ANNEE 2017 THESE : 2017 – TOU 3 – 4101

UNDERSTANDING EBOLA RISKS IN HUMAN-BATS CONTACTS : EXPLORATORY STUDY ON KNOWLEDGE, ATTITUDES AND PRACTICES IN SOUTHERN CAMEROON

THESE
pour obtenir le grade de
DOCTEUR VETERINAIRE

DIPLOME D'ETAT

présentée et soutenue publiquement
devant l'Université Paul-Sabatier de Toulouse

par

BAUDEL Hélène
Née, le 22/11/1992 à TOULOUSE (31)

Directeur de thèse : Mme Mathilde PAUL

JURY

PRESIDENT :	
M. Pierre DELOBEL	Professeur à l'Université Paul-Sabatier de TOULOUSE
ASSESSEURS :	
Mme Mathilde PAUL	Maître de Conférences à l'Ecole Nationale Vétérinaire de TOULOUSE
M. Stéphane BERTAGNOLI	Professeur à l'Ecole Nationale Vétérinaire de TOULOUSE

Répartition des Enseignants-Chercheurs par ***Département.***
Mise à jour : 03/11/2017

DIRECTRICE : **ISABELLE CHMITELIN**

ELEVAGE ET PRODUITS/SANTE PUBLIQUE VETERINAIRE	SCIENCES BIOLOGIQUES ET FONCTIONNELLES	SCIENCES CLINIQUES DES ANIMAUX DE COMPAGNIE, DE SPORT ET DE LOISIRS
Responsable : M. SANS	***Responsable : Mme GAYRARD***	***Responsable : Mme CADIERGUES***
ALIMENTATION ANIMALE : M. **ENJALBERT Francis**, PR Mme **PRIYMENKO Nathalie**, MC Mme **MEYNADIER Annabelle**, MC EPIDEMIOLOGIE : **Mathilde PAUL**, MC PARASITOLOGIE-ZOOLOGIE : M. **FRANC Michel**, PR M. **JACQUIET Philippe**, PR M. **LIENARD Emmanuel**, MC Mme **BOUHSIRA Emilie,** MC HYGIENE ET INDUSTRIE DES ALIMENTS : M. **BRUGERE Hubert**, PR M. **BAILLY Jean-Denis**, PR Mme **BIBBAL Delphine**, MC Mme **COSTES Laura**, AERC Mme **DAVID Laure**, MCC PATHOLOGIE DE LA REPRODUCTION : M. **BERTHELOT Xavier**, PR M. **BERGONIER Dominique**, MC Mme **CHASTANT-MAILLARD Sylvie**, PR Mme **HAGEN-PICARD Nicole**, PR M **NOUVEL Laurent-Xavier**, MC Mme **MILA Hanna**, MC PATHOLOGIE DES RUMINANTS : M. **SCHELCHER François**, PR M. **FOUCRAS Gilles**, PR M **CORBIERE Fabien,** MC M. **MAILLARD Renaud**, PR M. **MEYER Gilles**, PR PRODUCTION ET PATHOLOGIE AVIAIRE ET PORCINE : Mme **WARET-SZKUTA Agnès,** MC M. **JOUGLAR Jean-Yves**, MC M. **GUERIN Jean-Luc**, PR M. **LE LOC'H Guillaume**, MC PRODUCTIONS ANIMALES AMELIORATION GENETIQUE ECONOMIE : M. **DUCOS Alain**, PR M. **SANS Pierre**, PR M. **RABOISSON Didier**, MC	ANATOMIE : M. **MOGICATO Giovanni**, MC M. **LIGNEREUX Yves**, PR Mme **DEVIERS Alexandra**, MC ANATOMIE PATHOLOGIQUE - HISTOLOGIE : M. **DELVERDIER Maxence**, PR Mme **LETRON-RAYMOND Isabelle**, PR Mme **BOURGES-ABELLA Nathalie**, PR Mme **LACROUX Caroline**, PR M **GAIDE Nicolas**, AERC BIOLOGIE MOLECULAIRE : Mme **BOUCLAINVILLE-CAMUS Christelle**, MC MICROBIOLOGIE – IMMUNOLOGIE - MALADIES INFECTIEUSES : M. **MILON Alain**, PR M. **BERTAGNOLI Stéphane**, PR M. **VOLMER Romain**, MC Mme **BOULLIER Séverine**, MC Mme **DANIELS Hélène**, MC BIOSTATISTIQUES : M. **CONCORDET Didier**, PR M. **LYAZRHI Faouzi**, MC PHARMACIE-TOXICOLOGIE : M. **PETIT Claude**, PR Mme **CLAUW Martine**, PR M. **GUERRE Philippe**, PR M. **JAEG Philippe**, MC PHYSIOLOGIE –PHARMACOLOGIE THERAPEUTIQUE : M. **BOUSQUET-MELOU Alain**, PR Mme **GAYRARD-TROY Véronique**, PR Mme **FERRAN Aude**, MC M. **LEFEBVRE Hervé**, PR BIOCHIMIE. : Mme **BENNIS-BRET Lydie**, MC ANGLAIS : M. **SEVERAC Benoît**, PLPA Mme **MICHAUD Françoise**, PCEA	ANESTHESIOLOGIE M. **VERWAERDE Patrick**, MC CHIRURGIE : M. **AUTEFAGE André**, PR M. **ASIMUS Erik**, MC M. **MATHON Didier**, MC Mme **MEYNAUD-COLLARD Patricia**, MC Mme **PALIERNE Sophie**, MC MEDECINE INTERNE : Mme **DIQUELOU Armelle**, MC M. **DOSSIN Olivier**, MC Mme **LAVOUE Rachel**, MC Mme **GAILLARD-THOMAS Elodie**, MCC OPHTALMOLOGIE : M. **DOUET Jean-Yves**, MC DERMATOLOGIE : Mme **CADIERGUES Marie-Christine**, PR IMAGERIE MEDICALE **M. CONCHOU Fabrice,** MC BIOLOGIE MOLECULAIRE. : Mme **TRUMEL Catherine**, PR PATHOLOGIE DES EQUIDES : M. **CUEVAS RAMOS Gabriel**, MC Mme **LALLEMAND Elodie**, AERC

A Monsieur le Professeur Pierre Delobel
Professeur de l'université Paul Sabatier de Toulouse
Chef du Service au Centre Hospitalier Universitaire de Toulouse
Maladies Infectieuses et Tropicales

A Madame Docteur Mathilde Paul
Maître de conférences à l'Ecole Nationale Vétérinaire de Toulouse
Epidémiologie, gestion de la santé des élevages avicoles et porcins

A Monsieur le Professeur Stéphane Bertagnoli
Professeur à l'Ecole Nationale Vétérinaire de Toulouse
Virologie-Infectiologie

A l'équipe de terrain au Cameroun Innocent Ndong Bass, Thomas Atemkeng Fotsop, Joseph Moudindo and Aimé Mebenga

Au docteur Eitel Mpoudi Ngole
Directeur du CREMER, Cameroun

A Mesdames Hélène De Nys, Martine Peeters, Alice Desclaux
Membres de l'unité UMR-233 à l' IRD (Institut de Recherche pour le Développement)

A FVI (France Vétérinaire International), INP Midi-Pyrénées, IRD
Contributeurs financiers

Table des matières

Table des illustrations

Figures

Tables

Abbreviations

BDBV: Bundibugyo Ebola Virus
EBOV: Zaire Ebola Virus
EBV: Ebola virus
EVD: Ebola Virus Disease
DRC: Democratic Republic of Congo
RC: Republic of Congo
RESTV: Reston Ebola Virus
SUDV: Sudan Ebola Virus

Evaluation des risques de transmission du virus Ebola des chauves-souris à l'homme: étude exploratoire sur les connaissances, les attitudes et les pratiques dans le Sud du Cameroun

Chapitre 1 - Introduction

Depuis la première épidémie humaine connue, en 1976, les virus Ebola continuent d'émerger de manière imprévisible en Afrique tropicale et suscitent une inquiétude grandissante dans un contexte socio-économique en plein changement (Leroy, 2004; Feldmann et Geisbert, 2011). Au cours de l'épidémie ayant affecté l'Afrique de l'Ouest entre 2013 et 2016, la plus grande connue jusqu'ici, , des chaînes de transmission ont pour la première fois atteint des centres urbains, causant plus de cas et de morts que dans toutes les épidémies précédentes combinées (Holmes et al, 2016). Tout comme la plupart des agents pathogènes émergents, le virus Ebola (EBV) semble avoir une origine zoonotique. Afin de permettre la prévention de telles transmissions de l'animal à l'Homme, les efforts de recherche actuels se concentrent sur l'identification de réservoirs animaux du virus.

Le nombre limité de spécimens positifs détecté jusqu'ici (Leroy et al., 2005), malgré des efforts d'échantillonnages longitudinaux intensifs, ainsi que la richesse de la faune d'Afrique centrale, limitent aujourd'hui la compréhension de l'écologie de EBV au sein de la faune sauvage.

Les données actuelles suggèrent que le réservoir d'EBV est complexe et pourrait impliquer plusieurs espèces. L'attention a été portée sur les chauves-souris chez lesquelles de l'ARN viral a été détecté chez quelques spécimens vivants (Leroy et al., 2005), mais les connaissances concernant la maintenance du virus dans les populations de chauves-souris sont minces.

Les chauves-souris sont également suspectées d'être impliquées dans la transmission zoonotique, bien que les preuves restent jusqu'à présent limitées et basées uniquement sur des liens épidémiologiques. Tout d'abord à partir de l'épidémie de 2007, il a été suggéré que le cas index avait été infecté asymptomatiquement via un contact avec de la viande de chauves-souris (Leroy et al., 2009). Puis lors de l'épidémie de 2013, le cas index, un garçon de 2 ans aurait joué avec une colonie de chauves-souris insectivores dans un arbre creux (Mari Saez et al., 2015). Mais pour la plupart des épidémies, la source initiale de transmission zoonotique n'a pas été identifiée. La seule source de cas humain d'Ebola confirmée en laboratoire sont les grands singes et des antilopes, populations où le virus engendre une mortalité importante (Pigott et al., 2014).

Dans le même temps, les contacts à risque entre hommes et faune sauvage sont divers, la chasse, la préparation et la consommation d'animaux sauvages, dont les chauves-souris, étant répandue en Afrique tropicale. Ces contacts peuvent potentiellement

transmettre des agents pathogènes zoonotiques au travers de morsures, égratignures, contact avec des fluides corporels infectés, des tissus et excréments (Wolfe et Daszak, 2005). Plus spécifiquement, les interactions entre les communautés humaines et les chauves-souris, et par conséquent les routes les plus probables et risques de transmission à l'homme, sont très peu documentées (Mickleburgh et al, 2009). Les informations sur la chasse des chauves-souris et les pratiques de consommations sont rares. La compréhension des attitudes et perceptions des communautés envers les maladies liées aux chauves-souris est également limitée, étant donné que les seules études de grande échelle ont été conduites au Ghana (Kamins et al., 2015).

L'objectif de cette étude exploratoire est d'explorer l'étendue et les types de contacts entre hommes et chauves-souris ainsi que les attitudes et perceptions vis-à-vis de ces dernières dans le sud du Cameroun, région considérée comme à risque d'épidémies d'EBV (Pigott et al., 2014). Les informations sur les risques de transmission des virus hébergés par les chauves-souris à l'homme ainsi collectées devraient participer à l'amélioration de la gestion des risques sanitaires.

Chapitre 2 - Méthodes

2.1. Sites d'étude

L'étude fut menée dans 11 villages de 4 zones rurales du sud du Cameroun (Figure 1), dont trois (Campo, Dja, Mambele) bordent des parcs naturels protégés, et ont encore une faune relativement riche. Dans la quatrième zone (Gwap) en revanche, la viande de brousse est devenue rare au cours de la dernière décennie, du fait d'une combinaison de facteurs (sur-chasse, déforestation, intensification de l'activité agricole). Les sites d'étude avaient précédemment été choisis pour leur richesse en populations de gorilles et chimpanzés dans le contexte de la recherche sur l'origine du virus de l'immunodéficience humaine (VIH), sujet sur lequel l'équipe de recherche travaille depuis 2000. Ces zones reculées sont difficilement accessibles et les déplacements des villageois aux centres urbains limités. Les villages s'organisent autour de la piste principale, généralement construite pour le transport de bois (dans les quatre zones) ou de produits de l'industrie minière (à Gwap). Des arbres fruitiers sont situés autour des maisons ; les champs cultivés sont à proximité des villages, à la bordure de la forêt. Au regard de l'accessibilité à l'eau, excepté à Gwap où l'eau courante provenant d'une source souterraine voisine alimente presque tous les foyers, dans les autres zones les villageois dépendent d'un unique point d'eau de source ou de l'eau de la rivière. A Gwap, l'activité agricole n'est pas seulement destinée à la subsistance – comme c'est le cas dans les autres zones étudiées – mais constitue aussi une source de revenu pour les habitants qui vendent une partie de leur production.

Figure.1. Carte de la localisation des quatre sites d'étude dans le sud du Cameroun

2.2. Questionnaires

Les enquêtes ont été conçues par H.D.N. et menées par H.B. et quatre assistants de recherche locaux, de février à mai 2017 . Les questionnaires semi-structurés standardisés ont été développés sur la base de l'expérience de l'équipe de terrain. Les foyers ont été sélectionné par échantillonnage de convenance le long de l'unique route de chaque village, et en choisissant pour personne interrogée un habitant par foyer se portant volontaire. Au préalable, les assistants de recherche rencontraient le chef du village afin d'obtenir son accord pour mener l'enquête effectuée en parallèle de l'échantillonnage de chauves-souris, les informations sur ces deux compartiments connectés étant précieuses. Tous les entretiens ont été menés en personne d'abord en français, avec un villageois traduisant dans le langage local ponctuellement si la personne interrogée ne comprenait pas une question. La chasse des chauves-souris n'est pas illégale et il n'y a pas de tabou ou de stigma associé à leur chasse dans le sud du Cameroun. En général, les personnes interrogées étaient à l'aise pour répondre aux questions. Cependant, dans les lieux où la consommation des chauves-souris est associée au groupe ethnique Pygmée, une minorité souvent marginalisée et stigmatisée, il ne peut être exclu que certaines personnes interrogées, en présence d'un interprète et interviewer Bantus, n'aient pas été à l'aise pour aborder ce sujet.

2.3. Analyse des données

L'ensemble des réponses ont été résumés par analyses descriptives. Les tests de Fisher ainsi que celui du Chi-deux de Pearson ont été utilisés pour tester les différences entre catégories. Les tests statistiques ont été considérés significatifs au seuil de 5%.

Une analyse multivariée a été réalisée afin d'identifier les variables ayant un effet significatif sur la variable réponse du modèle linéaire généralisé: la proportion de consommateurs de chauves-souris. Les variables explicatives suivantes ont été incluses dans le modèle maximal, sur la base d'hypothèses biologiques: le genre, l'âge, le groupe ethnique, le niveau d'éducation, la village, la participation aux activités de chasse, la connaissance des lieux de repos des chauves-souris, la perception des dangers ou bénéfices liés à la consommation

des chauves-souris, l'existence d'un totem traditionnel, l'usage des chauves-souris par les guérisseurs. La sélection du modèle final s'est basée sur le critère d'Akaike (AIC). Les variables dont l'effet apparaissait être significatif – en ayant pris en compte les interactions entre variables – étant : le site d'étude, la pratique personnelle de la chasse et la perception des dangers associés aux chauves-souris. Nous avons utilisé le logiciel R version 3.3.1 pour toutes les analyses statistiques.

