. Identification of reported plant specimens and data analyses were completed in Dresden, Germany.

Morphological and molecular identification of insects

Insects were identified based on morphological characters and by using traditional taxonomic literature as well as based on the DNA-Barcode.

For morphological identification, moths were placed in a relaxing jar and wings spread on a spreading board. After labelling, they were identified based on wing pattern elements using taxonomic literature (Oberprieler 1995; Bouyer 1999; Lampe 2010; Schintlmeister 2013) or online databases (De Prins and De Prins 2012; Goff 2016–2017; Cigliano et al. 2017; Peña 2013). Notodontid larvae were identified using Gerasimov (1937), Stehr (1987), Miller (1991), Carter and Kristensen (1998), Kitching and Rawlins (1998), Beck (1999). Additionally, taxonomic experts have been consulted (see Acknowledgements).

The material for DNA isolation is derived from either canned (99% absolute) caterpillars or from dried moths. For the extraction, tissue from the abdomen (caterpillars) or a leg (imagoes) was used for this purpose. The DNA was extracted with the NucleoSpin Tissue Kit (Macherey-Nagel) according to the manufacturer's protocol.

The mitochondrial COI gene was amplified using the primers HybLCO (forward) and HybHCO (reverse) (Folmer et al. 1994; Wahlberg and Wheat 2008). Both primers contained a 5' tail of the universal sequencing primers T7 (forward) or T3 (reverse), denoted by the 'Hyb' in the primer names.

Standard PCRs were performed in a total volume of 20 µl using 1.5 µl of DNA of concentration as extracted, 0.5 unit Bio-X-ACT short DNA polymerase (Bioline) in the recommended buffer, 2.5 mM of each dNTP (Fermentas), 0.25 µM of forward and reverse primer and 2.5 mM $MgCl_2$ (Bioline).

Cycling conditions were as follows: 39 cycles were used with denaturation at 94 °C (30 s but 5 min for the first cycle), annealing at 49 °C (30 s) and extension at 72 °C (45 s but 10 min for the last cycle).

PCR results were examined via gel electrophoresis on a 1% agarose gel and GelRed as dying agent. Successful PCR samples were cleaned with ExoSAP-IT™ [Exonuclease I (Exo) and Shrimp Alkaline Phosphatase (SAP)]. PCR and ExoSAP-IT™ were performed on an Eppendorf Mastercycler S thermo cycler. For the Sanger-sequencing PCR reactions, we used 0.25–3.0 µl PCR sample, depending on the thickness of the respective agarose gel band and 160 nM of the sequencing primers T7 (forward) or T3 (reverse), 0.5 µl BigDye, 2.25 µl BigDye-sequencing buffer and made up with distilled water to the 10 µl reaction volume. Sequencing was conducted either at the Senckenberg Museum of Zoology Dresden (ABI 3730 Genetic Analyser; Applied Biosystems) or at Macrogen Europe. Sequences were aligned using Bioedit version 7.2.5. and analysed in MEGA 7.025 using the Neighbour Joining Algorithm. Sequences were submitted to GenBank (see Table 1 for accession numbers).

Market study

To investigate the quantity and prices of the offered species during several years and seasons, four markets were visited for market analysis. To match prices, central markets in Uíge city and Negage city were compared to markets on their peripheries.

Analysis of major nutrients

To evaluate the nutritional value of insects, samples from the adjacent municipalities Uíge, Bungo, Puri, Negage and Mucaba were selected in January and February 2014 and analysed for the major nutrients, protein and fat. Water content was calculated through the loss of weight due to freeze drying. All chemicals used were of analytical or higher quality.

Insects usually eaten after evisceration were analysed after removal of the gut as indicated in the results section. All samples were freeze-dried (Beta 1-8K, Martin Christ Gefriertrocknungsanlagen GmbH, Osterode, Germany) and ground for 20 s at 1000 rpm in a Grindomix 200 knife mill (Retsch GmbH, Hahn, Germany). The resulting powders were stored at -18 °C until analysis. Protein analysis was carried out by determination of the nitrogen content according to the Kjeldahl method (System of Büchi Labortechnik AG, Flawil, Switzerland) and application of a conversion factor of F=6.25 for protein content calculation.

For the determination of the fat content, samples were extracted with petroleum ether for 5 h in a Soxhlett extractor. After evaporation of the solvent and drying of the remaining fraction, the fat content was quantified gravimetrically (Matissek et al. 2006).

Results

Insect species overview

Our surveys in northern Angola revealed 18 species of insects eaten by local people. Sixteen of them were moth larvae, one a beetle larva and one a cricket. Fourteen species have been identified at species level and another four only at family level (Table 1).

Table 1. Species overview. Scientific and vernacular names of insects and host plants according to local Kikongo dialect, except one name, which is marked with (Kim.) according to Kimbundu language; Plant names according to plantlist.org; plant family in square brackets; [ARE] *Arecaceae,* [CAN] *Cannabaceae*, [EUP] *Euphorbiaceae*, [FAB] *Fabaceae*, [MOR] *Moraceae*, [MYRI] *Myristicaceae*, [MYRT] *Myrtaceae*, [PHY] *Phyllanthaceae*, [SAP] *Sapindaceae*, [STE] *Sterculiaceae*; voucher number of herbarium sheets according to Herbarium Dresdense, vouchers marked with F are photo vouchers.

Insect species	Vernacular insect name	ID	NCBI	Host plant species	Vernacular plant name	Vouch. no.
LEPIDOPTERA Saturniidae						
Cirina forda (Westwood, 1849)	Nkuati	R24	MG489854	*Erythrophleum africanum* (Benth.) Harms) *[FAB]*	Ngungu	43233
	Nkuati			*Burkea africana* Hook. *[FAB]*	Kilobo	44200
Imbrasia epimethea (Drury, 1772)	Monguela	R20	MG489850	*Celtis gomphophylla* Baker *[CAN]*	Pau capitão	44219
	Monguela	R23	MG489853	*Ricinodendron heudelotii* subsp. *africanum* (Müll. rg.) J.Léonard *[EUP]*	Monguela	42845
	Nsati	R15	MG489845		Vukua	45866
	Monguela	R21	MG489851	*Ricinodendron heudelotii* subsp. *africanum* (Müll.Arg.) J.Léonard *[EUP]*	Monguela	42845
	Mifuongongo	R17	MG489847			
	Mbukuambukua	R16	MG489846		Mbukuabu-kua	
	Munzundu a mfinda	R3	MG489838	*Celtis gomphophylla* Baker *[CAN]*	Munzundu a mfinda	44219
	Nkumbi			*Entada abyssinica* A.Rich. *[FAB]*	Nsofi	43942
Imbrasia obscura (Butler, 1878)	Mansende	R19	MG489849	*Dichrostachys cinerea* (L.) Wight & Arn. *[FAB]*	Vanga	44232
	Mansende	R18	MG489848	*Macaranga monandra* Müll. Arg. *[EUP]*	Nsasa	42642
	Mansende			*Inga edulis* Mart. *[FAB]*	Banana makako	44781
	Tubula (Kim.)			*Ficus* spec. *[MOR]*	Mulembeira	45865
Imbrasia truncata Aurivillius, 1908	Mbambi	R27	MG489856	*Uapaca vanhouttei* De Wild. *[PHY]*	Musambi	44171
Gonimbrasia (*Nudaurelia*) *alopia* (Westwood, 1849)	Mansendenguenia	R8	MG489839	*Trema orientalis* (L.) Blume *[CAN]*	Mazenden-guenia	44216
Gonimbrasia (*Nudaurelia*) *dione* (Fabricius, 1793)	Mansende	R40	MG489862	*Croton mubango* Müll.Arg. *[EUP]*	Mban-gobango	44230
Pseudantheraea discrepans (Butler, 1878)	Makaba	R9	MG489840		Nsuemba	
Micragone cana (Aurivillius, 1893)	Makuakua	R29	MG489858	*Syzygium guineense* (Willd.) DC. *[MYRT]*	Nkizu	44138
Notodontidae						
Anaphe panda (Boisduval, 1847)	Mukalakala da mata	R14	MG489844	*Bridelia micrantha* (Hochst.) Baill. *[PHY]*	Mukalakala	44224

Insect species	Vernacular insect name	ID	NCBI	Host plant species	Vernacular plant name	Vouch. no.
Anaphe panda (Boisduval, 1847)	Munzunzu	R12	MG489843	*Bridelia micrantha* (Hochst.) Baill. *[PHY]*	Munzunzu	44224
	Minzunzu	R11	MG489842	*Bridelia micrantha* (Hochst.) Baill. *[PHY]*	Munzunzu	44224
	Munzundu	R34	MG489861	*Bridelia micrantha* (Hochst.) Baill. *[PHY]*	Minzundu	44224
Anaphe venata Butler, 1878	Milenda	R1	MG489837	*Sterculia tragacantha* Lindl. *[STE]*	Milenda	44004
Notodontidae sp. 1	Minsinda	R22	MG489852	*Eriosema glomeratum* (Guill. & Perr.) Hook.f. *[FAB]*	Wandu	43168
Notodontidae sp. 2	Mbanzubanzu	R31	MG489860	*Allophylus africanus* P. Beauv. *[SAP]*	Mban-zubanzu	41878
Notodontidae sp. 3	Mindelumuka	R28	MG489857			
Notodontidae sp. 4	Minsangula	R30	MG489859	*Pycnanthus angolensis* (Welw.) Warb. *[MYRI]*	Didila	44478
Erebidae						
Sciatta inconcisa Walker, 1869	Milenda	R10	MG489841	*Ficus bubu* Warb. *[MOR]*	Mindel-emuka	44223
Lasiocampidae						
Gastroplakaeis rubroanalis Wichgraf, 1913	Mbuokutu	R26	MG489855		Mbuokutu	
COLEOPTERA Curculionidae						
Rhynchophorus phoenicis (Fabricius, 1801)	*Larva:* Nsombe *Chrysalis:* Kinkekete *Imago:* Kinkakala			*Raphia spec. [ARE]*	Bordão	F_60
ORTHOPTERA Gryllidae						
Brachytrupes membranaceus (Drury, 1770)	Grilho	MB3108	MG489863	*different crop plants*		

Half of the moth species belonged to Saturniidae (Figs 2, 3), the larvae of which could both be reared to imagoes and identified based on the wing pattern of the imagoes and/or identified using DNA-barcodes. The same holds true for the two *Anaphe* species belonging to Notodontidae (Fig. 4). Another four species of Notodontidae were identified based on morphological characters of the larvae. Their species names could not be identified, neither by comparing their DNA-barcodes with the BOLD database nor with collected moth samples. Notodontidae sp. 1 is a green larva which coincides with a figure given by Latham (2005: 24), who identified it as *Antheua* sp. and who provided information that the larva first feeds on *Eriosema psoraleoides* and later changes to *Hyparrhenia diplandra* and other grasses. We recorded this species only once on *Eriosema glomeratum* and local people reported that it would later change to grasses.

Larvae of *Sciatta inconcisa* (Erebidae) were reared to imagoes and identified using Goff (2016–2017). The larva of *Gastroplakaeis rubroanalis* (Lasiocampidae) (Fig. 5) has been identified on BOLD using the DNA-barcode. *Rhynchophorus phoenicis* (Curculionidae) has been identified by imagoes found in parallel with the larvae using Peña (2013) and Tanyi Tambe et al. (2013). *Brachytrupes membranaceus* (Gryllidae) has been identified using Cigliano et al. (2017).

Beside the species mentioned above, we collected dried termite samples in May 2014 at the local market in Uíge. Unfortunately, these termites had already been processed. Therefore, they were neither suitable for DNA-barcoding nor for morphological identification. Though we visited the area during different times of the year, we never met people harvesting termites. For all other insect species, we were able to obtain DNA-barcodes (Table 1).

Host plants

Along with the sampled larvae, we collected vouchers for the food plants. Their scientific and vernacular names are given in Table 1.The main habitats of the documented food plants are found in dense forest formations and forest margins (63%). Thirty two percent (32%) of the plants are typical plants from open forests and wooded savannah whereas different savannah formations like Zambesi or Guinese are involved (Fig. 1). As the studied area in Northern Angola is characterised by a distinct mosaic-like vegetation structure, the mentioned habitats are alternating perpetually. The species are mainly trees (90%), only Notodontidae sp. 1 was found on the perennial herb *Eriosema glomeratum* and the cricket *Brachytrupes membranaceus* was detected in fields, feeding on crop plants. As per the Prota 4U data base (www.prota4u.org), six out of the 17 tree species are of international importance due to their timber qualities and therefore under increasing anthropogenic pressure. These are *Erythrophleum africanum* (internationally traded under the name missandi or tali), *Burkea africana*, *Celtis gomphophylla* (ohia), *Ricinodendron heudelotii* subsp. *africanum* (essessang), *Bridelia micrantha* (assas) and *Pycnanthus angolensis* (ilomba). One food plant (*Inga edulis*) was detected as being an invasive plant species in Africa.

Phenology

Local differences in climate, rainfall and thus fresh growth of host plant foliage cause a strong seasonality of the appearance of edible caterpillars (Malaisse 2005). In the Province Uíge, the main caterpillar season starts in January and lasts until the end of February (Table 3).

Larvae of *Rhynchophorus phoenicis* are to be found throughout the year, but with a decrease in availability during the dry season, according to local harvesters. We found *Brachytrupes membranaceus* from November to February.

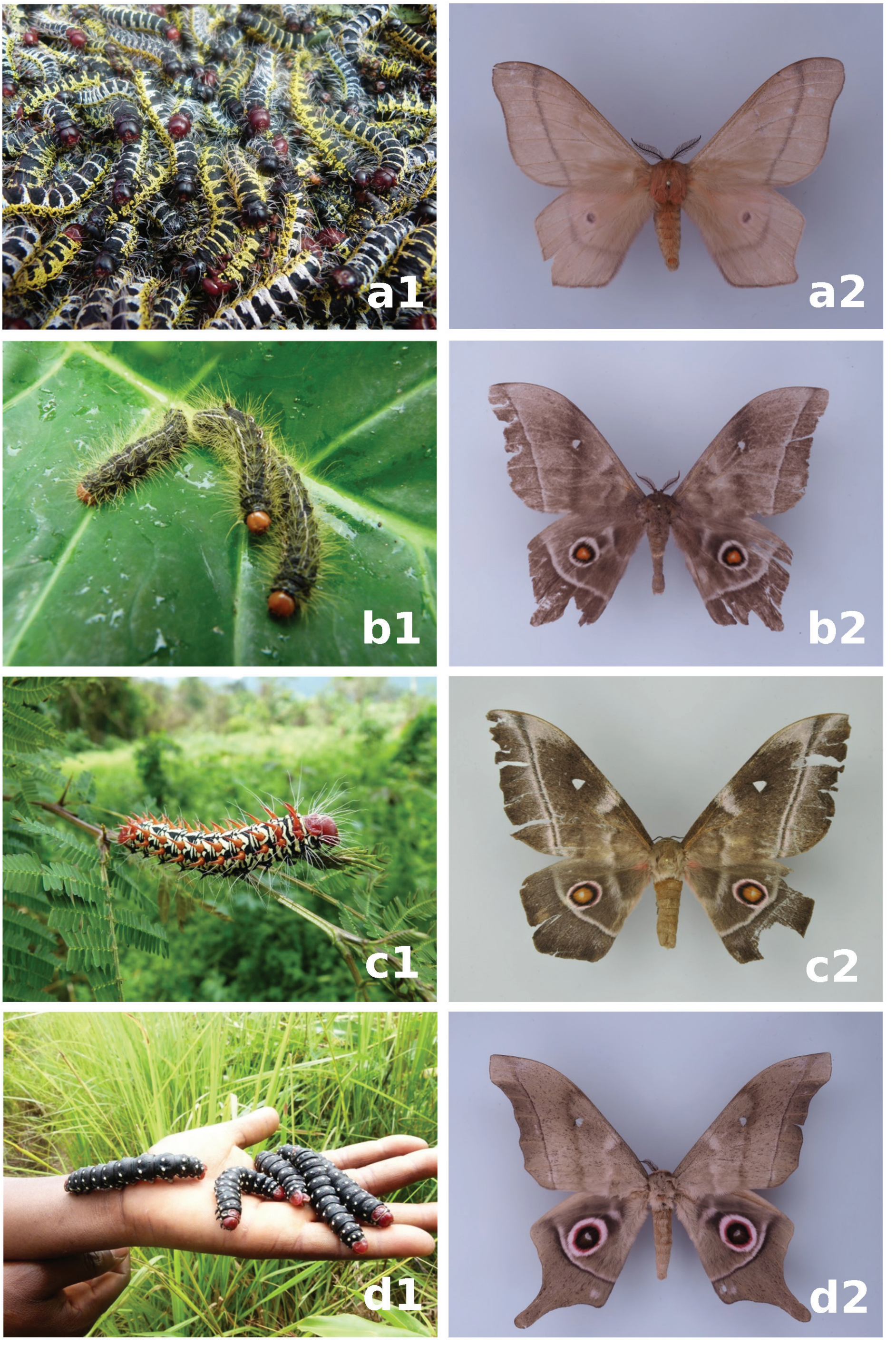

Figure 2. Photographs of 4 edible Saturniidae-larvae collected in the Province Uíge and its imagoes. **a** *Cirina forda* (1) larva, (2) male imago **b** *Imbrasia epimethea* (1) larva, (2) male imago **c** *Imbrasia obscura* (1) larva, (2) male imago **d** *Imbrasia truncata* (1) larva, (2) male imago.