Chapitre 3 - Résultats

3.1. Démographie de la population d'étude

Les caractéristiques démographiques des sondés sont présentées dans la Figure 2. L'échantillon comprend135 personnes, dont 106 hommes (79%) et 29 femmes (21%). Ce déséquilibre est largement dû au fait que le membre du foyer se portant volontaire pour répondre au questionnaire était généralement un homme. La majorité des personnes interrogées (78, 58%) ont uniquement un niveau d'éducation élémentaire, 37 (28%) un niveau secondaire, 11 (8%) sont allés au lycée et 8 (6%) n'ont jamais été scolarisé. La plupart des sondés (100/135) pratiquent une agriculture de subsistance, sans distinction entre hommes et femmes. Seuls 5 sondés, employés d'ONG, ont déclaré avoir un revenu régulier. 31 (23%) ont déclaré chasser ou pêcher comme activité secondaire (traditionnellement, seuls les hommes chassent). Cependant, la viande d'animaux domestiques n'étant ni disponible ni abordable dans ces zones, les communautés dépendent de la viande de brousse chassée par les membres du foyer. Il est possible que le faible taux de personnes mentionnant des activités de chasse soit lié à la peur de la répression du braconnage.

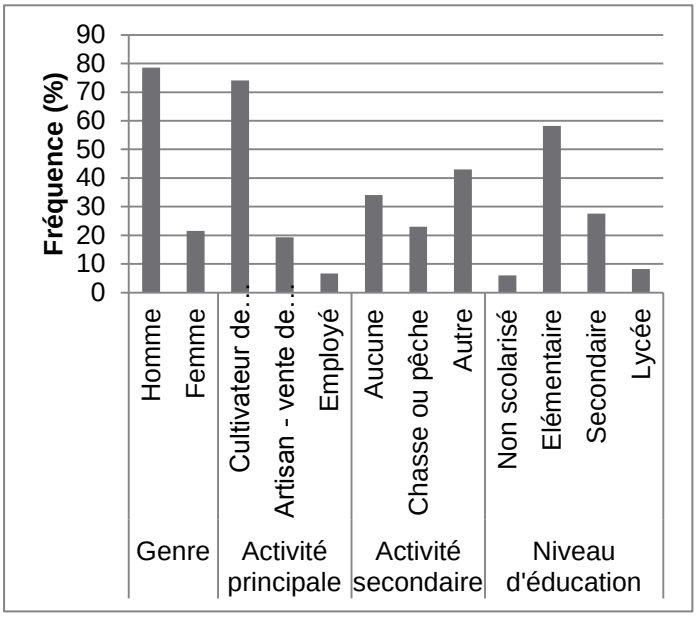


Figure 2. Fréquence de distribution des caractéristiques démographiques des sondés dans les communautés du sud rural du Cameroun. N=135

Au total, les sondés sont de 16 ethnies (Table 1) qui peuvent être regroupées, d'après des critères anthropologiques, en deux plus larges unités : Pygmée et Bantu. Dans les analyses qui suivent, nous considèrerons seulement la localisation géographique par souci

de clarté, au vu de la grande diversité de groupes ethniques ne permettant pas d'avoir des échantillons par groupe ethniques suffisants.

Tableau 1. Distribution des sondés au sein des quatre zones et diversité ethnique

Site	Nombre total de répondants	Nombre total de groupe ethnique
Campo	22	5
Gwap	39	6
Dja	35	2
Mambele	39	4
Total	135	17*

*Différent du nombre total de groupes ethniques (N=16), étant donné que les Pygmées Bajele sont présents à Campo ainsi qu'à Gwap.

3.2. Evaluation des risques d'exposition au travers la consommation de chauves-souris

Les pratiques de consommation

Tout d'abord la consommation de chauves-souris est significativement associée au site d'étude. Aucun des sondés dans la zone de Campo n'a déclaré manger des chauves-souris (0/22), alors que 23% (8/35), 31% (12/39) et 87% (34/39) des sondés en consommaient respectivement à Dja, Mambele et Gwap (test exact de Fisher, p-value<10^{-12}, Tableau 2). Dans seulement un des sites, Mambele, une nette différence dans les pratiques de consommation entre groupes ethniques a été observée, avec les Baka consommant significativement (test exact de Fisher, p-value<0,01) plus (12/29, soit 41%), que les non-Pygmées (0/10) (Figure 3).

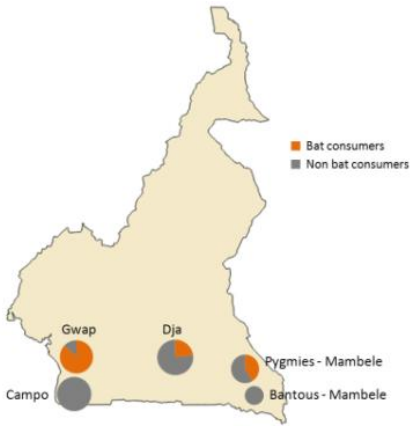


Fig.3. Carte du pourcentage de consommation dans les 4 sites étudiés, parmi les sondés.

Lorsque les personnes interrogées chassent elles-mêmes les chauves-souris, elles sont logiquement davantage susceptibles de les consommer (95%, 37/39) que celles qui ne les chassent pas (18%, 17/78) (test exact de Fisher, p<10^{-15}). De plus, la consommation de chauves-souris est significativement associée à une moindre perception du danger lié à la consommation des chauves-souris. En effet, parmi les consommateurs, seuls 7% (4/54)

pensent que cela peut être associé à un danger (20% d'entre eux ne savent pas), comparé à 32% (26/81) parmi ceux qui ne consomment pas de chauves-souris (test exact de Fisher, p<0,001).

Table 2. Distribution des sondés ayant répondu aux questions sur les pratiques de consommation des chauves-souris

Répartition de la consommation de chauves-souris	Consomment	Ne consomment pas	**Origine des chauves-souris consommées**	Chassées personnellement	Reçues	Achetées
Campo	0 (0%)	22				
Gwap	34 (87%)	5	Gwap	23	12	25
Dja	8 (23%)	27	Dja	6	2	0
Mambele	12 (31%)	27	Mambele	12	3	0
Total (N)	54	81				

Qui consomme les chauves-souris		**Importance des chauves-souris pour la subsistance**		**Raisons de non consommation**	
Tous	49	Aucune	37	Anciens ne mangaient pas	56
Hommes uniquement	3	Confort	15	Autres ressources*	9
Adultes uniquement	2	Essentielle	1	Praticité de chasse**	4
				Perception de danger***	4

*autres ressources, non considéré comme nourriture/ **ne chasse pas, difficile à attraper/ ***sorcellerie, transmission de maladies

Contexte social de consommation

Le questionnaire évaluait également les caractéristiques de la consommation des chauves-souris : les espèces consommées, les méthodes et habitudes de préparation. Habituellement les femmes préparent la carcasse sans précaution spécifique hormis le lavage des mains (à l'eau disponible, le savon étant rare.

L'importance des chauves-souris comme source de nourriture

Les chauves-souris ne sont pas une source majeure de protéines pour les communautés : 69% des personnes interrogées mangeant des chauves-souris (37/54) pensent qu'elles n'ont « aucune importance », 28% (15/54) jugent qu'elles constituent un « confort », et pour un répondant dit c'est essentiel au vu de son goût pour la viande de chauve-souris (Table 2). Parmi les consommateurs de chauves-souris, la consommation annuelle médiane est de 3 (allant de 1 à environ 75) et 75% d'entre eux mangent des chauves-souris moins de 11 fois par an.

Méthodes de chasse et saisonnalité

Les villageois qui chassent les chauves-souris (38/106) les capturent de diverses manières suivant le site (Figure 4).

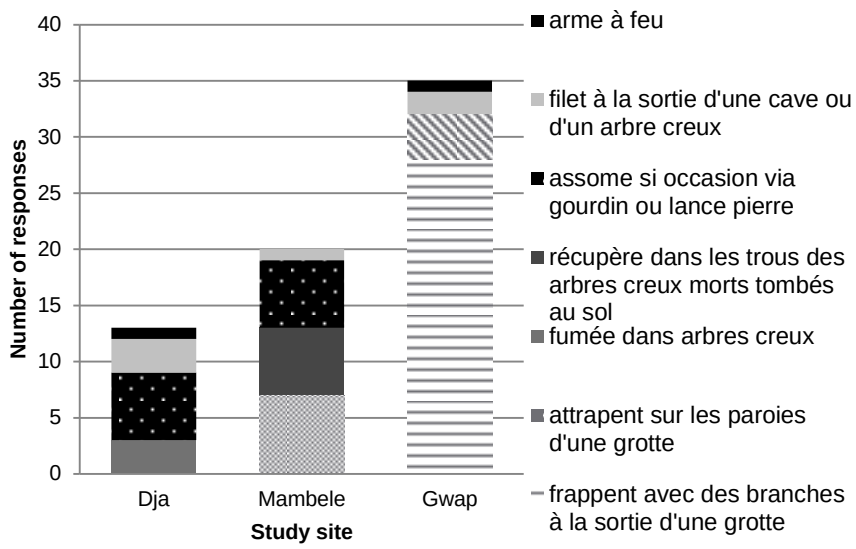


Fig.4. Différentes méthodes de chasse suivant les différents sites d'étude

Le contexte de chasse à Gwap est assez spécifique étant donné que les villageois chassent les chauves-souris exclusivement dans une grotte, connue par tous localement, difficile et dangereuse d'accès, raison pour laquelle seuls les jeunes hommes s'y rendent. Cette grotte est interdite d'accès aux femmes et est associée à des rituels sacrés pour la communauté.

Risques de blessures au cours de la chasse

18/38 des sondés qui chassent les chauves-souris ont déjà été mordus par celles-ci, et 3 sondés, trop âgés pour aller chasser dans la grotte de Gwap avaient déjà été mordus. 2 sondés qui ne chassent pas les chauves-souris, ont été mordus une fois. Les chasseurs capturant dans les grottes à l'aide de bâtons ou à mains nues sont davantage susceptibles d'avoir été mordu plusieurs fois (10/22, 45%) comparé à ceux capturant dans les arbres (2/16, 13%) (test exact de Fisher, $p<0,01$). Seul un chasseur a rapporté utiliser des gants comme mesure de protection, les autres n'en utilisent aucune, mais la plupart ne ramassent pas les chauves-souris sans les avoir d'abord tuées.

3.3. Evaluation des contacts directs entre enfants et chauves-souris

30/135 (22%) des sondés rapportent que les enfants attrapent des chauves-souris : 14 pour jouer uniquement, la plupart à Campo où ils ne consomment pas de chauves-souris, 12 pour jouer et manger, et 4 pour manger uniquement. 13/30 les gardent vivantes, en les attachant habituellement à un bâton via une ficelle. Les enfants des consommateurs de chauves-souris attrapent significativement plus les chauves-souris (35%,19/54) comparé à 14% (11/81) pour les enfants des non consommateurs (test de Pearson's Chi-squared, $p<10^{-2}$). 2 sondés ont rapporté que leurs enfants avaient été mordu à plusieurs reprises par des chauves-souris, un à Mambele, l'autre à Gwap.

3.4. Contacts indirects

De façon homogène entre sites, les sondés déclarent que les chauves-souris mangent les fruits (86%, 116/135) provenant des arbres autour du village.

Au total 67% (90/135) des sondés déclarent manger des fruits déjà croqués (soit eux-mêmes soit leurs enfants). Bien que cette proportion varie significativement suivant le site, de 41% à Mambele à 89% à Dja (test exact de Fisher, $p<10^{-4}$). La plupart des fruits nécessitent d'être pelés avant d'être mangés, excepté la prune et le fruit du parassolier. La mangue est le fruit le plus largement cité, par 59 des 90 sondés qui déclarent manger des fruits déjà croqués, parmi les autres : goyave, prune, avocat, corossol, papaye.

55% (21/38) des chasseurs utilisent les grottes pour s'abriter des conditions météo (pluie), ce qui implique qu'ils pourraient être en contact avec du guano (fèces de chauves-souris) tombé sur le sol des grottes. 65% (88/135) des sondés déclarent voir des chauves-souris voler au-dessus des ruisseaux près du village. Les sondés n'exploitent pas les fèces déposés dans les grottes, par exemple comme engrais, et n'ont jamais entendu parler de cette pratique.

3.5. Perception des dangers et croyances traditionnelles envers les chauves-souris

Dans l'ensemble, la perception du danger lié à la consommation de chauves-souris est faible, avec 78% des sondés qui ne croient pas que manger des chauves-souris puisse être dangereux. Parmi les ceux qui le croient, la transmission de maladies est mentionnée par 70% (21/30) d'entre eux, et 15% (5/30) croient que les chauves-souris sont associées à des activités de sorcellerie. Les autres dangers évoqués sont liés à la défiance vis-à-vis des chauves-souris, en lien avec le peu de familiarité des villageois avec leur «mode de vie ». Lors de discussions informelles, certains ont qualifié les chauves-souris « d'étranges créatures vivant la nuit », « ni animal, ni oiseaux », « déféquant par la bouche ». 10 sondés (qui sont aussi consommateurs de cahuves-souris), pensent que la consommation de chauves-souris est bénéfique, que ce soit comme source de nourriture/ protéines (n=5), pour améliorer la santé (n=3) et par satisfaction à Gwap (n=2).

Chapitre 4 - Discussion

Les résultats de ce questionnaire montrent que les contacts directs entre homme et chauve-souris sont fréquents, avec 54/135 des sondés qui consomment des chauves-souris, 38/135 qui les chassent et 30/135 qui rapportent que les enfants les attrapent. Ceci est d'autant plus remarquable lorsque l'on sait qu'un seul évènement de transmission zoonotique peut avoir des conséquences majeures sur des communautés entières (Baize et al., 2014), en menant à de larges épidémies d'EVD propagées par transmission interhumaine. Concernant les contacts indirects, les communautés sont exposées de façon homogène aux fruits potentiellement contaminés par des fèces ou la salive des chauves-souris, avec 67% des sondés mangeant des fruits déjà croqués. Ce résultat suscite

l'inquiétude, puisqu'il est prouvé que d'autres virus dont les chauves-souris sont porteurs tels le virus Nipah ayant causé des encéphalites mortelles et détresses respiratoires (Breed et al, 2006; Chua, 2000), sont transmis à l'homme via cette route.

Autre résultat remarquable, la perception du danger lié aux chauves-souris est très bas, dans la mesure où 78% des sondés ne croient pas que la consommation de chauves-souris puisse être associée à des risques pour la santé. Ce n'est pas surprenant au vu de résultats similaires d'autres études (Gbogbo et Kyei, 2017; Kamins et al., 2015), bien qu'elles aient été mené dans des pays où des campagnes de sensibilisation avaient été conduites au préalable, contrairement au Cameroun. Plus surprenant encore, même lorsque les personnes interrogées mentionnent spontanément la maladie Ebola, elles déclarent ne pas se sentir « à risque » dans leur pays, puisque aucune épidémie ne s'y est produite jusque-là. Par conséquent, il apparaît que la sensibilisation aux enjeux de santé publique doive être initiée au Cameroun. Cependant, les précédentes campagnes de communication sur Ebola ont été marqué par une série d'erreurs, où des messages erronés ou inappropriés ont contribué aux doutes et créé de l'anxiété (Seytre, 2016). Ceci souligne la nécessité de repenser les stratégies d'intervention, au travers la mobilisation sociale, l'éducation sanitaire, et la promotion de la santé comme le suggère l'Organisation mondiale de la Santé (UNICEF, et others, 2014).

Bien que les chauves-souris attirent l'attention, cette étude suggère que les contacts directs avec des chauves-souris sont bien moins fréquents en comparaison des contacts avec d'autres espèces régulièrement chassées et essentielles pour la subsistance des communautés. En effet, bien que la consommation de viande de chauve-souris soit répandue, 69% des sondés estiment que ça n'a « aucune importance » comme ressource de nourriture. Il semble plutôt que cela constitue un plat occasionnel (les trois quarts des consommateurs mangeant des chauves-souris moins de 11 fois par an environ), ou dans certaines communautés un met apprécié. La pression de chasse augmentant la probabilité de contacts directs avec des fluides corporels, qui est la principale voie suspectée de transmission de pathogènes, des informations sur ces autres compartiments potentiels du réservoirs seraient par conséquent précieuses.