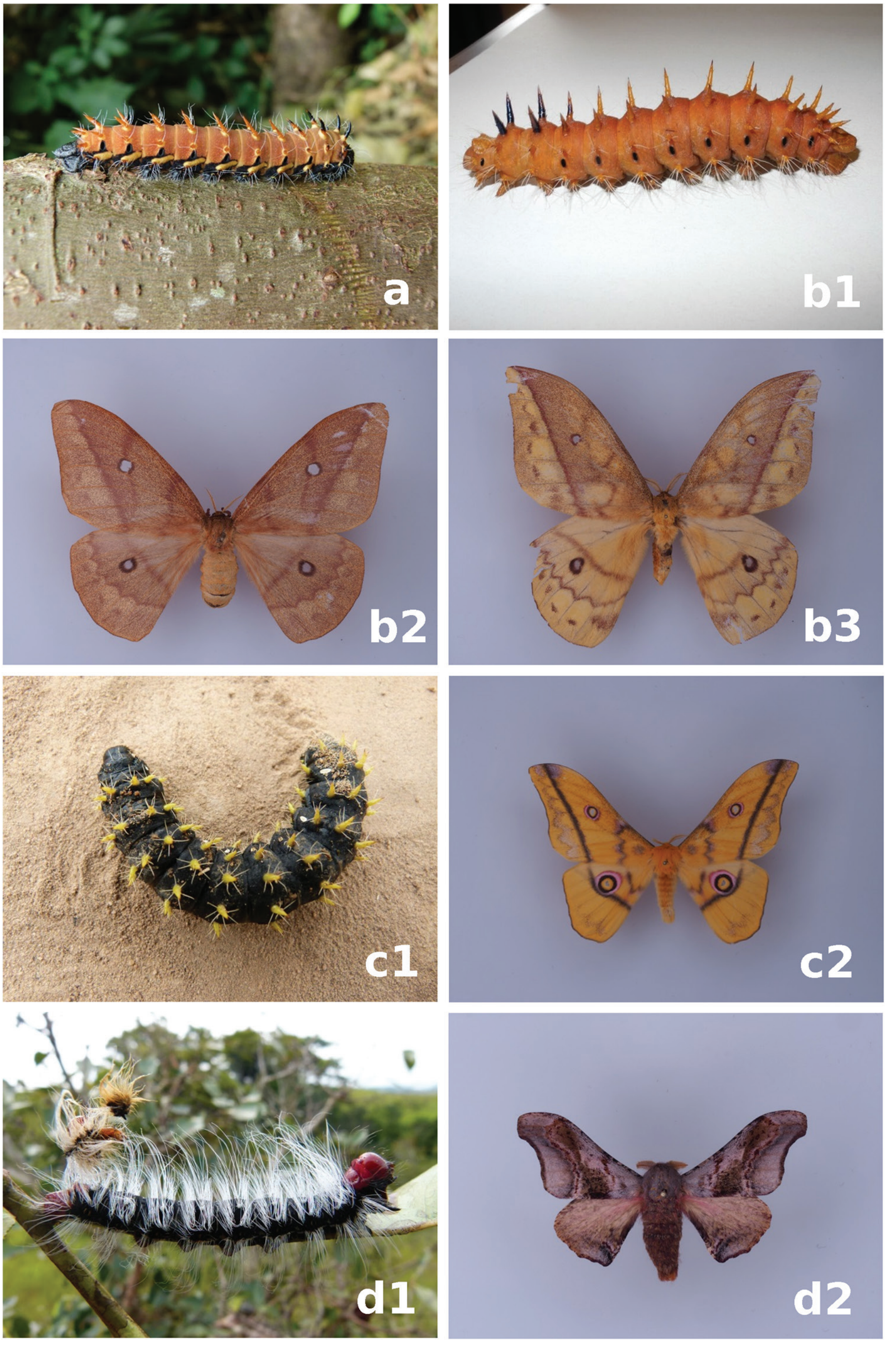

Figure 3. Photographs of another 4 edible Saturniidae-larvae collected in the Province Uíge and its imagoes. **a** larva of *Gonimbrasia alopia* **b** *Pseudantheraea discrepans* (1) larva, (2) female imago (3) male imago **c** *Gonimbrasia dione* (1) larva, (2) male imago **d** *Micragone cana* (1) larva, (2) male imago.

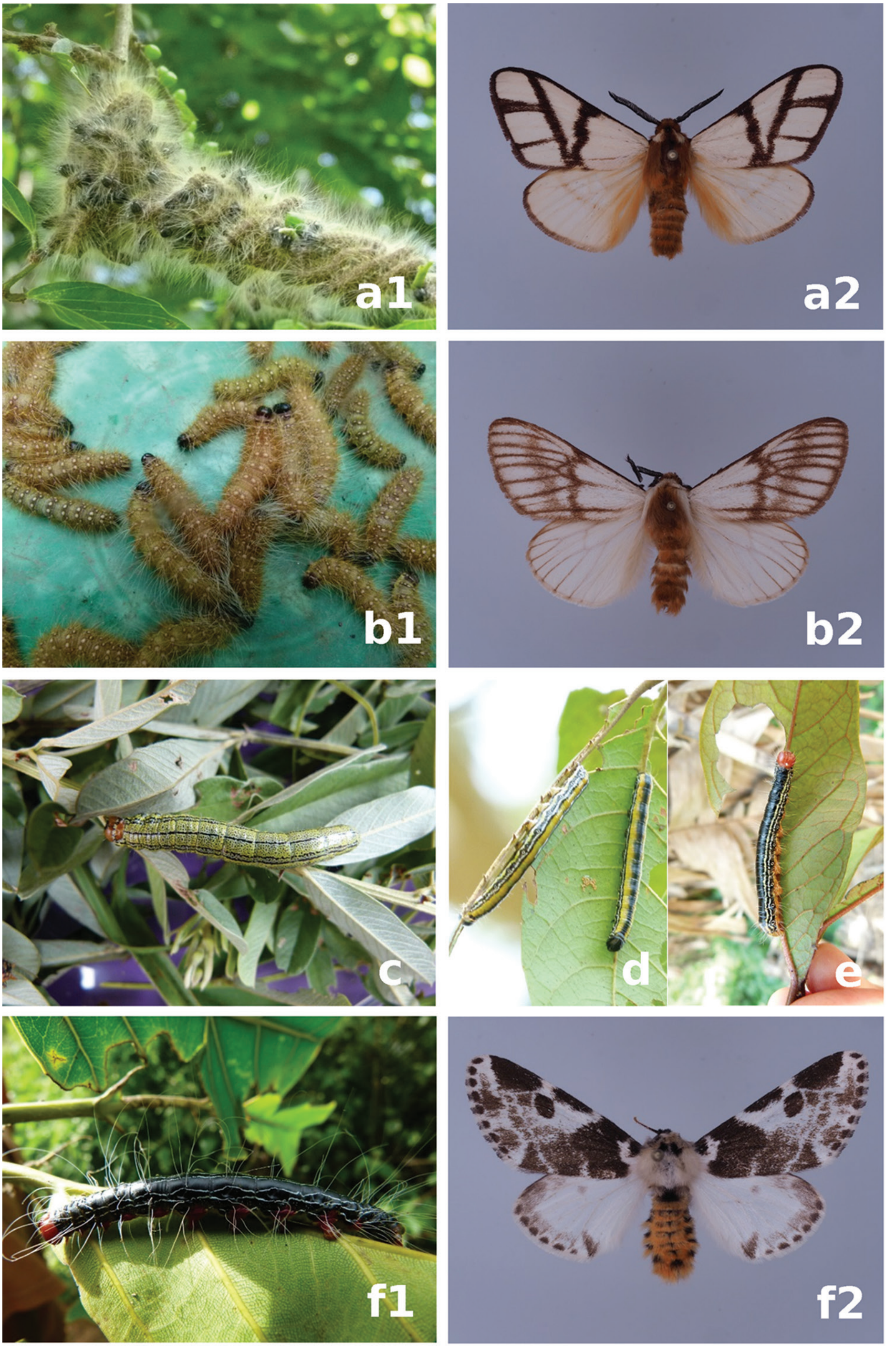

Figure 4. Photographs of edible larvae of Notodontidae (**a–e**) and Erebidae (**f**), collected in the Province Uíge. **a** *Anaphe panda* (1) larva (2) male imago **b** *Anaphe venata* (1) larva, (2) male imago, **c** Notodontidae sp. 1 **d** Notodontidae sp. 2 (left) and **e** Notodontidae sp. 4 (right) **f** *Sciatta inconcisa* (1) larva, (2) male imago.

Figure 5. Photographs of edible larvae of Lasiocampidae (**a**), Curculionidae (**b**), photo taken by Barbara Ditsch and Gryllidae (c) collected in the Province Uíge. **a** *Gastroplakaeis rubroanalis* (1) in cocoon and (2) without **b** *Rhynchophorus phoenicis* **c** *Brachytrupes membranaceus.*

Traditional collection and preparation

The majority of identified caterpillar species live on trees. Children usually collect them, as they are skilful and agile enough to climb up the trees and pick them from the twigs. In addition, men and women going into the field or hunting in the forest focus on larvae in the upper vegetation or individuals which have dropped to lower levels. The characteristic faeces on the ground indicate their presence. Several times, we also detected the quite unsustainable method by which caterpillars are collected - cutting down the whole tree or at least large branches (Fig. 1c). Nests, formed by larvae of *Anaphe panda*, are usually cut down from the tree and stored at home until preparation.

Caterpillars are first washed in water. The long hairs of *Anaphe panda* must be removed before boiling. Normally, local people singe them off in a frying pan over the fire. The gut of the collected Saturniidae caterpillars, except *Cirina forda*, has to be removed because host plants, according to the statements of interviewed persons, contain toxic substances (or rather the faeces do) which spoil the flavour. Since several host plant species belong to the plant family Euphorbiaceae, well-known for their poisonous secondary compounds (Mwine and Damme 2011), this is not surprising. Different methods are used for that cleaning. A time-consuming but cleaner method is to break

Table 2. Alphabetical order of insect species with vegetation unit, collection date, GPS coordinates (DMS); map ID according to Fig. 1c in square brackets; [B] Bungo, [D] Damba, [K] Kangola, [M] Mucaba], [N] Negage, [P] Puri], [Q] Quimbele, [U] Uíge.

Insect species	Vegetation unit	Municipality	Collection date	Eastern longitude	Southern latitude	Level [m]	ID in map
Anaphe panda	Forest	Uíge	26.i.2014	14°57'40"	7°37'00"	1.000	U
	Forest	Bungo	06.ii.2014	15°10'23"	7°25'59"	1.244	B
	Forest	Uíge	06.ii.2014	15°05'07"	7°27'05"	909	U
Anaphe venata	Village	Damba	25.ii.2015	15°07'47"	6°55'16"	1.061	D
Brachytrupes membranaceus	Field	Negage	11.xi.2013	15°36'29"	7°41'13"	1.152	N
Cirina forda	Savanna	Puri	30.i.2014	15°36'23"	7°41'48"	1.085	P
	Savanna	Puri	30.i.2014	15°35'32"	7°41'40"	1.085	P
Gastroplakaeis rubroanalis	Forest	Quimbele	20.ii.2015	16°17'05"	6°31'36"	741	Q
Gonimbrasia alopia	Forest	Bungo	06.ii.2014	15°10'23"	7°25'59"	1.244	B
	Forest	Bungo	17.ii.2015	15°10'23"	7°25'59"	1.244	B
Gonimbrasia dione	Village	Damba	28.vii.2015	14°55'06"	6°51'07"	812	D
Imbrasia epimethea	Forest	Uíge	26.i.2014	14°58'46"	7°37'47"	790	U
	Forest	Negage	28.i.2014	15°11'38"	7°39'35"	1.178	N
	Forest	Uíge	29.i.2014	14°57'33"	7°40'48"	610	U
	Forest	Uíge	02.ii.2014	14°58'26"	7°37'38"	859	U
	Forest	Bungo	06.ii.2014	15°10'23"	7°25'59"	1.244	B
	Forest	Bungo	06.ii.2014	15°09'32"	7°24'04"	1.244	B
	Forest	Damba	25.ii.2015	15°07'47"	6°55'16"	1.061	D
Imbrasia obscura	Forest	Uíge	27.i.2014	14°57'14"	7°34'27"	813	U
	Forest	Uíge	29.i.2014	14°57'34"	7°40'32"	622	U
	Forest	Uíge	11.ii.2017	15°05'40"	7°27'06"	937	U
	Forest	*Malanje Province*	01.iii.2017	16°00'00"	9°04'26"	1.063	
Imbrasia truncata	Forest	Quimbele	19.ii.2015	16°16'57"	6°38'01"	801	Q
Micragone cana	Savanna	Damba	23.ii.2015	15°11'22"	6°55'10"	1.094	D
Pseudantheraea discrepans	Forest	Negage	08.ii.2014	15°11'38"	7°39'35"	1.178	N
	Forest	Quimbele	20.ii.2015	16°17'05"	6°31'36"	741	Q
	Forest	Damba	26.ii.2015	15°07'47"	6°55'16"	1.061	D
Rhynchophorus phoenicis	Market	Uíge	10.x.2016	15°03'27"	7°36'48"	(M)	U
	Forest	Kangola	12.xi.2015	15°50'20"	7°56'53"	1.095	K
Sciatta inconcisa	Savanna	Uíge	06.ii.2014	15°07'07"	7°27'05"	909	U
*Notodontidae*sp. 1	Savanna	Mucaba	03.ii.2014	15°06'23"	7°12'53"	1.160	M
*Notodontidae*sp. 2	Forest	Bungo	17.ii.2015	15°10'23"	7°25'59"	1.244	B
*Notodontidae*sp. 3	Forest	Damba	25.ii.2015	15°07'47"	6°55'16"	1.061	D
*Notodontidae*sp. 4	Forest	Bungo	17.ii.2015	15°10'23"	7°25'59"	1.244	B

open each individual caterpillar and pull out the green contents of the gut. Alternatively, a handful of caterpillars is mashed so that faeces are squeezed out, though some of the green gut content remains inside. According to local collectors, the gut of cat-

Table 3. Phenology of collected edible insect species, based on collected samples: **grey** larvae, **black** imagoes.

Species	Month											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Cirina forda												
Imbrasia epimethea												
Imbrasia obscura												
Imbrasia truncata												
Gonimbrasia alopia												
Gonimbrasia dione												
Pseudantherea discrepans												
Micragone cana												
Anaphe panda												
Anaphe venata												
Sciatta inconcisa												
Notodontidae sp. 1												
Notodontidae sp. 2												
Notodontidae sp. 3												
Notodontidae sp. 4												
Gastroplakaeis rubroanalis												
Rhynchophorus phoenicis												
Brachytrupes membranaceus												

erpillars, which are found on the ground, is not removed because these individuals are ready to pupate and therefore have self-cleansed. In a further step, caterpillars are boiled in salt water, optionally with hot pepper (*Capsicum frutescens*) until water is evaporated and larvae are dry. The spines of *Pseudantheraea discrepans* and *Imbrasia obscura* are not removed but also eaten. The gut of caterpillar species belonging to Notodontidae and Erebidae do not have to be pulled out. Local consumers reported that *Gastroplakaeis rubroanalis* (Lasiocampidae) is pulled out of its cocoon before boiling because the hairs are extremely irritating to human skin.

The high fat content of the African palm weevil *Rhynchophorus phoenicis* enables it to be prepared easily by cutting open the larvae and frying it. Crickets of *Brachytrupes membranaceus* are strung on a wooden stick, roasted over a fire and later sold at the markets.

Cultural aspects and etymology of vernacular caterpillar names

Edible caterpillars have different local names in the Bantu-language Kikongo, which is spoken by the Bakongo ethnic group in Uíge. In the various research areas, the general terms vary: in the municipality of Uíge, it is called *mankoko*, whereas in the municipality of Damba local people describe it as *impiatu*. In the northern municipality of

Quimbele, which borders the Democratic Republic of Congo, people name caterpillars as *nvukwa* or *mihuka.* Furthermore, local taxonomy divides caterpillar species into *mazende* (caterpillars with spines), *mazende mika* (caterpillars with spines and hairs) and *mvuka, mihuka* or *huka* (caterpillars without spines or hairs).

Local names on species level often refer to the main food plants, which appear to be similar throughout Africa, wherever caterpillars are eaten (Malaisse 2010, Latham 2005). Thus, the same caterpillar species can be named with different local names.

Interestingly, *makuakua* (*kwâkwa*) translated from Kikongo means caterpillar with long stinging bristles (Laman 1936). According to Latham (2017), in the DRC, *makuakua* caterpillars are not eaten, probably due to their stinging hairs. However, people who were interviewed in our study, do eat this species as they burn off the hairs before cooking.

As already mentioned, the life cycle of holometabolic insects is often not known. Instead, in the eyes of many local people, larvae and their imagoes share no relation to each other. Nevertheless, the connection between caterpillars and birds is drawn. With the beginning of the rainy season in October, migratory birds return and within their beaks, they often bring along caterpillars. A symbol for the concurrent starting season of caterpillars is a bird which sings "makoko é" – translated from Portuguese and, in the figurative sense, it means "the caterpillar season starts". Due to its call, this bird could probably be Klaas´s Cuckoo (*Chrysococcyx klaas*) as cuckoos are also major consumers of caterpillars (Mills 2015). People believe that when caterpillars reach maturity, they come off the trunk and bury themselves in the soil to die. During this period, one traditional method for collection is to knock on the trunk with a machete. According to local inhabitants, caterpillars hear the noise and curiously descend the trunk where they can be collected easily. This accumulation of individuals refers especially to gregarious species like *Imbrasia epimethea* or *Anaphe panda*.

Market analysis

Some insect species are commonly offered for sale at local markets. After collection and boiling in salt water, the larvae of Saturniidae or Notodontidae are dried in the sun. The dried larvae of *Cirina forda* are found at the most important city market in the provincial capital, Uíge, throughout the whole year until the new season starts, whereas *Imbrasia epimethea* and *Anaphe panda* are offered only at a certain time. Prices vary depending on market, quantity and the variety on offer from the sellers. Women selling these larvae also often offer beans and peanuts.

From 2013/2014 to 2016/2017, we noticed a significant increase in prices of one caterpillar species. While in 2013 and 2014, one kilo of *Cirina forda* was sold for 2 to a maximum of 3 US$, in 2016 and 2017 the prices had already doubled to 6-7 US$, irrespective of whether larvae were alive or dried.