Chapitre 5 - Conclusion

Les diversités géographique et culturelle des contacts et perceptions vis-à-vis des chauves-souris au Cameroun indique une grande variabilité en terme de risque de transmission des pathogènes des chauves-souris à l'homme. Ceci souligne le besoin de mener des études de plus grande ampleur afin d'identifier les sites à risque élevé et les populations à cibler pour une surveillance ainsi que pour des campagnes d'éducation et de santé plus efficaces, notamment dans un contexte de ressources limitées. Les cas récents d'EBV en RDC en mai 2017 rappellent vivement que la prévention de la maladie EBV peut être améliorée.

Understanding Ebola risks in human-bats contacts: exploratory study on knowledge, attitudes and practices in Southern Cameroon

Chapter 1 – Literature Review

1.1. Ebola virus: history of the different outbreaks

Geography and severity of previous outbreaks

Since the first recognized outbreak of Ebola in 1976, Ebola viruses (EBV) continue to emerge unpredictably and cause Ebola virus disease (EVD) in humans and susceptible animals in tropical Africa (Leroy, 2004; Feldmann et Geisbert, 2011) (Figure 1, Table 1). Ebola is a complex zoonosis and each outbreak is the result of a zoonotic event. However, the animal reservoir is not yet clearly identified which has hampered control of new Ebola disease outbreaks.

Table 1. Demographic impact and geographical range of outbreaks in Africa (Centers for Disease Control and Prevention (CDC), 2016; Pigott et al., 2014). Only outbreaks with more than 1 lethal case are reported in this table. And outbreaks occurring in close spatio-temporal proximity were grouped.

Year(s)	Country	Number of cases (confirmed or suspected)	Total recorded deaths	Ebola virus species
1976	Zaire (DRC)	318	280	Zaire
1976	South Sudan	284	151	Sudan
1979	South Sudan	34	22	Sudan
1994	Gabon	52	31	Zaire
1995	DRC	315	250	Zaire
1996*	Gabon	97	66	Zaire
2000- 2001	Uganda	425	224	Sudan
2000-2003**	Congo, Gabon	300	253	Zaire
2004	South Sudan	17	7	Sudan
2005	Congo	12	10	Zaire
2007	DRC	264	187	Zaire
2008	Uganda	149	37	Bundibugyo
2009	DRC	32	15	Zaire
2012	DRC	36	13	Bundibugyo
2012-2013***	Uganda	17	7	Sudan
2014	DRC	66	49	Zaire
2013-2016	Guinea,Sierra-Leone, Liberia	28,652	11,325	Zaire
2017	DRC	8?	4?	Zaire

*Described as 2 distinct outbreaks, distant of 3 months
**Described as 4 distinct outbreaks, distant of a maximum of 10 months
***Described as 2 distinct outbreaks, distant of 1 month

The 2013-2016 outbreak in West Africa was the largest Ebola outbreak, which caused more cases and deaths than all the others combined. Importantly, for the first time, the virus spread between countries and in major cities, starting in forest regions of south-eastern Guinea before moving across land borders to Sierra-Leone and Liberia and to the capital cities of those countries. Most recently in May 2017, new cases were reported in Democratic Republic of Congo (DRC). In total 26 outbreaks of Ebola virus were identified in humans across Africa (including the one of May 2017), consisting of at least a hypothesized 26 zoonotic transfers (Pigott et al., 2014). It cannot be excluded that more EBV outbreaks occurred but were not recognized and thus not reported, since they occur mainly in isolated and remote forest areas, with poor health infrastructure and poor knowledge of the disease.

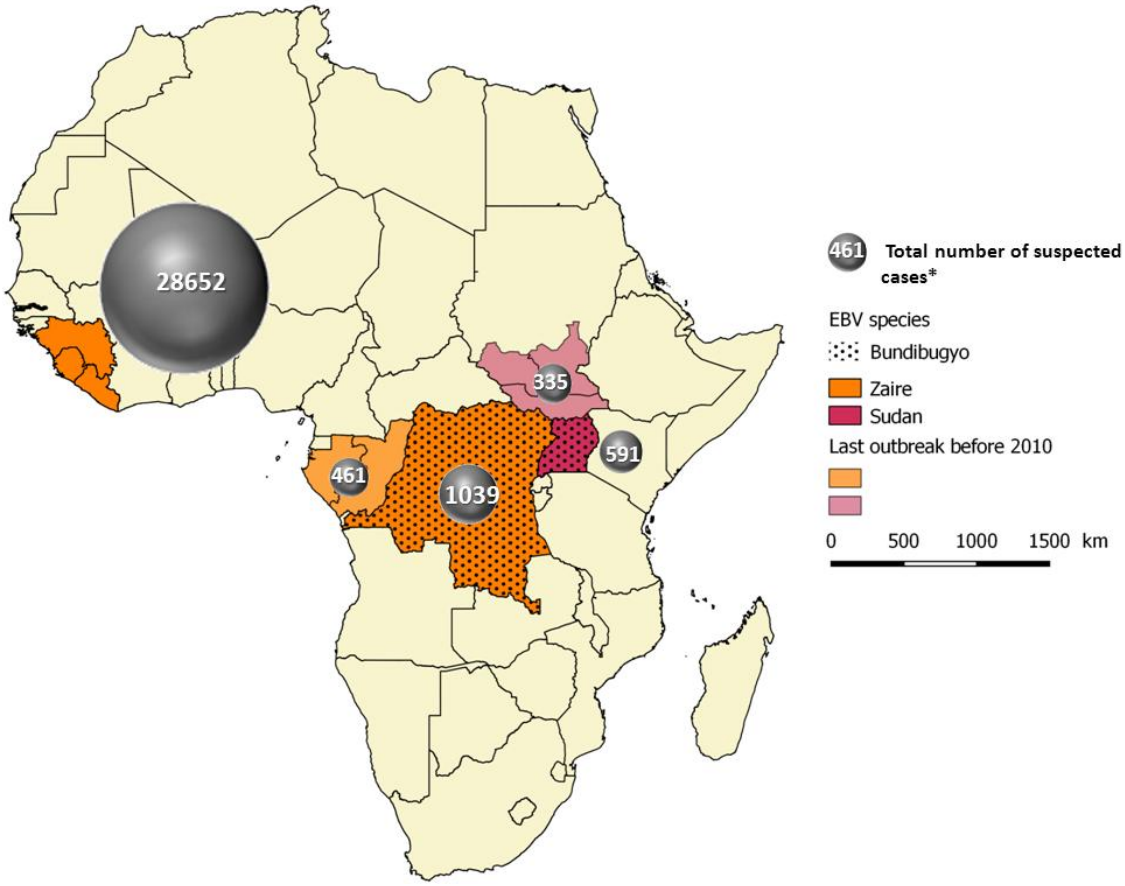


Figure 1. History and severity of Ebola outbreaks - Data from the table 1, adapted with QGIS, Geographical Information System software - *The total number of cases was grouped accordingly: Guinea, Liberia and Sierra-Leone ; Gabon and Republic of Congo ; DRC ; Uganda ; South Sudan.

Virus classification

Ebola virus belongs to the virus family *Filoviridae* which includes three genera: Cuevavirus, Marburgvirus and Ebolavirus. Within the genus *Ebolavirus* (Kuhn, 2009), five species have been identified: *Zaire (EBOV), Bundibugyo (BDBV), Sudan (SUDV), Reston (RESTV) and Taï Forest*. The first three have been associated with large outbreaks in Africa, *Taï Forest* virus was involved in a single case in a primatologist and RESTV which is not harmful in humans was only reported in Asia. Ebolaviruses are negative-sense single-strand RNA viruses and, like most other RNA virus, they quickly generate mutations through error-

prone replication. In the last 2013-2016 epidemic, the Ebola virus species in cause was *Zaire ebolavirus*, variant Makona, which diverged from other EBOV variants about a decade ago (Gire et al., 2014). Thus it may be fairly new to West Africa, sharing recent common ancestry with Central African variants that are found thousands of miles away.

Particularities of the 2013-2016 epidemic, explaining its magnitude

The 2013-2016 epidemic, in contrast to the previous ones, was the first affecting West Africa, it also had the largest scale and severity. The simpler scenario explaining this extent is that the 2013-2016 EVD epidemic reflects a different epidemiological (susceptible host population and or environment) context than previous outbreaks. Indeed, it was the first time an EVD epidemic resulted in sustained community transmission from rural settings to major urban centers with extremely weak health care facilities, where it was easier to establish large-scale transmission networks. An alternative explanation for this record in terms of scale and severity, stating that EBOV Makona possessed mutations that enhanced its transmissibility in humans, is debated, but is not thought to be the major driver of the epidemic magnitude (Holmes et al., 2016). Viruses evolutionary dynamics is not so straight-forward, and is time-dependent as well as host-dependent. As a result, the 2013-2016 epidemic cannot be compared to others in term of “real time” estimate of evolutionary rate (Holmes et al., 2016).

Although the last 2013-2016 epidemic was extensively investigated, today many questions still remain on the animal reservoir: how is Ebola virus maintained and transmitted among wildlife and across the African continent? What is the role of reservoir and/or amplifying hosts regarding human outbreaks occurrence?

1.2. Knowledge on animal species suspected to be involved in EVD epidemiology

Conceptual model of reservoir

A reservoir is defined as “one or more epidemiologically connected populations or environments in which the pathogen can be permanently maintained and from which infection is transmitted to the defined target population” (Haydon et al., 2002). In the case of EVD, the target population is human population, defined as the population of concern, susceptible to the disease. In epidemiologic theory (Barlett MS., 1960), the critical community size (CCS) is the minimum size of a closed population within which a pathogen can persist indefinitely. In populations smaller than this critical community size, the number or density of infected hosts frequently falls to low levels, random extinction (fadeout) becomes inevitable, and the pathogen cannot persist. Such populations are termed nonmaintenance populations. Pathogens will persist in populations larger than the critical community size, and these populations are termed maintenance populations. In complex systems, pathogen transmission between nonmaintenance populations could constitute a maintenance

community, and thus contribute to the maintenance of the pathogen. Although not essential to pathogen maintenance, if a species contributes to transmission of the pathogen to the target, it is still considered as part of the reservoir. However, this concept of CCS has limitations. First the concept is highly theoretical, and it can be very difficult to determine in practice in a complex ecosystem involving nonlinear interactions between individuals. Furthermore, making the total number of individuals from a population the main driver for pathogen persistence can be misleading. Indeed, it doesn't necessarily reflect the amount of contacts which can depend of the season and more generally of the behavior of the species. In addition, it doesn't take into account inter-species interactions , although some pathogens cannot persist without those. For instance, in the case of frequency dependent pathogens, this concept appears to be less relevant than for density-dependent pathogens.

Bats, which role in the reservoir?

Bats are the only animal species where viral RNA was amplified and sequenced from alive specimens. In total, 13 PCR products from which 7 sequences were obtained from 3 species of fruit bats (*Hypsignathus monstrosus, Epomops franqueti, Myonycteris torquata*), in Gabon, during the 2003 Ebola outbreak (Leroy et al., 2005). Although hundreds of birds and small terrestrial animals were tested for evidence of infection by Ebola virus. Several studies confirmed EBOV-specific antibodies (Zaire Ebola virus) in certain populations of *Eidolon helvum, Epomophorus gambianus, Rousettus aegyptiacus, Micropteropus pusillus, Epomops franqueti, and Hypsignathus monstrosus* (Hayman et al., 2010; Hayman, 2012; Ogawa et al., 2015; Pourrut et al., 2007; Pourrut et al., 2009) ; in different countries, but seroprevalence was generally low. It suggests bats of these species are exposed to EBV and survive infection. This was also confirmed by experimental infections of *Epomophorus wahlbergi* (Swanepoel et al., 1996). EBOV-specific antibodies were also found in 3 insectivorous bats*, Mops condylurus, in Gabon* (Pourrut et al., 2009). Specimens from *Mops condylurus* and *Chaerephon pumillus* have also survived to experimental infection while displaying high viremia (Swanepoel et al., 1996).

Each of the 3 species where viral RNA was found has a broad geographical range that includes areas of Africa where human Ebola outbreaks occur (Figure 2). Although bat migration is mainly found in temperate and some subtropical areas, where cold winter forces bats to migrate or hibernate, there is evidence of bat population movements between southern and central Africa (Monadjem et al, 2010). Thus, they could play a role as spatial amplifying hosts. Overall, very little is known about bats ecology in Africa, especially in West and Central Africa.

Bats being able to survive infection, replicate the virus, and migrate across Central and West Africa, point towards a putative role of bats in the reservoir of EBV. However, current evidence is still lacking to confirm that bats constitute a maintenance population.

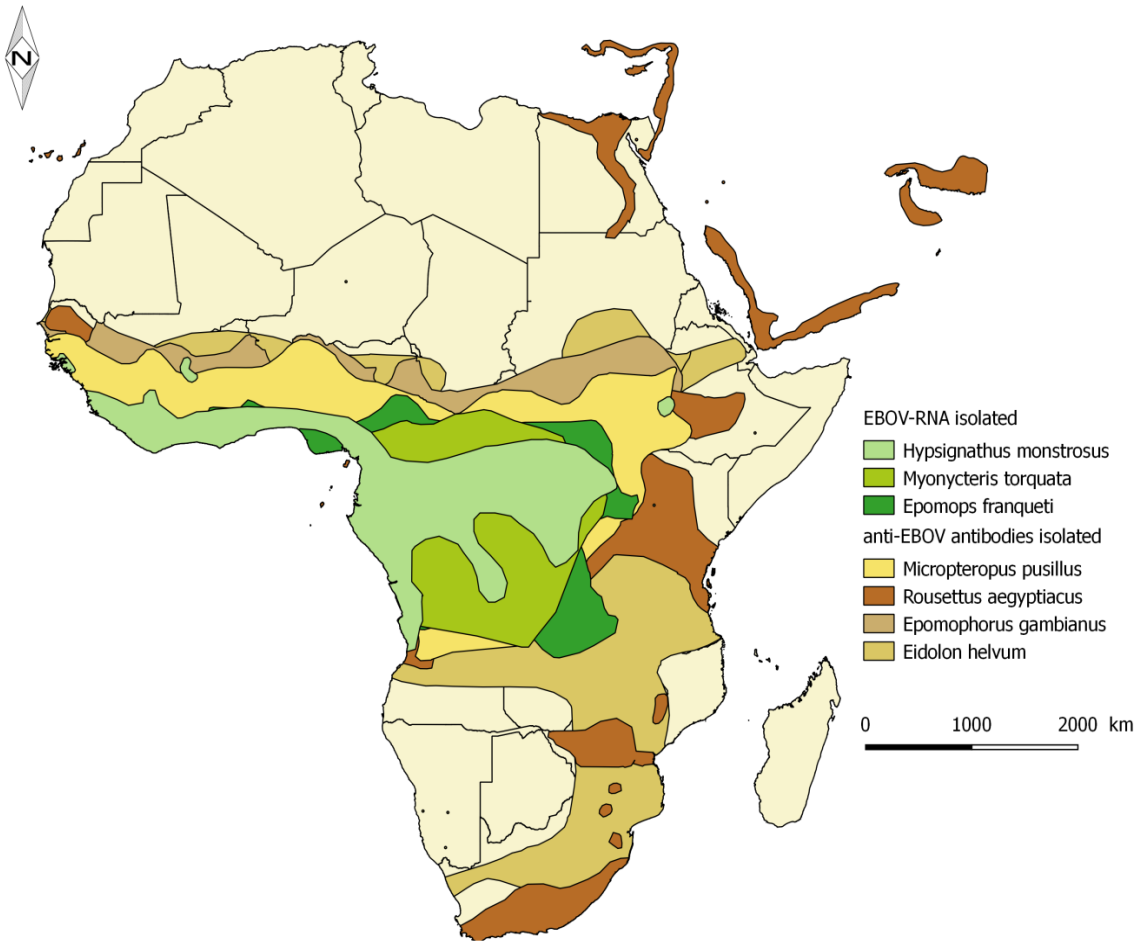


Figure 2. Distribution map of bat species possibly involved in EVD epidemiology - Data from the IUCN 2012. *IUCN Red List of Threatened Species. Version 2012.1*, adapted with QGIS, Geographical Information System software

Current data on virus circulation in bat populations is not sufficient to demonstrate that the virus is able to persist in this sole host species. Despite intensive longitudinal sampling efforts, the inability to find further EBOV sequences and the patchy pattern of seropositive bat populations suggest EBOV are not widely and generally present in bat population (Pigott et al., 2014).The shift in the proportion of PCR+ and seropositive individuals over a 5-months period (Leroy et al., 2005) during the 2003 outbreak would privilege the hypothesis of a seroconversion. That is, fruit bats at the beginning of the outbreak seemed not to have had previous EBOV exposure and appeared being able to clear infections. The seemingly dead-end infection of experimentally infected bats (Jones et al., 2015; Leendertz, 2016) corroborates this postulate. Furthermore seropositivity indicates that infection has occurred but does not provide information as to whether a non-target population is a maintenance host, especially as seropositivity for EBV in wildlife is not straight-forward to determine and may lead to over interpretation. High seropositivity at a single point in time may simply indicate an outbreak in the host population, rather than pathogen persistence. Low seroprevalence may arise when case mortality rates are high in the reservoir, during an interepidemic period, or when a pathogen persists at a stable but low

prevalence, particularly when the duration of the infectious period is high (e.g., as in carrier animals).