It is hard to find caterpillar species other than those already mentioned at local markets. During the caterpillar season, *Pseudanthera discrepans*, *Imbrasia obscura, Imbrasia epimethea* and *Anaphe panda* are frequently found. As *Pseudanthera discre-*

pans and *Imbrasia obscura* are comparatively large larvae, prices are higher (0.5 US$ for 10 units) than for gregarious species like *Imbrasia epimethea* and *Anaphe panda,* which always occur in large quantities (0.5 US$ for 50 units). Since these species are rarely sold, accurate statements about distribution and trends in their occurrence are not possible. In our study, 11 of the 18 insect species are exclusively consumed in the villages where they were collected. However during the caterpillar season in January and February, while passing through rural areas by car, it is possible to buy some recently collected caterpillars in plastic bags offered by children (roadside vendors). A quantitative analysis of the percentage of caterpillars sold at local markets is still not possible. Nevertheless it can be said that the occurrence of different insect species represents a key source of income for local people. Prices are relatively high, comparing one kilo of *Imbrasia epimethea* or *Cirina forda* (6 to 7 US$) with one kilo of beans and peanuts (3 to 4 US$) at the same market in Uíge city. Moreover, these caterpillar species are simply collected from the wild while beans and peanuts need to be cultivated.

Larvae of *Rhynchophorus phoenicis* are also sold the whole year round and priced at 4 pieces for 1US$ which is relatively expensive. Muafor et al. (2014) documented lower prices in Cameroon (0.2 US$). Roasted crickets (*Brachytrupes membranaceus*) are sold mainly during the rainy season at 0.5 to 1 US$ for 10 units.

Nutritional value

Table 4 gives the results of moisture, protein and fat analyses for Lepidoptera (Saturniidae, Notodontidae and Erebidae), Coleoptera (Curculionidae) and Orthoptera (Gryllidae) collected from the municipalities of Uíge, Bungo, Puri, Negage and Mucaba in January and February 2014. For *Brachytrupes membranaceus*, the analyses of the 'native' species were supplemented by data from the grilled individuals. Non-prepared samples of all insects show high moisture contents, ranging from 70 to 80%. Prepared Gryllidae differ due to the loss of water caused by the grilling process.

Discussion

Insect species

We recorded 18 insect species eaten by humans in northern Angola, 14 species for the first time from Angola and *Sciatta inconcisa* and *Gastroplakaeis rubroanalis* for the first time as edible insects. Considering all records about edible insects from Angola together with our results, in total 38 insect species are used as sources of food. This number is more or less equal to those of neighbouring provinces, e.g. 30 species in Kwango (Leleup and Daems 1969), 42 species in Bas-Congo (Latham 2005), 35 species in Katanga (Malaisse and Parent 1980) and 60 species in Zambia (DeFoliart 1999).

Table 4. Composition of major nutrients. Values per 100 g dry matter, moisture per 100 g fresh weight; indices give the number of analyses [a]single, [b]double, [c]triple, [d]quadruple, [e]sextuple; d.m.: dry matter,[1]: Malaisse and Parent 1980,[2]: Adriaens 1953,[3]: Kokondi et al. 1987,[4]: Lautenschläger et al. 2017,[5]: Santos Oliveira et al. 1976,[6]: Idolo 2010,[7]: Edijala et al. 2009,[8]: Ekpo 2010 and 2011,[9]: Mbemba 2013 (sun or oven dried),[10]: Agbiye 2009 (oven dried samples),[11]: Yhoung-Aree 1997,[12]: Okaraonye and Ikewuchi 2008.

	moisture [g/100 g]		**protein** [g/100 g d.m.]		**fat** [g/100 g d.m.]	
LEPIDOPTERA **Saturniidae**		*references*		*references*		*references*
Cirina forda	79.4 +- 3.8[b]	73.0[1]	57.8 +- 1.1[d]	62.3[2] 51.9[1] 74.4[10]	13.1 +- 3.6[b]	12.5[2] 13.4[1] 14.3[10]
Imbrasia epimethea without gut	79.8 +- 3.2[c]	93.0[3] 85.0[1]		73.1[4] 64.5[2] 58.1[3] 65.9[1]	6.4 +- 3.8[d]	5.9[4] 9.1[2] 12.4[3] 14.2[1]
Imbrasia obscura without gut	83.0 +- 1.0[b]	9.0[5]	62.3 +- 3.4[d]	53.5[5]	5.4 +- 3.3[c]	12.2[5]
Gonimbrasia alopia without gut	85.7[a]		62.0 +- 0.6[b]		1.9[a]	
Pseudantheraea discrepans without gut	72.2[a]		48.9 +- 0.8[b]		21.3 +- 0.9[b]	
Notodontidae						
Anaphe panda	83.4 +- 0.1[b]	73.9[1]	53.2 +- 1.3[d]	45.6[1]	5.6 +- 3.0[b]	35.0[1]
Notodontidae sp. 1	79.5[a]		41.4 +- 0.4[b]		10.1[a]	
Erebidae						
Sciatta inconcisa	73.7[a]		46.2 +- 0.6[b]		28.02[a]	
COLEOPTERA **Curculionidae**						
Rhynchophorus phoenicis	76.8[a]	77.4[1] 89.2[5] 60.4[6] 64.7[7] 61.9[8]	32.8 +- 0.3[d]	56.6[2] 42.6[1] 22.8[5] 25.3[6] 28.0[7] 22.0[8] 38.6[12]	38.2 +- 1.1[b]	12.0[2] 20.2[1] 46.7[5] 69.9[6] 62.0[7] 66.4[8] 19.5[12]
ORTHOPTERA **Gryllidae**						
Brachytrupes membranaceus 'native' 'grilled'	68.6[a] 5.3[a]	44.3[9] 14.2[9]	61.6 +- 0.3[b] 63.1 +- 1.1[d]	35.2[9] 63.4[9] 35.1[10] 47.9[11]	11.9[a] 32.3 +- 0.1[b]	47.6[9] 36.6[9] 53.1[10] 21.3[11]

Besides the species recorded as edible in Northern Angola, we also found imagoes of a further three saturniid species attracted by artificial lights during the night, the larvae of which are known from the Democratic Republic of Congo to be edible. These are *Gonimbrasia* (*Nudaurelia*) *eblis* Streck, 1876, *G.* (*N.*) *melanops* (Bouvier, 1930) and *Melanoceranereis* (Rothschild, 1898) (Mitsuhashi 2017). So far, we do not know whether these species are consumed in Northern Angola, but these findings point to the possibility that more species might be used and/or that there is potential to use more insect species. In our interviews, some people explained that they were aware of insect species which were not eaten in their own territory but were consumed in other regions. This might be due to different food plants used by the caterpillars, along with different secondary compounds in the plants influencing taste or making them toxic. Further species might also be used in other parts of Angola. As an example, 'mopane worms' (*Gonimbrasia belina*) which are widely used in Namibia and South Africa and nowadays commercially reared and traded, have also been recorded from Southern Angola (Rougeot 1964).

Some of the species consumed in Northern Angola are widely used in Africa. People eat caterpillars of *Cirina forda* from Togo (Badanaro et al. 2014) and Nigeria (Fasoranti and Ajiboye 1993; Ande 2002; Agbidye 2009) to South Africa (DeFoliart 1995). Similarly, *Rhynchophorus phoenicis* and *Brachytrupes membranaceus* are used northwards up to Nigeria (Fasoranti and Ajiboye 1993).

A major issue in studying edible insects is the difficulty with identification of the species. For many of the relevant species, information in identification keys and/or DNA-databases is not yet available. Identification is further hampered by the fact that insect identification largely focuses on the imagoes rather than on larvae. This necessitates rearing the individuals until adult stage or by using methods such as DNA-Barcoding. Furthermore, changes of nomenclature such as of synonyms and changed genus combinations complicate the comparison of results obtained in different countries and during different decades. In the genus *Imbrasia*, we have found a situation which deserves taxonomic revision. On the one hand, there are very different morpho-types of larvae (Figs b1, c1, d1), while on the other hand, adults displaying the morpho-type of *I. ertli* Rebel, 1904 and *I. obscura* are identical in the DNA-barcode.

Host plants

For Congo-Brazzaville, Mabossy-Mabouna et al. (2016) listed 50 plant species serving as host plants for edible caterpillars, five of which were documented again in our survey but for different caterpillar species, except for the citation of *Ricinodendron heudelotii* subsp. *africanum*, which is the host tree for the *Imbrasia epimethea* caterpillar. Moreover, two additional host plants belong to the same genera but different species are already listed there (*Erythrophleum*, *Uapaca*). Numerous statements from local people indicate that insect species, which we detected on just one host plant species, also feed on other plant species. As we could not validate this information, we did not list it here. Again a comparison with published data reveals that the studied insect species use further host plants. For Angola, Santos Oliveira et al. (1976) mention *Brachystegia speciformis* as the regular host plant for *Imbrasia obscura* and the oil palm, *Elaeis guineensis* for the palm weevil *Rhynchophorus phoenicis*. Fasoranti and Ajiboye (1993) observed in Nigeria that palm weevils often occur when trees are under stress e.g. due to the local traditional tapping for palm wine, as we observed for *Raphia* sp. in Uíge. The wider the area considered and the more publications that are taken into account, the greater the increase in the list of host plants per species should result. For the moment, we do not know about any monophagous behaviour of the considered insect species in the study area.