Another element that raises questions on bats being the maintenance population of the virus, concerns the geographical distribution of the three fruit bats species where viral RNA was found. Indeed, this spatial distribution is not consistent with the emergence of genetically distinct ebolaviruses (*Bundibugyo, Sudan, Taï Forest, Zaire*) that have occurred across Africa (Jones et al., 2015; Leendertz, 2016). Such separation speaks against a single well-mixed population able to cross river basin borders serving as the sole reservoir for all ebolaviruses. However, given the scarce knowledge on bat ecology in tropical Africa, it cannot be excluded that some populations, although belonging to the same species, form distinct entities that do not mix with one another.

Apes and other mammals, which role in the reservoir?

EBV viral RNA was isolated from carcasses of great apes (gorillas and chimpanzees) and duikers (Rouquet et al.). Significant mortality related to EBV has been reported in wild gorillas (*Gorilla gorilla gorilla*) and chimpanzees (*Pan troglodytes troglodytes*) in Gabon and Congo as well as in chimpanzees (*Pan troglodytes verus*) from the Tai forest in Ivory Coast (Bermejo et al., 2006; Formenty et al., 1999; Walsh, 2003). Those species are susceptible to the virus, and entire populations can be decimated by an outbreak. Therefore, they are unlikely maintenance populations. High mortality rates rule out an indefinite infection chain (Leroy, 2004), with the size of the population decreasing so dramatically and probably below the threshold of the critical size defined for a maintenance population. However, EBV antibodies have been observed in several wild-captured but captive non-human primate (NHP) species (chimpanzees, gorillas, mandrills, drills, baboons and Cercopithecus species) from Cameroon and Gabon, suggesting that non-lethal or asymptomatic infections could occur in certain NHPs and that EBV could be more widespread among NHP (Leroy, 2004). Thus, they might play a role of amplifying host, spreading the virus to other animal species, and creating a chain of maintenance for the virus.

Between the different EBV outbreaks from 1994 to 2003, bush pigs and sitatungas were also concerned by the 35 mortality and morbidity episodes reported in wild animals in Gabon in areas where EBV epidemics occurred (Lahm et al, 2007). Unfortunately, no EBV PCR or other tests have been done to identify the reason of the animals' death. But these observations may suggest that other species might be involved in the epidemiology of the disease. Finally domestic animals could also play a role. EBV antibodies have been detected in >30% of dogs living in villages where EBV outbreaks have been documented in Gabon, although no disease has been observed in dogs (Allela et al., 2005).

1.3. Knowledge on transmission events from wildlife to human

Existing evidence on wildlife-human zoonotic transmission

Each EVD outbreak probably is the result of independent zoonotic events. For some of the earlier EVD outbreaks, there was evidence of multiple spill-over infection (Leroy, 2004). Concerning the epidemic of 2013-2016, it was agreed that the most likely scenario is a single initial spill-over from the animal reservoir (Mari Saez et al., 2015).

Knowledge on EVD in humans has made noteworthy progress, notably thanks to epidemiological and sequence-based investigations that have provided information on transmission chains, which differ among the different outbreaks. Recent developments in high-throughput next-generation sequencing enabled rapid and in-depth viral genomic surveillance during the 2013-2016 EVD epidemic. Yet, links between target and reservoir is still particularly elusive in the case of EVD transmission. This may be due to the fact that transmission from reservoir to target is a rare and sporadic event. In addition, epidemiology of multi-hosts pathogens is quite challenging (Haydon et al., 2002); also reservoir for the west-Africa outbreak has still not been clearly identified.

The only laboratory-confirmed sources of human EVD outbreaks are great apes and duikers, (Leroy, 2004; Georges et al., 1999). In total 9 of the 26 outbreaks have been related to contact with NHP (including the one of 2017), mainly apes. But for many outbreaks, the initial source of zoonotic transmission has not been identified (Pigott et al., 2014; Pourrut et al., 2005).

Another investigated source of human infection is bats. First from the Luebo-2007 outbreak (Leroy et al., 2009), it was suggested that a 4-year old child was infected by the sweat of his father, presumed to be the index-case and asymptomatically infected with the virus he might have contracted through contact with bat bushmeat. It is unclear whether the child got exposed to an alternative zoonotic source. Secondly, in December 2013, in the small village of Meliandou in Guéckédou Prefecture, Guinea, the index case would appear to be a 2-year-old boy who may have been infected by playing in a hollow tree housing a colony of free-tailed bats (*Mops condylurus*) (Mari Saez et al., 2015). This hypothesis was formulated after a retrospective study following the beginning of the major outbreak in West Africa.

However, the proposed epidemiological link between bats and outbreak relies on limited evidence. Indeed, no EBV-positive specimens were detected in the area following the outbreak. Also, even though bats are eaten by some communities in this part of Africa, no fruit bat hunter has been reported as index-case. Questions about the ability of the virus to spread in bat bodily fluids are also raised. Since the only PCR-positive organs were liver and spleen, the viral RNA load in tissues was extremely low. This might be the reason why the virus itself wasn't isolated, and no viral RNA was detected in other blood-filled organs (heart, lung, kidneys) (Leroy et al., 2005). These bat specimens were collected soon after the onset

of the human outbreak, thus virus circulation in the wildlife reservoir would be expected to be high, specifically with high viral loads in all bodily fluids, including those involved in transmission (feces, urine, saliva).

Possible routes of transmission

In some outbreaks, it has been documented that the index individual had recent contact with blood of mammals through either hunting, butchering or animal carcasses (Pourrut et al., 2005). Regarding bats, the routes of transmission to other mammals and to human remain unclear. The current hypothesis is formulated according to other viral transmission routes. The main hypothesis regarding the way of transmission from bats to other susceptible mammals is through contact with fruits contaminated with EBV by feces or saliva from bats. This is supported by the experimental infection of *E.wahlbergi* that resulted in fecal shedding (Swanepoel et al., 1996), although evidence of EBOV fecal shedding has not been described yet in wild bat populations. Overall, the low number of EBV-positive bats detected in the wild has limited our understanding of shedding and transmission (Leendertz et al., 2016).

1.4. Summary of hypotheses on Ebola reservoir

Neither bat, nor apes alone appear to gather the criteria defining a maintaining population. Rather, current evidence would suggest those species are part of a complex, unresolved maintenance community. It is likely that other host species which may play a major role in epidemiological dynamics exist, even though they have not been identified yet despite important sampling efforts. Truly understanding the ecology and evolution of EBV, as well as its mechanisms of pathogenicity, would require information on the virus in all its host-virus interactions, and not just those associated with EVD outbreaks in humans. Humans represent a dead-end host for the virus, with only unbroken transmission chains reported between humans in the majority of previous outbreaks (Chowell et al., 2004; Legrand et al., 2007), and no indication that humans can reintroduce the virus back into reservoir species (Karesh et al., 2012). Although the lack of positive wildlife specimens has limited our understanding of EBV reservoir, two main scenarios can be reasonably considered.

In scenario 1 (Figure 3), the maintenance community would be constituted by bats interacting with other species not yet determined. Although all populations are sources, in this theory, apes and duikers are not required to maintain infection. Instead, they fall outside of the maintenance community but they are still part of the reservoir because they are a source and serve as amplifying hosts.

In the second scenario, an hypothetic, undetermined animal species would constitute a maintenance population. Elimination of infection in bats, or any species from the maintenance community, will not result in elimination of infection in the target, as the species from the X compartment is an independent maintenance population. In the case of EVD, scientists are searching for such a maintenance population, hosts where EBV circulates

without major negative effects (Leendertz et al., 2016); this would allow to implement disease control measures. This scenario seems less likely, as despite extensive sampling of diverse animal species no clues have been found for such a population where the virus would be expected to circulate consequently. However, this scenario cannot be ruled out, since the rich fauna of Central Africa makes it difficult to grasp fully all its components.

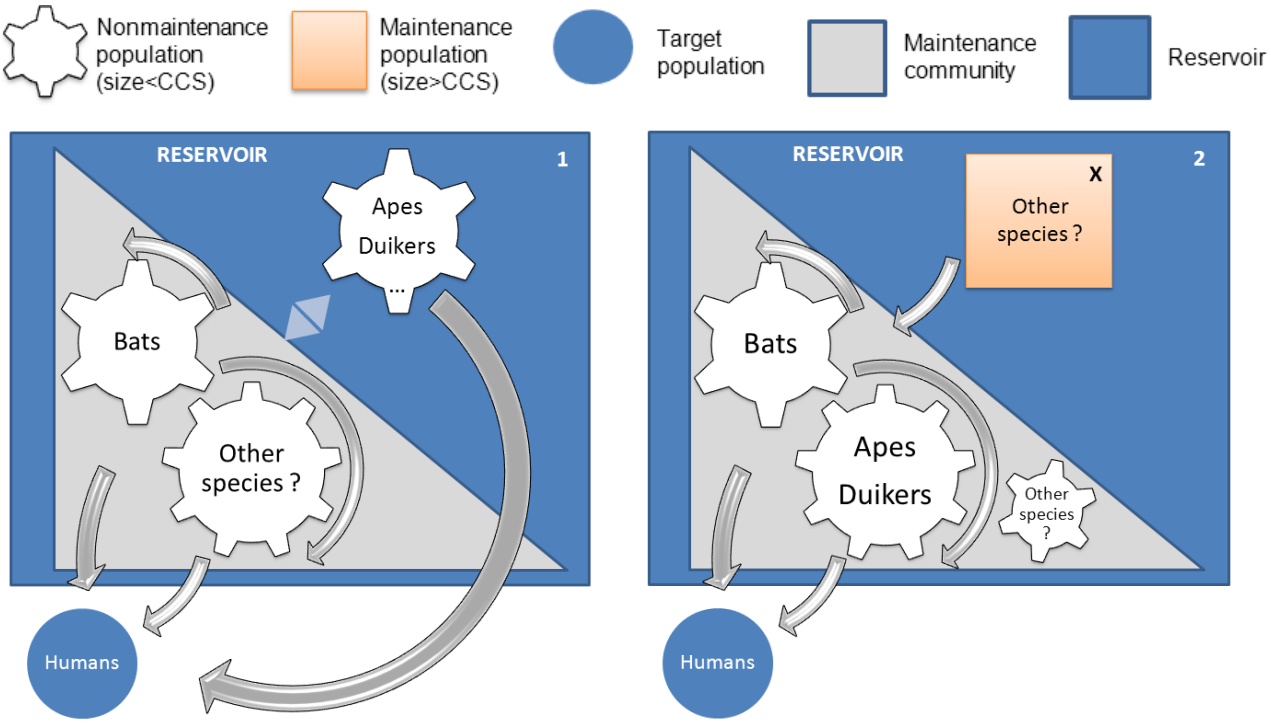


Figure 3. Hypothesis of target-reservoir system in the case of Ebola, adapted from conceptual models of (Haydon et al., 2002).

Ultimately, viral emergence might be more related to environmental factors and other hosts than bats themselves. The combination of ecological factors determining the occurrence of outbreaks has not been identified (Pigott et al., 2014), and there is little agreement on if and how movement of EBV occurs between the large distances observed between outbreaks (Biek et al., 2006; Leroy, 2004; Walsh et al., 2005; Wittmann et al., 2007). A “river-linked” Ebola ecology hypothesis has been raised (Leendertz, 2016), since river basins match strikingly to the delimitation of virus species, but no evidence sustains this theory at the present time.

1.5. Current knowledge on human-bat interactions in Central Africa

Despite the lack of reliable information on contacts leading to transmission events, findings suggest zoonotic transmission processes from bats to humans. The different modes of interactions that index cases had with wildlife are not well known, since a posteriori investigation is most of the time incomplete, the disease being rapidly lethal.

Information on bat hunting and consumption practices is scarce, even in countries where EBV outbreaks occurred. The majority of bushmeat survey papers failed to establish a

comprehensive picture of bat bushmeat consumption, although it gives some basic elements of understanding (Mickleburgh et al., 2009). In the Republic of Congo (RC), Democratic Republic of Congo (DRC), Uganda, Gabon, studies report that bat meat is hunted for family consumption, although not enough to pose a threat to bat populations. In RC and DRC different bat species (*E.helvum*, *Epomops franqueti* and *Hypsignathus monstrosus)* were found in some markets, sometimes at a lower price than any other bushmeat. Some reports also mention higher consumption levels locally, in some regions of Uganda, resulting in *E.helvum* population's decline (Monadjem et al., 2007). In Guinea, consumption level of populations of cave-dwelling bats is high, possibly threatening bat populations of *Rhinolophus* spp (Fahr et al., 2002). In none of those countries any control on bat hunting is implemented.

In Cameroon, the only information comes from anecdotal information. It suggests that bat consumption can be considered negligible, especially in comparison to other bushmeat. It was reported that *E.helvum* appears to be a delicacy in the Bomboko area, in the north west, where it can be a major source of income at peak harvesting season (Mickleburgh et al., 2009).

Understanding the attitudes and perception of communities in West and Central Africa towards bat related diseases is also limited, as large-scale studies were only conducted in Ghana (Gbogbo et Kyei, 2017; Kamins et al., 2015; Kamins et al., 2011). One of the findings was that despite the major campaigns associated with the recent Ebola outbreak, knowledge and disease risk perception of the communities was low, even more in rural areas than in cities.

Understanding Ebola risks in human-bats contacts: exploratory study on knowledge, attitudes and practices in Southern Cameroon

Chapter 2 – Introduction

As the majority of emerging pathogens, Ebola virus (EBV) appears to originate from wildlife. In the context of recent EVD outbreaks, focus has been set on finding out the wildlife reservoir of the virus. Although many questions remain, attention has been drawn to bats in which viral RNA was detected in a few wild living specimens (Leroy et al., 2005), but knowledge about the maintenance of the virus in bat populations is scarce. Moreover, recent studies are accumulating evidence that bats may not only host EBV, but also several other zoonotic pathogens including henipavirus (Hayman et al., 2008), paramyxoviruses (Baker et al., 2013; Drexler et al., 2012), lyssaviruses (Wright et al., 2010) and many others. In parallel, specific interactions between communities and bats, and thus the most probable routes and risks of transmission to humans, are very poorly documented. Existing information on this matter has generally been gathered in a retrospective way, when trying to elucidate transmission events leading to index cases of EBV outbreaks. Meanwhile, hunting, butchering and consumption of wild animals for food, which is common in Central Africa, can potentially transmit zoonotic pathogens through animal bites, scratches, contact with infected body fluids, tissues and excrements (Wolfe et Daszak, 2005). Thus, the use of bats as food raises particular concern, especially as the role they play as reservoir and in the transmission of viruses to humans is not elucidated yet. Therefore, it is of prime importance to understand and characterize communities' behaviors and beliefs towards bats in order to focus surveillance and prevention efforts on those which are particularly at risk.

Cameroon is considered at risk for EBV epidemics (Pigott et al., 2014) given that neighbors countries have already been hit by EBV outbreaks. Rural areas, where communities live in close contact with wildlife are of specific concern, yet, not investigated. As a step towards improving risk assessment and response to health risks, we carried out this exploratory study to investigate the communities at risk by characterizing the extent and modes of contact with bats and their attitudes and perception regarding bat diseases. In addition, importance of bats as food resource and for cultural purposes was also assessed in order to understand the impact of restrictive policies which might be implemented during outbreaks.

3.1. Study sites

The study was conducted in a total of 11 villages in four rural areas of southern Cameroon: the area of Gwap (nearby Bipindi), the border of Campo-Man Reserve, in south-west Cameroon, the northern periphery of Dja reserve, and in the region of Mambele near Lobeke National Park in the extreme south-east (Figure 4). Three of these areas surround protected natural parks, and still have a relatively rich fauna. In contrast, in Gwap, bush-meat has become quite scarce in the last decade, due to a combination of factors, among those: over-hunting, deforestation, agricultural intensification. The study sites had previously been chosen for their richness in gorilla/chimpanzee populations in the context of studies on the origin of HIV, on which the team has been working since 2000. These remote areas are hardly accessible, from Yaoundé, it takes an average of 4 hours to reach Gwap (260 km) and Dja (280 km), 5 hours to Campo (430 km), and 14 hours to Mambele (800 km), with a 4x4. In each area, villagers do not possess cars, without public transport facilities, transportation to the closest city is rarely affordable for villagers. Villages consist of mud-houses (Annexes 1-5) organized along the main dirt road, usually built to transport wood (in all 4 areas) or products from mine industry (with BOCOM company exploiting iron in the area of Gwap). In Mambele and Gwap, logging companies left after having harvested most of the exploitable wood of the area, in Mambele, trucks loaded with wood coming from the neighboring country RDC, drive across the village. Fruit trees are located around the houses in the villages, cultivated fields are nearby the villages, at the border with the forest. Regarding water availability, except in Gwap where there is tap water from a nearby underground source for almost every household, in the other areas villagers rely on one-point source water or river water. In Gwap, agricultural activity is not only for subsistence purpose, but also a source of income for inhabitants that sell part of their production.

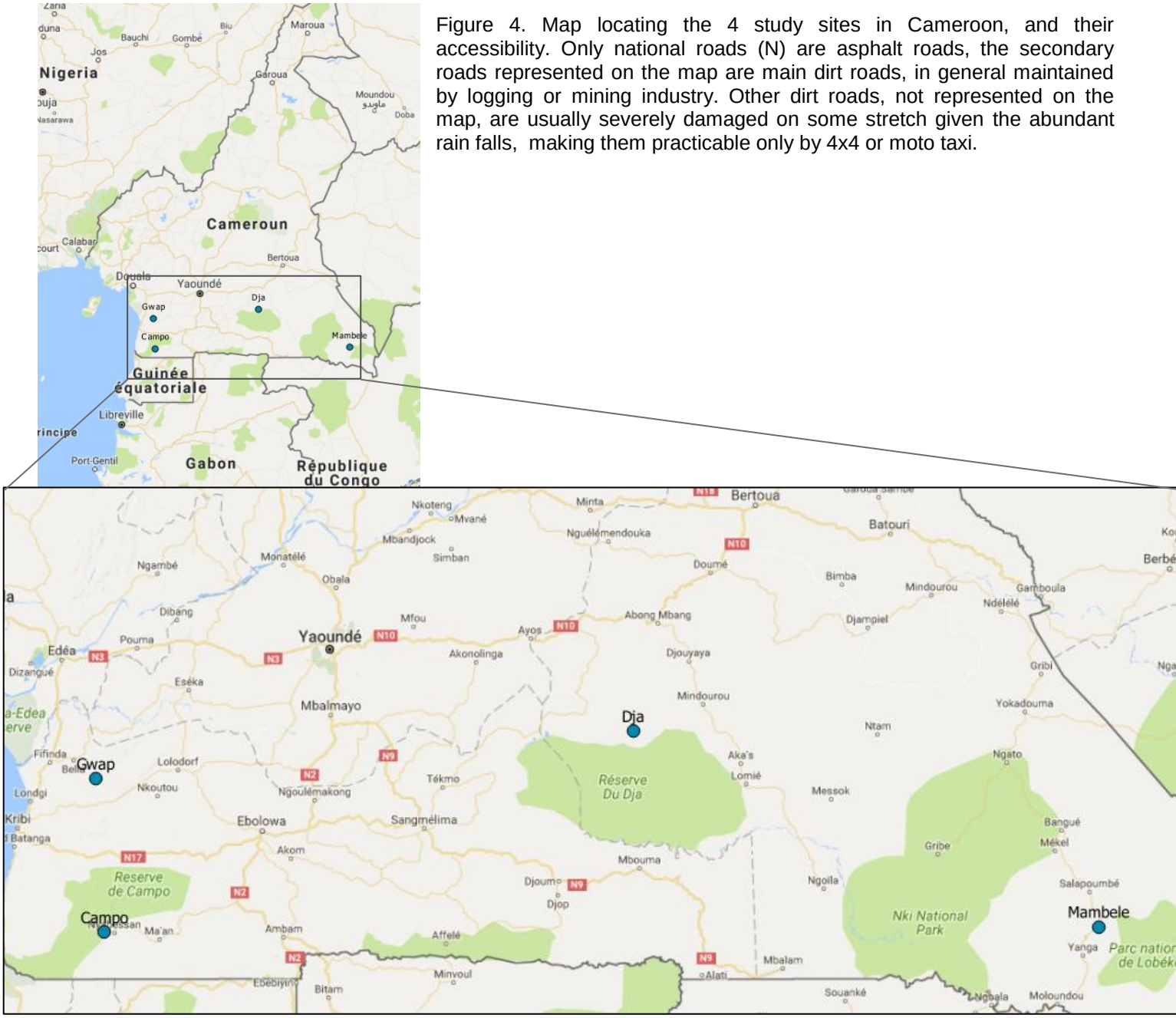


Figure 4. Map locating the 4 study sites in Cameroon, and their accessibility. Only national roads (N) are asphalt roads, the secondary roads represented on the map are main dirt roads, in general maintained by logging or mining industry. Other dirt roads, not represented on the map, are usually severely damaged on some stretch given the abundant rain falls, making them practicable only by 4x4 or moto taxi.

3.2. Questionnaires

Households surveys were designed by H.D.N. and conducted by H.B. and four local research assistants from February to May 2017 using standardized semi-structured questionnaires. Households were selected using convenience sampling along the only main road of each village and by choosing for interviewee one inhabitant of the household volunteering. Research assistants met with village chiefs to gain permission for conducting this survey which was performed in parallel to bat sampling, information on those two connected compartments being precious. All interviews were conducted in person first in French, with a local Cameroonian villager translating in the local language punctually if the interviewee did not understand something. Bats are legal to hunt, and there is no taboo or stigma associated with hunting bats in southern Cameroon. In general, interviewees were relaxed and comfortable answering our questions. However, in places where bat

consumption was associated to Pygmy ethnic group, a minority often marginalized and stigmatized, it cannot be excluded that some respondents, in presence of Bantus interpret and interviewer, might not have been comfortable addressing this topic. For example in Campo, where there wasn't an important community of Pygmies, a respondent declared he was Bantou, although the interpret from the village told us afterwards, he was in fact Pygmy. Our questionnaire design was based on the field team experience and accordingly to the questions we wanted to address. Specific attention was paid to distinguishing between "flying-squirrels" and bats, since in some places, villagers included this species into the denomination "bat". We used a standard semi-structured questionnaire, comprised of both multiple-choice and open-ended questions, for all respondents (Annex 6). This questionnaire enquired about demographic information of the respondent, direct interactions with bats (e.g. hunting or eating bats), specific contacts of children, possible indirect contacts (bat guano, fruits contaminated by saliva), beliefs about bat consumption, importance of bats as food resource and for cultural purposes, general meat preferences. We interviewed a total of 135 people in southern Cameroon.

3.3. Data analysis

Responses were summarized using descriptive statistics. Fisher's exact test as well as Pearson Chi-squared test were used to detect differences between the categories of responses. Statistical tests were considered significant at $p<0.05$. A multivariate analysis was performed in order to identify the variables having a significant effect on the response variable of the linear generalized model: the proportion of bat-consumers. The following explanatory variables were included in the maximal model, on the basis on biological hypotheses: gender, age, area, ethnic group, education, village, participation to bat hunting, awareness on bats resting places, perception of dangers or benefits related to bat consumption, existence of a traditional totem, usage of bats by healers. The selection of the final model was based on the Akaike's Information Criterion (AIC). Explanatory variables whose the effect appeared to be significant in the multivariate model were: study site, hunting practice and danger perception related to bats. We used R version 3.3.1 for all our statistical analyses.

4.1. Demographics of study population

The demographic characteristics of the respondents are presented in Figure 5. In total, there were 135 respondents consisting of 106 (79%) men and 29 (21%) women. This imbalance was largely due to the fact that the member of the household volunteering to answer the questionnaire was generally a man. Respondent's age ranged from 15 to 80 years, with a median of 45 years old. The majority of respondents 78 (58%) had only elementary education, 37 (28%) had secondary education, 11 (8%) went to high school, and 8 (6%) had no school education. Most of the respondents (100/135) were subsistence farmers, without distinction between women and men, and 31 (23%) declared hunting or fishing as a secondary activity. However, the communities rely on self-hunted bush-meat as their sole source of protein in the absence of domesticated animal meat neither available nor affordable in those areas. The low rate of interviewees mentioning this type of practices could potentially be linked to the fear of poaching repression. Only men hunt, some women declared fishing. For the remaining secondary occupation, 16 (13%) were craftsmen or sold services and 9 (7%) were employees. Except for 5 interviewees employed by NGOs (for a total of 9), respondents had no regular income. The average total number of inhabitants per household was 6 (ranging from 1 to 20), with a median number of children per interviewees of 4 (ranging from 0 to 11).

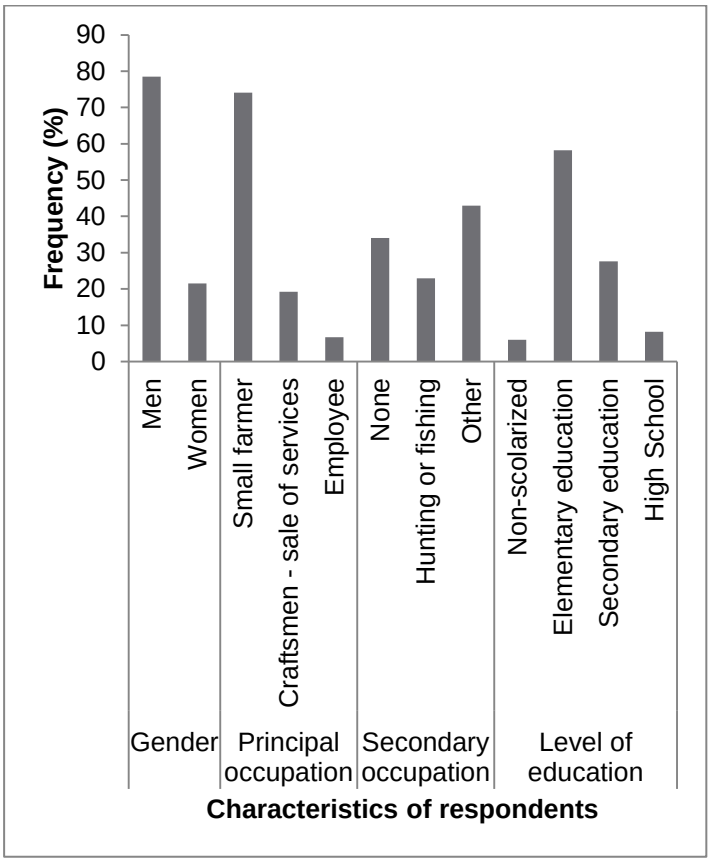


Figure 5. Frequency distribution of respondent's demographic characteristics in communities of rural southern Cameroon. N=135

In total, respondents were from 16 distinct ethnic groups. According to anthropological studies (Jean Fonkoué, 1981; Jean-Claude Barbier, 1981) taking into account the history of settlement, linguistic units, interethnic exchanges hierarchized in a socio-economic area, those ethnic groups can be gathered in larger units. Among Pygmies (n=37), 2 ethnic groups (among the 3 inhabiting Cameroon) were represented in our data: the Baka in the East, and the Bajele in the south-west. In majority, Pygmies interviewed were in Gwap (6/39) and Mambele (28/39), there were only 2 in Campo, and 1 in Dja. Among Bantus, the following ethnic groups were represented in our study: a first ethnic unit is the Beti-Fang group, from the south tropical forest, regrouping the ethnic groups Fang, Mvaé, Boulou, Beti, Ewondo and Ngoumba. Then, people from the East including the ethnic group : Bangandou, Badjoué, Kako. And finally the Bassa group: people from coastal tropical forest, including the ethnic group Bassa and Bakokos. Three people were part of 3 other distinct ethnic groups, originating from other areas of Cameroon. In our following analyses, we will consider area only for a matter of clarity, since it is highly associated to this ethnicity grouping, except for the distinction between Bantus and Pygmies.

Table 2. Distribution of respondents among the four areas and ethnic diversity

Site	Total number of respondents	Total number of ethnic groups
Campo	22	5
Gwap	39	6
Dja	35	2
Mambele	39	4
Total	135	17*

*different from the total number of distinct ethnic groups (N=16), given that Bajele Pygmies were present in Campo as well as in Gwap

4.2. Awareness of bat roosting sites and particularities of the areas

The type of roosting sites where respondents declare spotting bats during the day was found associated to the study site (Pearson's Chi-squared test, $\chi^2=44.74$, p-value$<10^{-7}$). In Gwap and Campo there was a high proportion of respondents mentioning caves as bat roosting sites (respectively 95% and 77%, Figure 6).Their geological specificities might explain this difference with the other sites. In Gwap, a several hundreds of meters-deep cave shelters important fruit and insectivorous bat colonies. In the area of Campo, a little cave in a rock (a dozen of meters high) is located only 2 km from the village and hosts insectivorous bats. A significant lower proportion of respondents mentioned bats hanging in trees during the day in Gwap (7/39) compared to 16/36 in Mambele (Fisher test, $p<0.05$). This might be partly linked to the fact that deforestation and agricultural activity is more developed in Gwap compared with the other areas. In Dja, the considerable proportion of respondents (91%) spotting bats hanging in trees during the day might be explained by the species particularly

present in this area. For more in-depth comparisons between habitats, an ecological study would be needed.

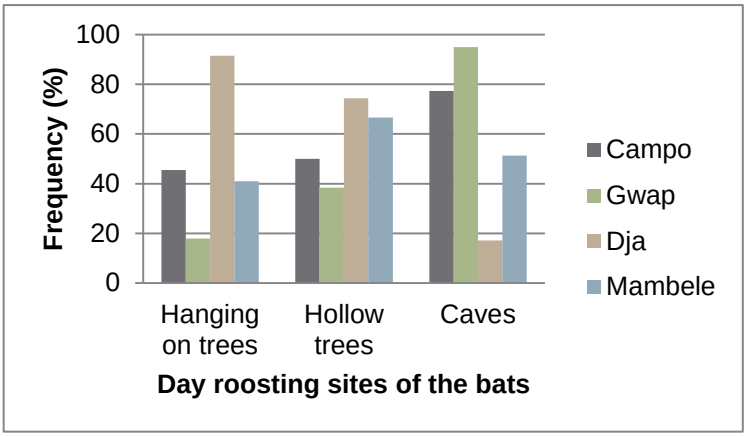


Figure 6. Distribution and characteristics of roosting sites by area, according to the knowledge of respondents

No seasonality of roosting period in caves was reported by respondents, 81% (59/75) thought they stay all year round, 16% (12/75) didn't know and only 5% (4/75) thought it was periodic. In Dja and Mambele, respectively 91% (21/22) and 79% (19/24) of the respondents reported no seasonality as well for bats staying in hollow trees. Regarding the period of roosting in trees, answers were not concordant.

4.3. Evaluation of risk of exposure through bat consumption

Consumption practices

The multivariate approach highlighted a few key factors affecting the probability a respondent consumes bats. These factors were : study site, hunting practice and perception of dangers related to bats. In the following sections we looked more closely at each variable.