Traditional harvesting methods and even host plant manipulations described by Latham (2005) or Itterbeeck and Huis (2012) could not be detected in our study area in Northern Angola. On the contrary, several times unsustainable tree felling was observed. When asked about this, harvesting people mentioned the rapid re-growth of trees in this region. Huis et al. (2013) enumerate this unsustainable harvesting method as one of several reasons (such as over-exploitation, deforestation or pollution) why some insect species are threatened or extinct. Considering earth observation satellite data, an increased forest loss in Angola is evident (Hansen et al. 2013) as well as observations by Lautenschläger and Neinhuis (2014) showing that Uíge province is an important target of the logging industry. The area of natural habitats of several edible insect species is therefore rapidly decreasing.

Phenology

Due to different climatic conditions, the phenology of insect life cycles observed in our study area partly deviates from adjacent regions. In the region Bas-Congo (Democratic Republic of Congo), the caterpillar season lasts longer, from November to February (Latham 2005) whereas in the Katanga region (Democratic Republic of Congo), the main harvesting time is from March to May (Malaisse 2013). Mabossy-Mabouna et al. (2016) list caterpillar collection seasons for three regions in the Republic of Congo: in the northern part from mid-July to mid-August; in the central-southern part from mid-October to mid-February; and in the southern-western part, in the Chaillu massif, from mid-August to mid-September.

The appearance of larvae of *Gonimbrasia dione* in July 2015 in the Uíge Province therefore was surprising. According to the respondents, a few other caterpillar species also occur outside the caterpillar season in February.

Larvae of *Rhynchophorus phoenicis* occur throughout the year. Differences in harvested grub quantities between dry and rainy season were also described for Nigeria, varying up to fourfold in the rainy season (Opara et al. 2012). This would confirm the statements from local people in Uíge about a decrease in grubs during the dry season.

Market analysis

Due to insufficient data, comparing market analyses results of prices and income with other countries is difficult. In addition, price analyses are valuable only in the context of each particular gross national product and vary from village level, in markets and online (Huis et al. 2013). Badanaro (2014) documented the Togo retailer prices on *Cirina forda* up to 2.5 US$ per kilo in 2013 while for Nigeria, in 2009 prices for one kilo of *Cirina forda* reached 1.4 US$ (Agbidye et al. 2009). However, collected data indicate that the collection and sale of some of the edible insects are part of the livelihood diversification strategy in Northern Angola that provides multiple income-generating opportunities for households, comparable to other countries (Huis et al. 2013). Nevertheless, initial indications of over-exploitation are starting to appear. Prices for the caterpillar species *Cirina forda* increased markedly within two years. When populations become sparser, it is increasingly costly to exploit them and exploitation ceases to be beneficial (Clark 1990). This leads to the assumption that the occurrence of *Cirina forda* might decrease or populations are disrupted since, in the same period, the price of other edible insects did not increase, as for larvae of the palm weevil (*Rhynchophorus phoenicis*) or crickets (*Brachytrupes membranaceus*). It is, however, also conceivable that considerable quantities are exported to the adjacent Democratic Republic of Congo. In Bas-Congo, this species, *Cirina forda*, was very popular until 1998 when it became rare. Now it has almost completely disappeared. Projects for its reintroduction until now have had limited success. Over-exploitation therefore can be a decisive reason for the extinction of a species; this effect is known as the anthropogenic Allee effect (Courchamp et al. 2006). On the other hand, according to FAOstat (16.06.2017), the domestic food price index in Angola has increased from 2002 to 2012 by 30 percent, still with an upward trend (FAOstat 16.06.2017) which could also lead to a general increase in distant provinces.

In Nigeria, differing prices for larvae of the palm weevil (*Rhynchophorus phoenicis*) depending on seasons were detected (Opara et al. 2012). In times of reduced supply in the dry season, prices increase by two thirds.

Nutritional value

Highest protein and fat contents amongst the Lepidoptera are found for the Saturniidae ranging from 50 to 65% protein and 2 to 21% fat per 100 g dry matter. The data obtained for *Cirina forda* and *Imbrasia epimethea* accord especially well with those reported in literature (these are also given in Table 4). Differences occur for *Imbrasia obscura* for which lower protein and higher fat contents were reported by Santos Oliveira et al. (1976). This might be caused by a number of reasons. Especially for the analyses of fat content, different solvents used for extraction (petroleum ether vs. sulphuric ether) influence the result significantly. In addition, samples analysed for reference data were already prepared (cooked, roasted or dried). The state of maturity and nutrition of the caterpillars may affect the nutritional composition, especially contents of fat and carbohydrates.

To our knowledge, no nutritional data have been published for *Gonimbrasia alopia* and *Pseudantheraea discrepans*, which are presented here for the first time. While the main nutrients of *Gonimbrasia alopia* generally match those of the Saturniidae discussed above, the fat content of *Pseudantheraea discrepans* exceeds the others by a factor of 2. As the fat content reported in this work tends to be in the lower range of already published data, this should be confirmed by further analyses.

Fewer references than for the Saturniidae are available for the Notodontidae and Erebidae. Thus, to our knowledge, this publication is the first to document moisture, protein and fat contents of Notodontidae sp. 1 and *Sciatta inconcisa*. Main nutrients for both species are in similar ranges to those reported by Malaisse and Parent (1980) for *Anaphe panda*, which is the third examined Notodontidae in this paper. Protein content was up to 53% for *Anaphe panda,* the minimum amount was analysed as 41% in Notodontidae sp. 1. Fat content ranges between 6 and 28% d.m. Malaisse and Parent (1980) found higher fat (35%) and lower protein content (46%) than reported in our study. Compared to the Saturniidae, the Notodontidae and Erebidae provided less protein and more fat. The latter therefore might be a better source of energy while the Saturniidae are possibly to be preferred when focusing on protein supply.

Our results for *Rhynchophorus phoenicis* fit within the broad range of data already reported in literature (Malaisse and Parent 1980, Adriaens 1953, Santos Oliveira et al. 1976, Idolo 2010, Edijala et al. 2009, Ekpo 2010 and 2011, Okaraonye and Ikewuchi 2008, FAO/INFOODS Food Composition Database 2006). Published nutritive contents range from 22 to 57% d.m. for protein and from 12 to 70% fat. The broad range emphasises the importance of factors like nutrition and state of maturation, affecting the nutritional composition of the larvae. Even the ratio of protein to fat differs within literature, pointing to fat as well as protein as the main ingredients in the dry matter. Similar observations could be made for *Brachytrupes membranaceus*. The comparison with reference data is limited by the reduced number of analyses due to small sample sizes on the one hand and differences in sample preparation and analytical methods on the other hand. Lipid contents, for instance, result from extractions with different solvents such as carbon tetrachloride applied by Mbemba (2013) for *Brachytrupes membranaceus* or petroleum ether used within the actual studies. The general problem of limited comparability between (and sometimes reliability of) published data is emphasised by Payne et al. (2014). Besides the need to apply comprehensive, comparable and standardised analytical methods, they refer to a systematic sample acquisition (sampling plan, number of samples) as well as to a accurate description of specific species and sample preparation (roasting, cooking etc.). More studies considering those markers of scientific quality are needed to obtain a more reliable insight into the nutritive qualities of specific insect species.

Our data supports the rating of (traditional African) insects as valuable source of protein and fat for human and animal nutrition, as stated by several authors and organisations (WHO FAO 2002; Belluco et al. 2013; DeFoliart 1992).

Possible anti-nutritive aspects have not yet been included in our work. As some caterpillars are known to feed on plants toxic to humans and accumulation of secondary metabolites in insects as repellents has already been documented, this topic should be part of further studies. Microbial and parasitical contamination as well as the allergenic potential should also be considered. However, Belluco et al. (2013) note that simple hygienic measures in preparation such as thermal processing or freezing should reduce the biological risks.

Conclusions

People in northern Angola use insects as an important part of their daily diet, at least during a certain season. With this work, we increase the number of documented edible insects in Angola from 24 to 38. Even if we could not quantify consumption of edible insects in Northern Angola, besides the few domestic animals, game and beans, they play an essential role in protein availability for rural people in the province of Uíge living at subsistence levels. Against this background of the importance of the edible insects, it is surprising to face such difficulties for species identification. Integrative taxonomy should be systematically applied in order to improve our knowledge of edible insects for a wider geographic range.

Acknowledgements

The fieldwork in Angola was supported by a travel fund from the German Academic Exchange Service (DAAD). These published results were obtained in collaboration with the Instituto Nacional da Biodiversidade e Áreas de Conservação (INBAC) of the Ministério do Ambiente da República de Angola. We thank the administration and the staff of the University of Kimpa Vita in Uíge for logistical support during the stay in Angola. We are grateful for support on the identification of species to Stefan Naumann (Berlin) for Saturniidae, Christian Schmidt for the cricket and Francesca Vegliante for noctuoid larvae. We thank Manuela Bartel, Théo Leger and Franziska Bauer (Senckenberg Museum of Zoology Dresden) for technical support. Andreas Kempe designed the illustrations of the figures. Last but not least, we thank Paul Latham for his helpful review on this manuscript.