First, bat consumption was found significantly associated to the study site. None of the respondents in the area of Campo declared eating bats (0/22), while 23% (8/35), 31% (12/39) and 87% (34/39) of the respondents did in Dja, Mambele and Gwap respectively (Fisher's exact test, p-value<10^{-12}, Table 3). Within one study site only, Mambele, a clear-cut difference between ethnic groups in consumption practices was observed, with the Baka ethnic group consuming significantly more 12/29 (41%, Fisher's exact test, p-value<0,01), compared to 0/10 non-Pygmies (0%) (Figure 7).

Table 3. Distribution of respondents answering to questions on bat consumption practices

Description	Area/ responses	Frequency of responses		
Number of consumers		Consume	Don't consume	
	Campo	0 (0%)	22	
	Gwap	34 (87%)	5	
	Dja	8 (23%)	27	
	Mambele	12 (31%)	27	
	Total (N)	54	81	
Type of bats eaten		Fruit bats only	Insectivorous bats only	All
	Campo	0	0	0
	Gwap	34	0	0
	Dja	6	0	2
	Mambele	2	3	7
	Total (N)	42	3	9
Who consumes bats			Importance of bats for subsistence	
	Everyone	49	None	37
	Males only	3	Comfort	15
	Adults only	2	Essential	1
Origin of bats consumed		Self-hunted	Given	Bought
	Gwap	23	12	25
	Dja	6	2	0
	Mambele	12	3	0
Reasons for non-consumption				
	Elders didn't eat	56		
	Other resources*	9		
	Hunting practicality**	4		
	Risk perception***	4		
	Other	8		

*other resources, not food / **don’t chase, difficult to catch / ***witchcraft, transmission of disease

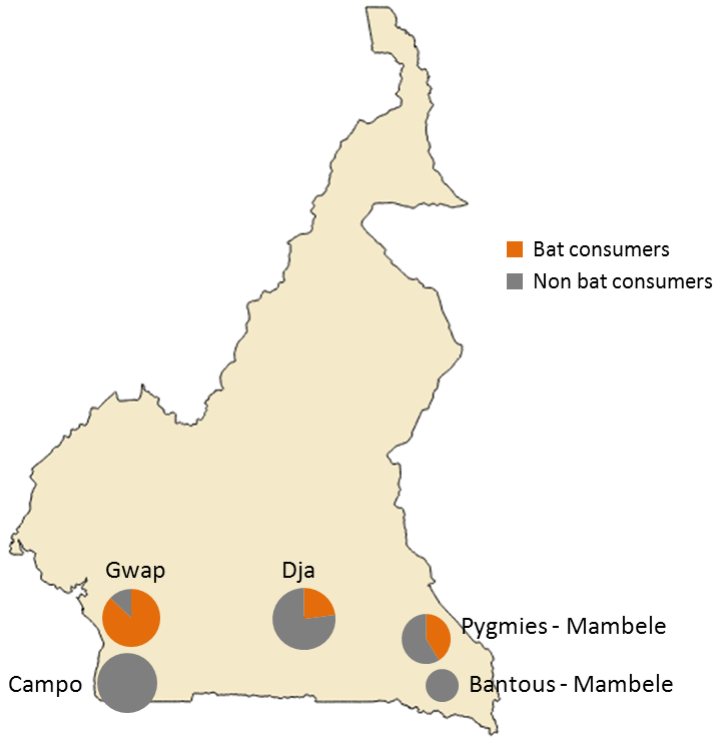


Figure 7. Map of bat consumption percentage in the 4 areas studied, among the respondents

When interviewees hunted bats themselves, they were logically more susceptible to eat bats (95%, 37/39), compared with those who didn't hunt bats (18%, 17/78) (Fisher's exact test, $p<10^{-15}$). Moreover, bat consumption was found significantly associated to a lower perception of danger related to bats. Indeed, among consumers, only 7% (4/54) thought this could be associated to some danger (20% of them didn't know), compared to 32% (26/81) among those who didn't eat bats (Fisher's exact test, p-value<0,001).

Social context of consumption

The questionnaire also assessed the characteristics of bat consumption: species consumed, bat meal preparation and habits. Mainly fruit bats are eaten (42/54, 78%), insectivorous bats are only consumed in 2 of the 4 areas (Table 3). All respondents clearly distinguished insectivorous and fruit bats, with distinct vocabulary. It appears some also had different vocabulary not only for the generic term of the sub-order (insectivorous/ fruit bats), but also specific vocabulary for several species of bats. For instance, some made a distinction between *Hypsignathus monstrosus* and other fruit bats, recognizable to its size, the specific aspect of the males' face (like a "horse") and their vocalization. However, without any type-specimen to match the respondents description, we are unable to describe more in details this lexical. Among the 54 villagers who eat bats, 91% (49) declared to share their meal with all the members of the household, or more generally "all of those present", including friends. 5 respondents declared only men or adults ate bats. Usually the women prepare the carcass without any specific precaution except for washing hands (with water,

soap being rare). Bat carcasses are first roasted over the fire to get rid of the fur and membrane of the wings, then, depending on the area, either gutted or not (in Gwap), before boiling. Overall, bats were consumed fresh (boiled) as well as smoked.

A majority (41/54, 76%) of respondents hunt themselves the bats they eat, 25/54 declared receiving them as well (Table 3). Selling of bats only takes place in Gwap, where not every hunter go to the specific cave, dangerous and difficult to access.

Reasons for not consuming bats were diverse, although a majority 56/81 (69%) didn't because elders never did. For the others, many different reasons were mentioned : 6 didn't eat them because they had other resources, 5 didn't like the taste, 3 thought bat isn't food, 2 didn't hunt, 2 thought it was difficult to catch, 2 because of witchcraft, 2 because of disease transmission, 2 just didn't want to and 1 thought it was repelling (Table 3).

Importance of bats as food resource

Bats were never mentioned among the three most important animals that people prefer to eat. Some interviewees who, during informal discussions, declared that bat meat is their favorite, said they did not cite it in the questionnaire because they don't eat bats often enough for it to be important. Other reason was because they do not consider bats as an animal, nor as a bird. Bats are not a major source of protein: 69% of the interviewees eating bats (37/54) thought it had "no importance", 28% (15/54) judged it was a "comfort", and one respondent said it was essential regarding how much he liked bat meat (Table 3). Among the consumers, the median value of consumption is three times a year (ranging from 1 to an approximate of 75 times a year) and 75% of the consumers eat bats less than 11 times a year (Figure 8). Although two respondents mentioned eating bats every week, in overall, this is an opportunistic bush meat. Even when it is highly appreciated by some communities, bat meat was never consumed in large quantities nor often enough to be considered important as a source of subsistence.

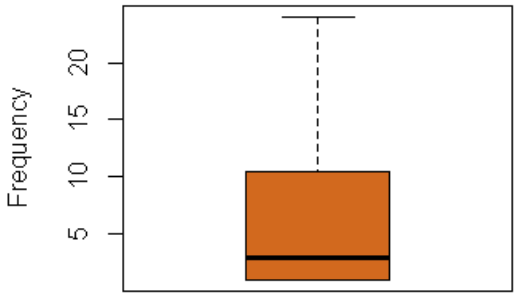


Figure 8. Boxplot of annual frequency of consumption among the consumers *For clarity, the extreme value of 75 wasn't represented on the graph.

4.4. Evaluation of risk of exposure through bat hunting

Hunting methods and seasonality

All bat hunters (38/135) were men. Hunting is culturally an activity practiced only by men, while women are in charge of the household, the children, cooking, and also the agricultural

activity. Hunters captured bats in various ways depending on the area (Figure 9), either in hollow trees by lighting a fire whose smoke chokes the bats, or scavenging trapped bats in fallen dead trees, or stunning them when spotting them on trees, houses or at the exit of a cave, or directly collecting them against the walls of the caves by climbing. Six hunters mentioned using nets, and two fire arms.

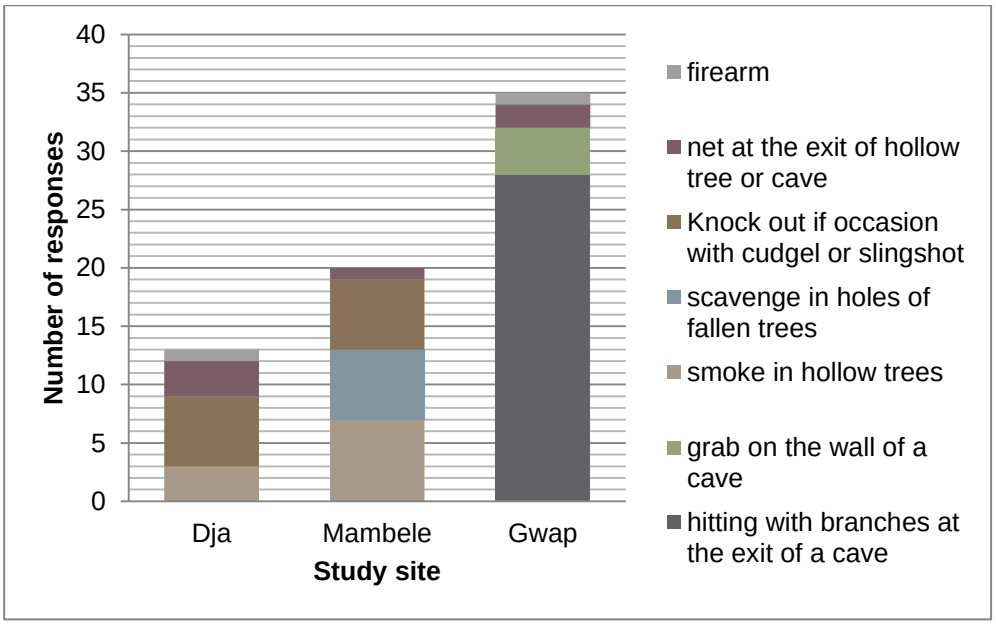


Figure 9. Different hunting methods across the interview sites

When capture takes place in caves (mainly in Gwap, Figure 9), hunting is reported all year round, although a majority (23/41, 56%) of respondents declared it was predominant during wet season. 29% (7/24) of respondents hunting bats in trees do it whenever they have the opportunity to do so, and 58% (14/24) hunt all year round (Table 4). The context of hunting in Gwap is quite specific since villagers hunt bats exclusively in one cave, well-known locally, difficult and dangerous to access. Thus only young men go there, and it is forbidden to women. It is also associated to a sacred ritual for the community. In this area, several reasons for this hunting seasonality were given by the respondents. First, the wet season matches the July-August holydays, when most of young men, able to go to the cave, come back to the village. Another reason described was that, during the wet season, bats would go out of the cave when hunters make noise, whereas, during the dry season, they would stay down the cave. Only hunters that climbed the walls of the cave could collect bats even during the dry season, by choking the bats between their back and the wall of the cave.

Risks of injuries during hunting

18/38 bat hunters have already been bitten by bats, and three respondents, too old to go hunting anymore in the cave in Gwap had also been bitten. Two respondents who did not hunt bat, got bitten once. Hunters capturing in caves with sticks or bare hands are more likely to have been bitten multiple times (10/22, 45%) compared to those capturing in trees (2/16, 13%) (Fisher's exact test, $p<0.01$) (Table 4). Only one hunter reported using gloves as

protective measure, others used none, but most of them didn't pick up the bat before killing it first.

Table 4. Distribution of respondents answering to questions on bat hunting practices

Description	Responses/Area	Frequency of responses		
Season/place of capture		Tree	Cave	
	Dry season (Nov-March)	2	2	
	Wet season (April-Oct)	1	23	
	All year round	14	14	
	When occasion	7	2	
	Total (N)*	24	41	
Risks of being bitten among bat hunters				Total
	Never	10	10	20
	Less than 5 times	4	2	6
	Multiple times	2	10	12
	Total	16	22	38
Children-bats direct contacts	Catch			Keep bats alive
		Respondent eat bats	Respondent doesn't eat bats	
	Yes	19	11	13
	No	35	70	122

* The total number of responses is above the total number of hunters, since non hunters were also asked this question

Evaluation of direct contacts between children and bats

30/135 (22%) respondents reported that children catch bats : 14 only to play, including in Campo where they don't eat bats, 12 to play and eat, and four to eat only.12/30 keep them alive, and one respondent reports that children keep bats alive, without catching them, when adults bring back live hunted bats. When kept alive, they are usually tied to a string and a stick. Bat consumption by the respondent was found significantly associated with a higher proportion of children catching bats: among bats consumers, 35% (19/54) declared that children catch bats, compared to 14% (11/81) for non-consumers (Pearson's Chi-squared test, $p<10^{-2}$). Two respondents reported their children had been bitten several times by bats, one in Mambele, the other in Gwap.

4.5. Indirect contacts

Homogeneously among areas, respondents declared bats were eating fruits (86%, 116/135) on trees surrounding the village (Table 5). However, a noteworthy difference is the kind of tree they feed on, especially in Mambele where 56% (27/48) of the fruit trees mentioned where *Parasolier* or *Ficus*, whose fruits are usually not eaten by villagers (Figure 10). “Etol” was mentionned in Dja, however we were unable to identify which tree species it designates.

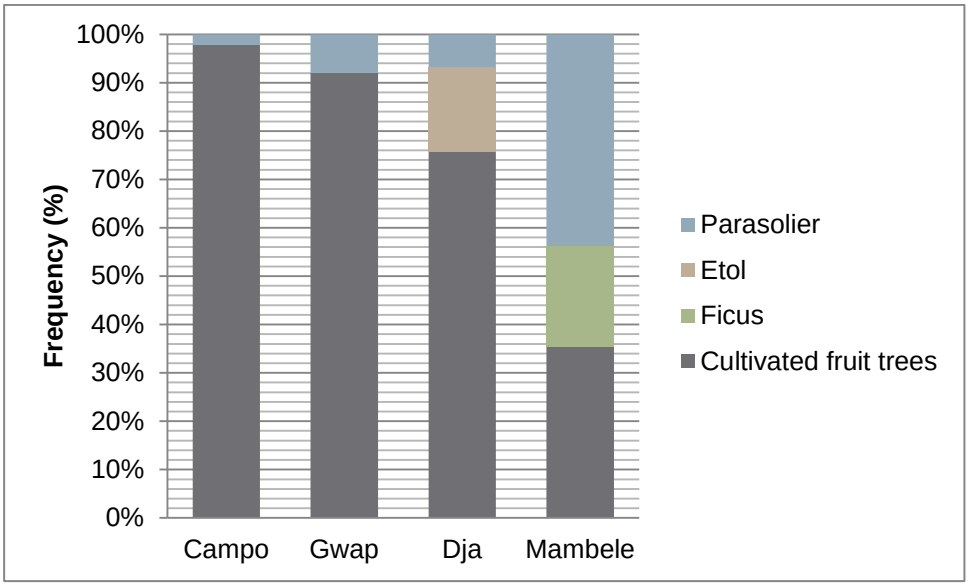


Figure 10. Proportion of trees where bats eat, according to respondents, depending on the interview area

67% (90/135) of the respondents declared (themselves or their children) to eat fruits already munched (Table 5). Although depending on the area, the proportion of respondents eating munched fruits varies, with 41% in Mambele, compared to 89% in Dja (Fisher’s exact test, $p<10^{-4}$). It could be associated to the abundance of Parasolier *(Musanga Cecropioides),* whose the fruit is not usually eaten by humans. In this area, deforestation and lack of agricultural activity enabled this heliophilous tree to grow at the forest border. Interviewees spontaneously reported removing the munched part before eating it, and to wash (with available water) and peal it, although they mentioned that they could not control whether their children were taking those precautions before eating. Mangos were cited by 59 of the 90 respondents declaring eating munched fruits and represented more than a third of the total number of fruits cited, among the others: guava, plum, avocado, soursop, papaya (Figure 11). 45% of the agricultural activities described by respondents as attractive for bats, were not related to eatable-fruit trees, but to other types of cultures: 13 mentioned maize, 10 coffee plant, four cacao tree and three cassava plant. This might be explained by the diet not exclusively frugivorous of certain fruit bats, that also feed on nectar.