References

Adriaens EL (1953) Note sur la composition chimique de quelques aliments mineurindigènes du Kwango. Annales de la Societe Belge de Medecine Tropicale 33: 531–544. [cited in Malaisse F (2010)]

Ashiru MO (1988) The food value of the larvae of *Anaphe venata* Butler (Lepidoptera: Notodontidae). Ecology of Food and Nutrition 22: 313–320. https://doi.org/10.1080/03670244.1989.9991080

Badanaro F, Amevoin K, Lamboni C, Amouzou K (2014) Edible *Cirina forda* (Westwood, 1849) (Lepidoptera: Saturniidae) caterpillar among Moba people of the Savannah Region in North Togo: from collector to consumer. Asian Journal of Applied Science and Engineering 3: 13–24. https://doi.org/10.15590/ajase/2014/v3i8/54479

Barbosa LAG (1970) Carta fitogeográfica de Angola. Instituto de Investigação Científica de Angola, Luanda, 323 pp.

Beck H (1999) Die Larven der europäischen Noctuidae. Revision der Systematik der Noctuidae (Lepidoptera: Noctuidae) Vol. 1. Herbipoliana, Bandreihe zur Lepidopterologie 5(1): 1–859.

Belluco S, Losasso C, Maggioletti M, Alonzi CC, Paoletti MG, Ricci A (2013) Edible Insects in a Food Safety and Nutritional Perspective: A Critical Review. Comprehensive Reviews in Food Science and Food Safety 12: 296–313. https://doi.org/10.1111/1541-4337.12014

Bennett BC (2002) Forest products and traditional peoples: Economic, biological, and cultural considerations. Natural Resources Forum 26: 293–301. https://doi.org/10.1111/1477-8947.00032

Bernard HR (2006) Research methods in anthropology: qualitative and quantitative approaches. Fourth Edition. AltaMira Press, Lanham, MD, 803 pp.

Bouyer T (1999) Catalogue of African Saturniidae. Entomologia Africana, suppl. 1: 1–73.

Briggs DJ, Smithson P (1986) Fundamentals of Physical Geography. Rowman & Littlefield, 520 pp.

Bukkens SGF (1997) The nutritional value of edible insects. Ecology of Food and Nutrition 36(2–4): 287–319. https://doi.org/10.1080/03670244.1997.9991521

Carter DJ, Kristensen NP (1998) Classification and keys to higher taxa. In: Kristensen NP (Ed) Handbook of Zoology IV (35), Lepidoptera, Moths and Butterflies. De Gruyter, Berlin & New York, 27–40. https://doi.org/10.1515/9783110804744.27

CENSO (2014) CENSO. http://censo.ine.gov.ao/xportal/xmain?xpid=censo2014&xpgid=provincias&provincias-generic-detail_qry=BOUI=10504841&actualmenu=10504841&actualmenu=8377485 [Accessed: 13/07/2017]

Cigliano MM, Braun H, Eades DC, Otte D (2017) Orthoptera Species File. Version 5.0/5.0. http://Orthoptera.SpeciesFile.org [Accessed: 13/07/2017]

CIA (2013) World Fact Book. https://www.cia.gov/library/publications/the-world-factbook/rankorder/2091rank.html [Accessed: 04/01/2015]

Clark CW (1990) Mathematical bioeconomics: Optimal management of renewable resources. Hoboken, New Jersey, Wiley, 386 pp.

Courchamp F, Angulo E, Rivalan P, Hall RJ, Signoret L (2006) Rarity value and species extinction: The anthropogenic Allee effect. PLoS Biology 4(12): e415. https://doi.org/10.1371/journal.pbio.0040415

DeFoliart GR (1992) Insects as human food. Crop Protection 11: 395–399. https://doi.org/10.1016/0261-2194(92)90020-6

DeFoliart GR (1995) Edible insects as minilivestock. Biodiversity and Conservation 4: 306–321. https://doi.org/10.1007/BF00055976

DeFoliart GR (1999) Insects as food: Why the western attitude is important. Annual Review of Entomology 44: 21–50. https://doi.org/10.1146/annurev.ento.44.1.21

DeFoliart GR (2002) The human use of insects as a food resource. A Bibliographic Account in Progress. http://labs.russell.wisc.edu/insectsasfood/

De Prins J, De Prins W (2012) Afromoths: online database of Afrotropical moth species (Lepidoptera). www.afromoths.net [Accessed: 13/07/2017]

Durst PB, Johnson DV, Leslie RN, Shono K (2010) Forest insects as food: humans bite back. Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific, Bangkok, 231 pp.

Edijala JK, Egbogbo O, Anigboro AA (2009) Proximate composition and cholesterol concentrations of *Rynchophorus phoenicis* and *Oryctes monoceros* larvae subjected to different heat treatments. African Journal of Biotechnology 8(10): 2346–2348. https://www.ajol.info/index.php/ajb/article/view/60595/48837

Ekpo KE (2011) Nutritional and biochemical evaluation of the protein quality of four popular insects consumed in Southern Nigeria. Archives of Applied Science Research 3: 428–444. http://www.scholarsresearchlibrary.com/articles/nutritional-and-biochemical-evaluation-of-the-protein-quality-of-fourpopular-insects-consumed-in-southern-nigeria.pdf

Ekpo KE (2010) Nutrient composition, functional properties and anti-nutrient content of *Rhynchophorus phoenicis* (F) larva. Annals of Biological Research 1(1): 178–190. http://www.scholarsresearchlibrary.com/articles/nutrient-composition-functional-properties-and-antinutrient-content-of-rhynchophorus-pheonicis-f-larva.pdf

FAO (2017) FAO/INFOODS Food Composition Database for Biodiversity Version 4.0-BioFoodComp4.0. Rome, Italy. http://www.fao.org/infoods/infoods/tables-and-databases/faoinfoods-databases/en/ [Accessed: 21/06/2017]

Fasoranti JO, Ajiboye DO (1993) Some edible insects of Kwara State, Nigeria. American Entomologist 39(2): 113–116. https://doi.org/10.1093/ae/39.2.113

Folmer O, Black M, Hoeh W, Lutz R, Vrijenhoek R (1994) DNA primers for amplification of mitochondrial cytochrome c oxidase subunit I from diverse metazoan invertebrates. Molecular Marine Biology and Biotechnology 3(5): 294–299. http://www.mbari.org/wp-content/uploads/2016/01/Folmer_94MMBB.pdf

Gerasimov A (1937) Bestimmungstabelle der Familien von Schmetterlingsraupen (Lep.). Stettiner Entomologische Zeitung 98: 281–300.

Goff R (2016–2017) African Moths. http://www.africanmoths.com [Accessed: 13/07/2017]

Göhre A, Toto-Nienguesse ÁB, Futuro M, Neinhuis C, Lautenschläger T (2016) Plants from disturbed savannah vegetation and their usage by Bakongo tribes in Uíge, Northern Angola. Journal of Ethnobiology and Ethnomedicine 12: 42. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC5030725/

Gomez PA, Halut R, Collin A (1961) Production de proteines animales au Congo. Bulletin Agricole du Congo 52(4): 689–815.

Grande F, Stadlmayr B, Fialon M, Dahdouh S, Rittenschober D, Longvah T, Charrondiere R (2017) FAO/INFOODS global food composition database for pulses. Version 1.0 – uPulses1.0. http://www.fao.org/infoods/infoods/tables-and-databases/faoinfoods-databases/en/ [Accessed: 05/09/2017]

Hansen MC, Potapov PV, Moore R, Hancher M, Turubanova SA, Tyukavina A, Thau D, Stehman SV, Goetz SJ, Loveland TR, Kommareddy A, Egorov A, Chini L, Justice CO, Townshend JRG (2013) High-Resolution Global Maps of21st-Century Forest Cover Change. Science 342: 850–853. https://doi.org/10.1126/science.1244693

Huis A van (2003) Insects as food in Sub-Saharan Africa. Insect Science and its application 23(3): 163–185. https://doi.org/10.1017/S1742758400023572

Huis A van, Itterbeeck JV, Klunder H, Mertens E, Halloran A, Muir G Vantomme P (2013) Edible insects: future prospects for food and feed security. FAO Forestry Paper 171, 187 pp. http://www.fao.org/docrep/018/i3253e/i3253e.pdf

Itterbeeck J van, Huis A van (2012) Environmental manipulation for edible insect procurement: a historical perspective. Journal of Ethnobiology and Ethnomedicine 8: 3. https://doi.org/10.1186/1746-4269-8-3

Jongema Y (2017) List of edible insects of the world. http://www.wur.nl/en/Expertise-Services/Chair-groups/Plant-Sciences/Laboratory-of-Entomology/Edible-insects/Worldwide-species-list.htm [Accessed: 22/08/2017]

Kitching IJ, Rawlins JE (1998) The Noctuoidea. In: Kristensen NP (Ed.) Handbuch der Zoologie, Band IV, Teilband 35, Lepidoptera, Moths and Butterflies, Vol. 1: Evolution, Systematics, and Biogeography. W. De Gruyter, Berlin & New York, 491 pp.

Kokondi KK (1987) Intéret nutritionnel de chenilles d`Attacidés du Zaire: composition et valeur nutritionnelle. Cahiers de nutrition et de diététique 22: 473–477. [cited in Malaisse F (2010)] http://cat.inist.fr/?aModele=afficheN&cpsidt=7420770

Laman KE (1936) Dictionnaire Kikongo - Français. Mêm. Inst. Royal Colonial Belge. http://www.kaowarsom.be/en/memoir_8

Lampe REJ (2010) Saturniidae of the world. Friedrich Pfeil, Munich, 368 pp.