Table 5. Distribution of respondents answering to questions on bat indirect contacts

Description	Responses/Area	Frequency of responses			
Indirect contacts through fruits	Bats feed on fruit-trees around the village		Consumption of fruits munched by bats	Yes	No
	Yes	116	Campo	19 (86%)	3
	Doesn't know	8	Gwap	24 (66%)	15
	No	11	Dja	31 (89%)	4
			Mambele	16 (41%)	23
			Total N	90 (67%)	45
Other indirect contacts		Caves as shelters for hunters		Streams flown over by bats	
	Yes	21		88	
	No	17		47	

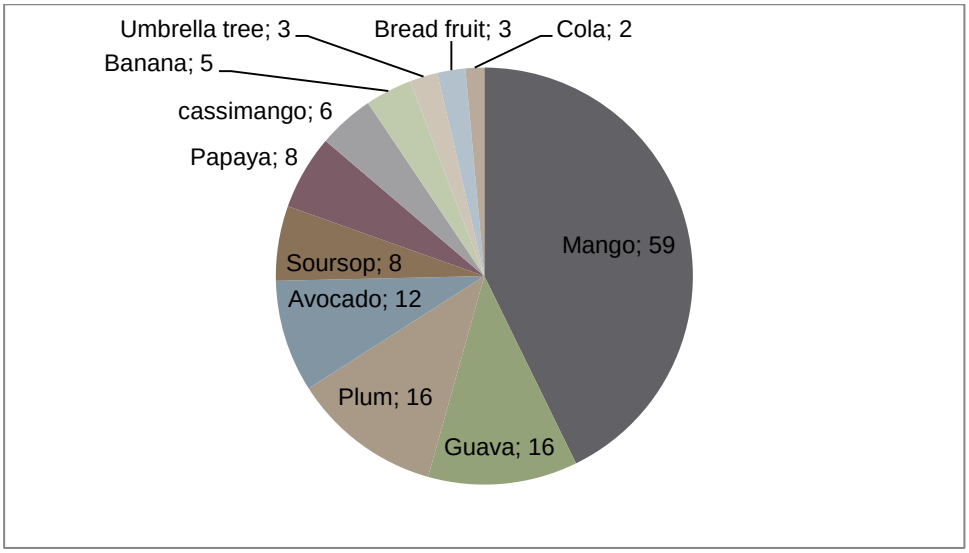


Figure 11. Proportion of munched fruits eaten by villagers reported by respondents

55% (21/38) of hunters used caves as a shelter from weather conditions (rain), which imply they might be in contact with guano (bats feces) dropped on the floor's cave. 65% (88/135) declared seeing bats flying over streams nearby the village. Although in Gwap, 59% of respondents declared not seeing bats there. This might be due to the availability of tap water for almost every household, contrary to the other areas where villagers rely on one-point source water or river water. Insectivorous bats often entered the door-less houses at night, but none of the respondents declared bats stayed under the houses roofs. None of the respondents exploited dropped feces in caves, for instance as fertilizer, and they had never heard of it.

4.6. Risk perception and traditional beliefs toward bats

In Campo, where none of the respondents eat bats, 64% (14/22) of them declared there is a danger associated with bat consumption (the rest did not know or did not think there is any), compared to 13% (5/39) in Gwap, where bats consumption is the most common (Fisher's exact test, p-value<0,0001) (Table 6). Transmission of disease was mentioned by 70% (21/30) of those believing bat consumption could be associated to some danger, and 15% (5/30) believed bats were associated to witchcraft activities. The other dangers mentioned were linked to the suspiciousness towards bats due to the unfamiliarity of villagers with their "lifestyle". Some respondents mentioned the fact that bats were weird creatures living at night, neither animal, nor bird, that they would defecate through their mouth. Only one of the totem mentioned (meaning forbidden to eat) was bats, the reason being it would transmit disease. Ten respondents thought bat consumption was beneficial, only among consumers, as source of food/protein for five, three for health improvement and two for satisfaction in Gwap.

Bats were thought to be used by healers by 21% (29/135) of the respondents, 36% didn't know. Generally respondents were not aware of the exact use healers made of bats, although some mentioned specific use. First of all as a medicine treating "ratte", a disease described as stomach aches affecting children (2), poisoning (1), infertility (1) and mosquitoes diseases (1). Some also mentioned witchcraft purposes: three mentioned it was used for women bewitchment, two for spell casting, one for fortune telling and a lucky charm for footballers. Among the respondents there were three healers, two of them didn't use bats, one used it for women bewitchment. Perception of usage of bats by healers varied per site, with 32% (7/22) believing so in Campo, compared to 8% (3/39) in Mambele.

Table 6. Distribution of respondents answering to questions on bat risk perception and traditional beliefs

Description	**Area/Responses**	**Frequency of responses**			
Bat risk perception		Danger associated to consumption	No danger		Danger's detail
	Campo	14	8	Disease transmission	21
	Gwap	5	34	Witchcraft	5
	Dja	4	31	Mistrust	4
	Mambele	7	32		
Healer's use of bats			Bat consumption benefits		
	Yes	29	10		
	Doesn't know	48			
	No	58	125		

The results of our questionnaires showed that direct human-bat contacts are substantial, with 54/135 respondents eating bats, 38/135 hunting them, 30/135 of them report children catch bats. This finding is especially relevant as it is known that a single zoonotic disease transmission can have major consequences on entire communities (Baize et al., 2014). Indeed, one spillover event can lead to large human EVD outbreaks perpetuated by human to human transmissions. In regard to indirect contacts, communities are homogeneously exposed to fruits possibly contaminated by bat feces or saliva, with 67% of respondent consuming munched fruits. This raises concern, since there is experimental evidence of virus secretion in bat feces (Swanepoel et al., 1996). There is also evidence of transmission of other viruses carried by bats to humans through this route. For instance henipavirus spillovers from fruit bats to humans have occurred in Asia and Australia, where they caused fatal encephalitis and respiratory failure (Breed et al., 2006; Chua, 2000).

Alarmingly, perception of danger related to bats was found very low, with as much as 78% of the respondents not believing that bat bush-meat consumption can be associated to health risk. This result is not surprising, when considering other studies which showed similar results (Gbogbo et Kyei, 2017; Kamins et al., 2015) even though they were conducted in countries where sensitization campaigns had been implemented, contrary to Cameroon. More strikingly, even when respondents mentioned spontaneously Ebola, they declared not to feel “at risk” of Ebola disease in their country, since no outbreak occurred yet. Therefore, it appears that public health education needs to be initiated in Cameroon. Previous Ebola communication, however, has been marked by a series of errors, erroneous or inappropriate messages that have contributed to doubts and created anxiety (Seytre, 2016). This emphasizes the need to re-think the way of interventions, through social mobilization, sanitary education, and health promotion as suggested by the Organisation mondiale de la Santé, 2014).

This study also revealed that although bat meat consumption is common, communities do not rely on it as their main source of protein with 69% of respondents stating it had “no importance” as a food resource. It rather appears to be an occasional dish (with three-quarter of consumers eating bats less than 11 times in a year), or in some communities an appreciated delicacy. Knowing how much people depend on bats for both survival and cultural purposes will help to inform any restrictive policies needed in case of an outbreak, thus minimizing negative consequences (Dry et Leach, 2010). Health organizations have sometimes reacted hastily to emerging zoonosis, discovering only later the complexities that accompany cross-species diseases. For example, in Gabon, the cultural inappropriateness of a top-down approach led to armed resistance against attempts to control the 2001 Ebola outbreak (Millerlili, 2004).

Although bats attract attention, this study suggests that direct contacts with bats is far less frequent compared to contact with animals essential for subsistence. Great insight on at-risk contacts with wildlife can be gained from other bushmeat sources, especially mammal species most regularly hunted. Indeed, hunting pressure raises the probability of direct contact with bodily fluids to occur, which is the main suspected way of pathogens' transmission. Species that are the most cited by the respondents as their "favorite meat by order of importance" (formulated this way to reduce possible taboo about poaching), were: porcupine, hare, pangolin, rat, duiker, varan, bush pig, hedgehog. Also, raw palm juice harvesting and drinking practices would need to be included in further investigations.

We found great discrepancies between study sites regarding bat consumption habits and cultural beliefs. A striking result that illustrates this conclusion is the proportion of respondents having a totem, significantly higher in Mambele with 95% (37/39), compared to 8% (3/39) in Gwap (Fisher's exact test, $p<10^{-5}$). These differences might reflect the ethnic cultural history of communities from the different areas, and more specifically the settlement history. This hypothesis is concordant with the fact that in one of the areas, bat consumption behavior was radically different according to the ethnic origin of the respondents. A second explanation, which does not exclude the other, is the environmental specificity of the area, that might influence human-bats contacts. This is quite striking in the area of Gwap, with the presence of a particular cave hosting bat colonies, and where most of the villagers consume bats. In regard to those discrepancies between areas geographically close, it would be important to cover larger areas in order to have a more complete idea of practices and behaviors in Cameroon. Furthermore, this study was carried out in environments relatively preserved in terms of biodiversity and abundance of bush-meat and as a result, practices might not reflect those in areas less preserved. Human-bats contacts characteristics may be quite different, for example, bats might represent a non-negligible protein resource for the communities. Overall, this exploratory study shows the importance of carrying out large surveys in order to exhaustively identify at-risk communities in Cameroon, and thus being able to efficiently target surveillance, prevention and health campaign, especially in a context of limited resources.

This exploratory study highlighted which method could be more effective in order to gather information on practices. Indeed, among one study site, homogeneity of practices and perception was striking, and it appeared after a few questionnaires from some key informant, our knowledge was "saturated". Thus, it might be more relevant in a following study to implement qualitative approach, with key informants. Also, for interviewing women, it appeared that individual interviews with men better educated, had some limitations. Indeed, most of the time women were impressed and did not provide much information, saying that "they do not know anything", although they are in charge of the preparation and cooking of all the bushmeat. Rather, focus groups formed by women and animated by a female animator would appear to be the best approach.

Geographical and cultural diversity of contacts and perceptions regarding bats in Cameroun points towards a high variability in potential transmission risks of bat pathogens to humans. This emphasizes the need for larger-scale surveys in order to identify high risk sites and populations to target for more efficient surveillance as well as health and education campaigns. The recent EBOV cases that occurred in DRC in May 2017 are a clear reminder that EBOV disease prevention can be improved.

ECOLE NATIONALE VETERINAIRE TOULOUSE

UNIVERSITÉ TOULOUSE III PAUL SABATIER Université de Toulouse

AGREMENT SCIENTIFIQUE

En vue de l'obtention du permis d'imprimer de la thèse de doctorat vétérinaire

Je soussignée, **Mathilde PAUL**, Enseignant-chercheur, de l'Ecole Nationale Vétérinaire de Toulouse, directeur de thèse, certifie avoir examiné la thèse de **Hélène BAUDEL** intitulée **«Understanding Ebola risks in human-bats contacts : exploratory study on knowledge, attitudes and practices in Southern Cameroon»** et que cette dernière peut être imprimée en vue de sa soutenance.

Fait à Toulouse, le 8 novembre 2017
Docteur Mathilde PAUL
Maître de Conférences
de l'Ecole Nationale Vétérinaire de Toulouse

Vu :
La Directrice de l'Ecole Nationale Vétérinaire de Toulouse
Isabelle CHMITELIN

ECOLE NATIONALE VETERINAIRE DE TOULOUSE

Vu :
Le Président du jury :
Professeur Pierre DELOBEL

Professeur Pierre DELOBEL
RPPS : 10001386842
Service des Maladies Infectieuses et Tropicales
CHU de Toulouse - Hôpital Purpan
Place Baylac - TSA 40031
31059 TOULOUSE Cedex 9
Tél. 05 61 77 75 08 - Fax 05 61 77 21 38

Vu et autorisation de l'impression :
Président de l'Université
Paul Sabatier
Monsieur Jean-Pierre VINEL

Le Président de l'Université Paul Sabatier
par délégation,
La Vice-Présidente de la CFVU

Régine ANDRE-OBRECHT

Mlle Hélène BAUDEL
a été admis(e) sur concours en : 2012
a obtenu son diplôme d'études fondamentales vétérinaires le : 23/06/2016
a validé son année d'approfondissement le : 13/07/2017
n'a plus aucun stage, ni enseignement optionnel à valider.

Université de Toulouse

Bibliographie

ALLE LA L, BOURRY O, POUILLOT R, DELICAT A, YABA P, KUMULUNGUI B, LEROY EM (2005). Ebola virus antibody prevalence in dogs and human risk. *Emerging Infectious Diseases,*11, 385.

BAIZE S, PANNETIER D, OESTEREICH L, RIEGER T, KOIVOGUI L, MAGASSOUBA N, GUNTHER S (2014). Emergence of Zaire Ebola Virus Disease in Guinea. *New England Journal of Medicine,* 371, 1418-14251.

BAKER KS, TODD S, MARSCH GA, CRAMERI G, BARR J, KAMINS AO, WANG LF (2013). Novel, Potentially Zoonotic Paramyxoviruses from the African Straw-Colored Fruit Bat Eidolon helvum. *Journal of Virology,* 87, 1348-1358.

BARBIER JC (1981). Les groupes ethniques et les langues. In Encyclopédie de la République Unie du Camerou (pp. 239–260). Doula : Nouvelles Editions Africaines.

BARLETT MS (1960). The critical community size for measles in the United States. *Journal of the Royal Statistical Society*.

BERMEJO M, RODRIGUEZ-TEIJEIRO JD, ILLERA G, BARROSO A, VILA C, WALSH PD (2006). Ebola Outbreak Killed 5000 Gorillas. *Science*, 314, 1564.

BIEK R, WALSH PD, LEROY EM, REAL LA (2006). Recent common ancestry of Ebola Zaire virus found in a bat reservoir. *PLoS Pathog*, 2, 90.

BREED AC, FIELD HE, EPSTEIN JH, DASZAK P (2006). Emerging henipaviruses and flying foxes - conservation and management perspectives. *Biological Conservation*.

SEYTRE B (2016). The Wanderings of the Communication on the Ebola Virus Disease. *Bulletin de La Société de Pathologique Exotique.*

CENTERS FOR DISEASE CONTROL AND PREVENTION (CDC) (2016). Outbreaks chronology: Ebola Virus Disease.

CHOWELL G, HENGARTNER NW, CASTILLO-CHAVEZ C, FENIMORE PW, HYMAN JM (2004). The basic reproductive number of Ebola and the effects of public health measures: the cases of Congo and Uganda. *Journal of Theoretical Biology*, 229, 119-126.

CHUA K (2000). Nipah virus: a recently emergent deadly paramyxovirus. *Science*.

DREXLER JF, CORMAN VM, MULLER MA, MAGANGA GD, VALLO P, BINGER T, DROSTEN C (2012). Bats host major mammalian paramyxoviruses. *Nature Communications*, 3, 796.

DRYS S, LEACH M (2010). Epidemics:“ Science, Governance and Social Justice.”

FAHR J, ERHAUS, KOCK DH, HUTTERER (2002). A revision of the Rhinolophus maclaudi species group with the description of a new species from West Africa (Chiroptera: Rhinolophidae). Myotis.

FELDMANN H, GEISBERT TW (2011). Ebola haemorrhagic fever. *The Lancet*, 377, 849-862.

FONKOUE JF (1981). Essai de nomenclature des populations et des langues du Cameroun (Centre d’études africaines, Vols. 1–2). Paris: Centre d’analyse et de recherche documentaire pour l’Afrique noire.

GBOGBO F, KYEI MO (2017). Knowledge, perceptions and attitude of a community living around a colony of straw-coloured fruit bats (Eidolon helvum) in Ghana after Ebola virus disease outbreak in West Africa. *Zoonoses and Public Health*.

GEORGES AJ, LEROY EM, RENAUT AA, BENISSAN CT, NABIAS RJ, NGOC MT(1999). Ebola hemorrhagic fever outbreaks in Gabon, 1994–1997: epidemiologic and health control issues. *Journal of Infectious Diseases*, 179,S65-S75.