Latham P (2005) Edible caterpillars and their food plants in Bas-Congo. Second Edition, 44 pp.

Latham P, Konda ku Mbuta A (2011) Some honeybee plants of Bas-Congo Province, Democratic Republic of Congo, Second Edition, 248 pp.

Latham P, Konda ku Mbuta A (2014a) Useful Plants of Bas-Congo Province, Democratic Republic of Congo, 283 pp.

Latham P, Konda ku Mbuta A (2014b) Useful Plants of Bas-Congo Province, Democratic Republic of Congo, 270 pp.

Latham P (2017) Personal correspondence via email. [30/10/2017]

Lautenschläger T, Neinhuis C, Kikongo E, Henle T, Förster A (2017) Impact of different preparations on the nutritional value of the edible caterpillar *Imbrasia epimethea* from northern Angola. European Food Research and Technology 243(5): 769–778. https://doi.org/10.1007/s00217-016-2791-0

Lautenschläger T, Neinhuis C (Eds) (2014) Riquezas naturais de Uíge - Uma breve introdução sobre o estado atual, a ameaça e a preservação da biodiversidade. Technische Universität Dresden, Dresden, 124 pp.

Leleup N, Daems H (1969) Les chenilles alimentaires du Kwango. Causes de leur raréfaction et mesures préconisées pour y remédier. Journal d'agriculture tropicale et de botanique appliquée 16: 1–21. https://doi.org/10.3406/jatba.1969.3015

Mabossy-Mabouna G, Bouyer T, Latham P, Roulon-Doko P, Konda Ku Mbuta A, Malaisse F (2016) Preliminary knowledge for breeding edible caterpillars in Congo-Brazzaville. Geo-Eco-Trop 40–2: 145–174. http://orbi.ulg.ac.be/bitstream/2268/206206/1/N40-2-5%20Mabossy%202.pdf

Malaisse F (2010) How to live and survive in Zambezian open forest (Miombo ecoregion). Les Presses Agronomiques de Gembloux, 422 pp. [1 CD-ROM]

Malaisse F, Parent G (1980) Les chenilles comestibles du Shaba méridional (Zaire). Naturalistes Belges 61: 2–24. [cited in Malaisse F (2010)]

Marquardsen H, Stahl A (1928) Angola. Berlin: Dietrich Reimer, Second Edition, 172 pp.

Matissek R, Steiner G (2006) Lebensmittelanalytik. Grundzüge, Methoden, Anwendungen. Third Edition. Springer, Berlin, 240 pp.

Mbata KJ, Chidumayo EN, Lwatula CM (2002) Traditional regulation of edible caterpillar exploitation in the Kopa area of Mpika district in northern Zambia. Journal of Insect Conservation 6: 115–130. https://doi.org/10.1023/A:1020953030648

Mbata KJ, Chidumayo EN (2003) Traditional values of caterpillars (Insecta: Lepidoptera) among the Bisa people of Zambia. Insect Science and its Application 23(4): 341–354. https://doi.org/10.1017/S1742758400012418

Mbemba F, Remacle J (1992) Inventaire et composition chimique des aliments et denrées alimentaires traditionnels du Kwango-Kwilu au Zaire. Presses universitaires de Namur, 80 pp. [cited in Malaisse F (2010)]

Miller JE (1991) Cladistics and classification of the Notodontidae (Lepidoptera: Noctuoidea) based on larval and adult morphology. Bulletin of the American Museum of Natural History 204: 1–230.

Mills M (2015) personal correspondence via email 04/05/2015.

Mitsuhashi J (2017) Edible insects of the world. Taylor & Francis Group, 286 pp.

Muafor FJ, Le Gall P, Levang P (2014) Final Project Report – Improving rural livelihoods through participative research on the domestication and breeding of the palm weevil larvae (*Rhynchophorus phoenicis* Fabr.) – The African palm weevil project. https://core.ac.uk/download/pdf/39828280.pdf

Mwine JT, Damme van P (2011) Why do Euphorbiaceae tick as medicinal plants? A review of Euphorbiaceae family and its medicinal features. Journal of Medicinal Plants Research 5(5): 652–662. https://biblio.ugent.be/publication/1849112/file/2095574.pdf

Oberprieler R (1995) The Emperor moths of Namibia. Ekogilde, Hartbeespoort, 91 pp.

Okaraonye CC, Ikewuchi JC (2008) *Rhynchophorus phoenicis* (F) Larva Meal: Nutritional Value and Health Implications. Journal of Biological Sciences 8(7): 1221–1225. https://doi.org/10.3923/jbs.2008.1221.1225

Opara MN, Sanyigha FT, Ogbuewu IP, Okoli IC (2012) Studies on the production trend and quality characteristics of palm grubs in the tropical rainforest zone of Nigeria. Journal of Agricultural Technology 8(3): 851–860. http://www.ijat-aatsea.com/pdf/v8_n3_12_may/6%20IJAT_2012_Opara,%20M.pdf

Payne CLR, Scarborough P, Rayner M, Nonaka K (2016) A systematic review of nutrient composition data available for twelve commercially available edible insects, and comparison with reference values. Trends in Food Science & Technology 47: 69–77. http://dx.doi.org/10.1016/j.tifs.2015.10.012

Peel MC, Finlayson BL, McMahon TA (2007) Updated world map of the Köppen-Geiger climate classification. Hydrology and Earth System Sciences 11(5): 1633–44. https://doi.org/10.5194/hess-11-1633-2007

Peña JE (2013) Potential invasive pests of agricultural crops. CAB International, 440 pp. https://doi.org/10.1079/9781845938291.0000

Ramos-Elorduy J (1997) Insects: A sustainable source of food? Ecology of Food and Nutrition 36: 247–276. https://doi.org/10.1080/03670244.1997.9991519

Romeiras MM, Figueira R, Duarte MC, Beja P, Darbyshire I(2014) Documenting Biogeographical Patterns of African Timber Species Using Herbarium Records: A Conservation Perspective Based on Native Trees from Angola. In: Vendramin GG (Ed.) PLoS ONE 9(7): e103403. https://doi.org/10.1371/journal.pone.0103403

Rougeot P-C (1964) Nouvelle note sur les Lépidoptères Attacidés du Musée de Dundo (Angola). Companhia de Diamantes de Angola, Lisboa, Publicações Culturais 68: 15–32.

Rumpold BA, Schlüter OK (2013) Nutritional composition and safety aspects of edible insects. Molecular Nutrition & Food Research 57: 802–823. https://doi.org/10.1002/mnfr.201200735

Santos Oliveira JF, Passos de Carvalho J, Bruno de Sousa RFX, Simão MM (1976) The nutritional value of four species of insects consumed in Angola. Ecology of Food and Nutrition 5(2): 91–97. https://doi.org/10.1080/03670244.1976.9990450

Schintlmeister A (2013) Notodontidae & Oenosandridae (Lepidoptera).World catalogue of Insects 11. Brill, Leiden & Boston, 605 pp. https://doi.org/10.1163/9789004259188

Stehr FW (1987) Immature insects. Vol. 1. Kendall/Hunt, Dubuque.

Tanyi Tambe J, Riolo P, Okolle JN, Isidoro N, Fanciulli PP, Dallai R (2013) Sexual size differences and colour polymorphism of *Rhynchophorus phoenicis* in the Southwest region of Cameroon. Bulletin of Insectology 66(1): 153–159. http://www.bulletinofinsectology.org/pdfarticles/vol66-2013-153-159tanyi-tambe.pdf

Wahlberg N, Wheat CW (2008) Genomic outposts serve the phylogenomic pioneers: Designing novel nuclear markers for genomic DNA extractions of Lepidoptera. Systematic Biology, London 57(2): 231–242. https://doi.org/10.1080/10635150802033006

Wattanapongsiri A (1966) A revision to the genera *Rhynchophorus* and *Dynamis* (Coleoptera: Curculionidae). Thesis, Corvallis, United States: Oregon State University, 431 pp.

White F (1983) The vegetation of Africa – a descriptive memoir to accompany the Unesco/AETFAT/UNSO vegetation map of Africa. Unesco, Paris, 356 pp. http://primoproxy.slub-dresden.de/cgi-bin/permalink.pl?libero_mab213695056

WHO FAO (2002) Living well with HIV/AIDS. A manual on nutritional care and support for people living with HIV/AIDS. Rome, 105 pp. http://www.fao.org/3/a-y4168e.pdf

Wellman FC (1908) Notes on some Angolan insects of economic or pathologic importance. Entomological News 19: 26–33. http://www.biodiversitylibrary.org/item/84800#page/44/mode/1up

Yhoung-Aree J, Puwastien P, Attig GA (1997) Edible Insects in Thailand: An Unconventional protein Source? Ecology of Food and Nutrition 36: 133–149. https://doi.org/10.1080/03670244.1997.9991511

Xiaoming C, Ying F, Hong Z, Zhiyong C (2010) Review of the nutritive value of edible insects. In: Durst PB, Johnson DV, Leslie RN, Shono K (Eds) Forest insects as food: humans bite back. – Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific, Bangkok, Thailand, 85–92.