GIRE SK, GOBA A, ANDERSEN KG, SEALFON RSG, PARK DJ, KANNEH L, SABETI PC (2014). Genomic surveillance elucidates Ebola virus origin and transmission during the 2014 outbreak. *Science*,345, 1369-1372.

HAYDON DT, CLEAVELAND S, TAYLOR LH, LAURENSON MK (2002). Identifying reservoirs of infection: a conceptual and practical challenge. *Emerging Infectious Diseases*, 8, 1468-1473.

HAYMAN DTS, EMMERICH P, YU M, WANG LF, SUU-IRE R, FOOKS AR, WOOD JLN (2010). Long-Term Survival of an Urban Fruit Bat Seropositive for Ebola and Lagos Bat Viruses. *PLoS ONE*, 5, e1178.

HAYMAN DTS, SUU-IRE R, BREED AC, McEACHERN ja, WANG L, WOOD JLN, CUNNINGHAM AA (2008). Evidence of Henipavirus Infection in West African Fruit Bats. *PLoS ONE*, 3, e2739.

HAYMAN UA (2012). Ebola Virus Antibodies in Fruit Bats, Ghana, West Africa. *Emerging Infectious Diseases*, 18, 1206-1207.

HOLMES EC, DUDAS G, RAMBAUT A, ANDERSEN KG (2016). The evolution of Ebola virus: Insights from the 2013–2016 epidemic. *Nature*, 538, 193-200.

JONES M, SCHUH A, AMMAN B, SEALY T, ZAKI S, NICHOL S, TOWNER J (2015). Experimental Inoculation of Egyptian Rousette Bats (Rousettus aegyptiacus) with Viruses of the Ebolavirus and Marburgvirus Genera. *Viruses*, 7,3420-3442.

KAMINS AO, ROWCLIFFE JM, NTIAMOA-BAIDU Y, CUNNINGHAM AA, WOOD JLN, RESTIF O (2015). Characteristics and Risk Perceptions of Ghanaians Potentially Exposed to Bat-Borne Zoonoses through Bushmeat. *EcoHealth*, 12, 104-120.

KAMINS AO, RESTIF O, NTIAMOA-BAIDU Y, SUU-IRE R, HAYMAN DTS, CUNNINGHAM AA, ROWCLIFFE JM (2011). Uncovering the fruit bat bushmeat commodity chain and the true extent of fruit bat hunting in Ghana, West Africa. *Biological Conservation*, 144, 3000-3008.

KARESH WB, DOBSON A, Lloyd-Smith JO, LUBROTH J, DIXON MA, BENETT M (2012). Ecology of zoonoses: natural and unnatural histories. *The Lancet*, 380, 1936-1945.

LAHM SA, KOMBILA M, SWANEPOEL R, BARNES RFW (2007). Morbidity and mortality of wild animals in relation to outbreaks of Ebola haemorrhagic fever in Gabon, 1994–2003. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 1, 64-78.

LEENDERTZ S (2016). Testing New Hypotheses Regarding Ebolavirus Reservoirs. *Viruses*, 8, 30.

LEENDERTZ SAJ, GOGARTEN JF, DUX A, CALVIGNAC-SPENCER S, LEENDERTZ FH (2016). Assessing the Evidence Supporting Fruit Bats as the Primary Reservoirs for Ebola Viruses. *EcoHealth*, 13, 18-25.

LEGRAND J, GRAIS RF, BOELLE PY, VALLERON AJ, FLAHAULT A (2007). Understanding the dynamics of Ebola epidemics. *Epidemiology and Infection*, 135, 610.

LEROY EM, EPELBOIN A, MONDONGE V, POURRUT X, GONZALEZ JP, MUYEMBE-TAMFUM JJ, FORMENTY P (2009). Human Ebola outbreak resulting from direct exposure to fruit bats in Luebo, Democratic Republic of Congo, 2007. *Vector-Borne and Zoonotic Diseases*, 9, 723-728.

LEROY EM, KUMULUNGUI B, POURRUT X, ROUQUET P, HASSANIN A, YABA P, SWANEPOEL R (2005). Fruit bats as reservoirs of Ebola virus. *Nature*, 438, 575-576.

LEROY EM (2004). Multiple Ebola Virus Transmission Events and Rapid Decline of Central African Wildlife. *Science*, 303, 383-387.

MARI SAEZ A, WEISS S, NOWAK K, LAPEYRE V, ZIMMERMANN F, DUX A, LEENDERTZ FH (2015). Investigating the zoonotic origin of the West African Ebola epidemic. *EMBO Molecular Medicine*, 7, 17-23.

MICKELBURGH S, WAYLEN K, RACEY P (2009). Bats as bushmeat: a global review. *Oryx*, 43, 217.

MILLERLILI (2004). Epidemics of Ebola haemorrhagic fever in Gabon: epidemiologic aspects and consideration on control measures. Bulletin de La Société Pathologiques Exotiques.

MONADJEM A, COTTERI FP, KITYO R, FAHR J (2007). Conservation status of bats in sub-Saharan Africa. Bat Research News.

MONADJEM A, TAYLOR PJ, COTTERILL FPD, SCHOEMAN MC (2010). Bats of Southern and Central Africa A Biogeographic and Taxonomic Synthesis.

OGAWA H, MIYAMOTO H, NAKAYAMA E, YOSHIDA R, NAKAMURA I, SAWA H, TAKADA A (2015). Seroepidemiological Prevalence of Multiple Species of Filoviruses in Fruit Bats (Eidolon helvum) Migrating in Africa. *Journal of Infectious Diseases*, 212, S101-S108.

ORGANISATION MONDIALE DE LA SANTE, UNICEF (2014). Communication pour un impact comportemental (COMBI): outil pour la communication comportementale et sociale dans le cadre de la riposte aux flambées épidémiques

PIGOTT DM, GOLDING N, MYLNE A, HUANG Z, HENRY AJ, WEISS DJ (2014). Mapping the zoonotic niche of Ebola virus disease in Africa. *Elife*, 3, e04395.

POURRUT X, DELICAT A, ROLLIN PE, KSIAZEK TG, GONZALEZ JP, LEROY EM (2007). Spatial and Temporal Patterns of Zaire ebolavirus Antibody Prevalence in the Possible Reservoir Bat Species. *The Journal of Infectious Diseases*, 196, S176-S183.

POURRUT X, KUMULUNGUI B, WITTMAN T, MOUSSAVOU G, DELICAT A, YABA P, LEROY EM (2005). The natural history of Ebola virus in Africa. *Microbes and Infection*, 7, 1005-1014.

POURRUT X, SOURIS M, TOWNER JS, ROLLIN PE, NICHOL ST, GONZALEZ JP, LEROY E (2009). Large serological survey showing cocirculation of Ebola and Marburg viruses in Gabonese bat populations, and a high seroprevalence of both viruses in Rousettus aegyptiacus. *BMC Infectious Diseases*, 9.

ROUQUET P, FROMENT JM, BERMEJO M, KILBOURN A, KARESH W, REED P (2001). Wild Animal Mortality Monitoring and Human Ebola Outbreaks, Gabon and Republic of Congo

SWANEPOEL R, LEMAN PA, BURT FJ, ZACHARAIDES NA, BRAACK LE, KSIAZEK TG, PETERS CJ (1996). Experimental inoculation of plants and animals with Ebola virus. *Emerging Infectious Diseases*, 2, 321.

WALSH PD, BIEK R, REAL LA (2005). Wave-Like Spread of Ebola Zaire. *PLoS Biology*, 3, e371.

WALSH PD (2003). Catastrophic ape decline in western equatorial Africa. *Nature*, 422, 608-611.

WITTMANN TJ, BIEK R, HASSANIN A, ROUQUET P, REED P, YABA P, LEROY EM (2007). Isolates of Zaire ebolavirus from wild apes reveal genetic lineage and recombinants. *Proceedings of the National Academy of Sciences*, 104, 17123-17127.

WOLFE ND, DASZAK P (2005). Bushmeat Hunting, Deforestation, and Prediction of Zoonotic Disease Emergence.

WRIGHT E, HAYMAN DTS, VAUGHAN A, TEMPERTON NJ, WOOD JLN, CUNNINGHAM AA, FOOKS AR (2010). Virus neutralising activity of African fruit bat (Eidolon helvum) sera against emerging lyssaviruses. *Virology*, 408, 183-189.

Annexes

Study sites

Annexe 1. Photo of Mambele crossroad where trucks, loaded with trunks of wood transit from Congo to Yaoundé. Some inns hosting truck drivers not allowed to cross the park at night and few small shops, constitute the center of village, at the crossroad.

Annexe 2. Photo of villagers houses along the main dirt road of Mambele.

Annexe 3. Photo of Pygmy traditional house where some Baka still live, Mambele

Annexe 4. Photo of houses in Gwap, with sheet steels, and a dinnerware usually more furnished than in the other study sites, with fields of cacao and other products destined to selling.

Annexe 5. Photo of a shaded bench, and grouping place in front of a house, in Gwap

Questionnaire

Annexe 6.

I. Demography

Gender
Age
Matrimonial situation
From
Number of children
Number of person in household
Lived
Ethnic appurtenance
Religion
Education
Principal and secondary occupation
Regular income [yes, no]

II. Bat roosting sites et feeding behavior

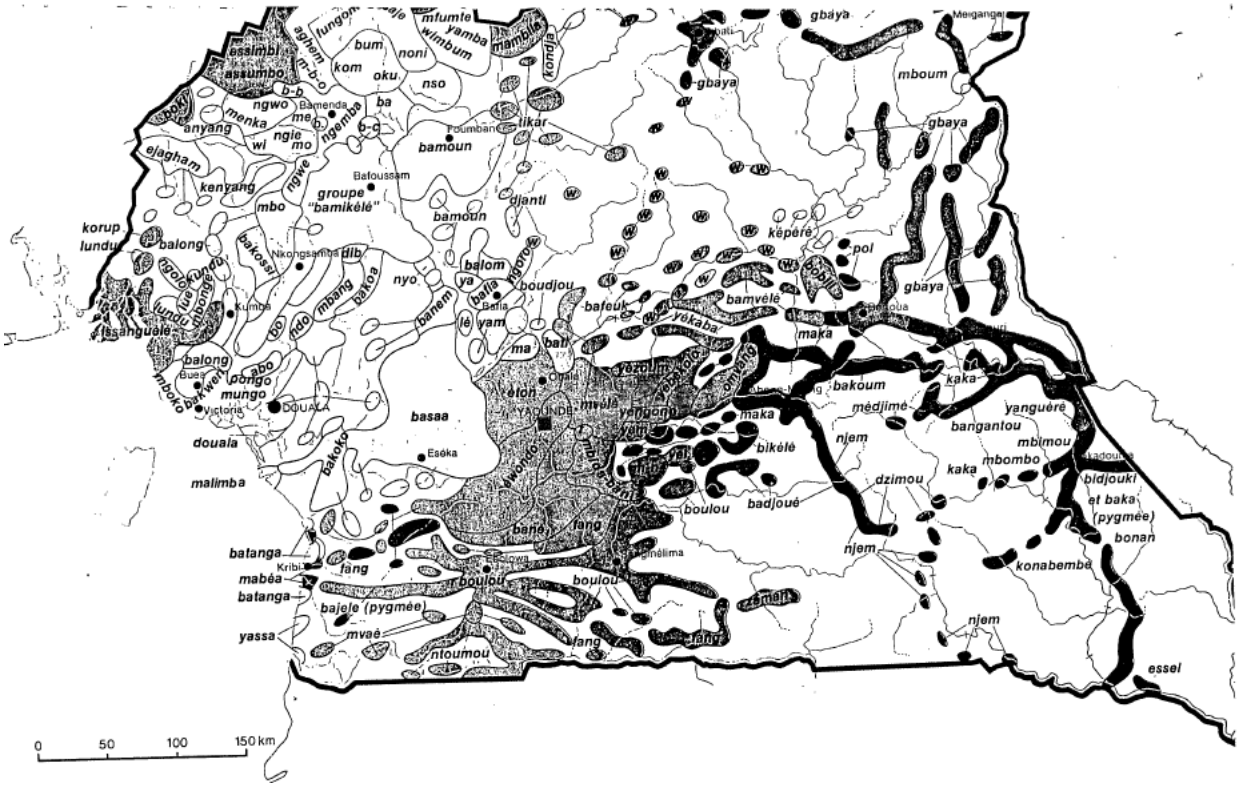
1. Is there trees where bats rest/ hang during the day? [yes, no]
    a. If so, where? [in the forest, in the village, in the field around the village]
    b. If so, where exactly? in which tree?
    c. If so, when? [all year, periodically: precise]
2. Idem in hollow trees
3. Idem in houses
4. Idem in caves
5. Does bat come eat at night in fruit trees? [yes, no]
    a. If so, which trees: precise
    b. If so, where? [around houses, in the fields, other: precise]
    c. If so, when? [all year, periodically: precise]
6. Is there stream that bats fly over at night? [yes, no]

III. Human-bat contacts

1. Do villagers consume bats? [yes, no: why]
    a. If so, who does? [all adults, only women, only men, all children, only girls, only boys]
2. Yourself, do you consume bats? [yes, no]
3. What type of bats do villagers eat? [big bats, small bats, every type of bats]
    a. Description, local names of the species consumed by adults
    b. Idem for children, and for the respondent
4. Yourself, how do you eat bats? [smoked, fresh, both]
5. At which season do villagers eat bats? [all year, periodically: precise]
    a. And yourself, when do you eat bats? [all year, periodically: precise]
6. Who catch/ hunt bats? [all adults, only women, only men, all children, only boys, only girls]
    a. Yourself, do you hunt bats? [yes, no]
7. How and where do villagers catch bats? [in trees, in caves, buildings, other]
    a. Yourself, where and how do you catch them?
8. Do you use precautions against bites? [yes: precise, no]
9. Are bats sold in the village? [no, yes: fresh, smoked, both]
    a. Yourself, do you catch bats for selling? [yes: to what price, no]
10. Where the bats you eat come from? [self-captured, bought: from whom, received: from whom, other]
11. Bats you eat, you prepare them yourself? [yes, no: who does]
12. Do you take any hygiene precautions while handling of carcasses?
13. With whom do you share bat meal? [your children, other members of the family, friends, no one]
14. During consumption period, at which frequence do you eat bats? [every day, 1x/week, less than 1x/week: precise]
15. Do villagers collect bat feces? [no, yes: precise]
    a. And yourself? [yes, no]
16. Do you have bats in your house? [yes going in and out, yes staying, no never enter]
17. Do villagers use caves as shelter? [no, yes: why]
18. Do children play in caves sheltering bats? [yes, no]
19. Do children catch bats? [yes, no]
    a. If so, what for? [playing, eating, both]
20. Do children keep bats alive? [yes, no]
21. Have you ever been bitten by a bat? [no, yes: how many times]
22. Has one of your children has ever been bitten by bats? [no, yes: how many times]
23. Do villagers eat fruits munched by bats? [yes, no]
24. Is there some agricultural activity attracting bats? [no, yes: precise]
25. Is there some agricultural activity that repel bats? [no, yes: precise]

IV. Attitudes and perceptions related to bats

1. What are the three animal species you prefer to eat, by order of importance?
2. What importance has bats for the alimentation of your family? [essential, confort, no importance]
3. Do you think there are benefits/ virtues eating bats? [no, yes: which ones]
4. Do you think there are dangers eating bats? [no, yes: which ones]
5. Are bats used by healers to cure diseases? [no, doesn't know, yes: which ones]
6. Do you have an animal or a plant totem (forbidden to consume)? [no, yes]
    a. If so, which one? For what reason? Is it only yours, your family, the village's, the ethnic group?
7. Do you think, if bats were eaten continuously, they could be extinguished? [yes, no: why]



LEGENDE

b.	: bali-nyonga	*mi*	: minéo
b-b.	: beba-bafut	*m-n*	: mvog-nienguè
ba	: bamuka, bamessing, etc . . .	*mo*	: moghamo
bc.	: bali-chamba - (bali-kumbat)	*mu*	: mouyenguè
bo	: bonkeng	*ndo*	: ndokpeuda
dib	: diboum	*nyo*	: nyokon
f	: foulfouldé	*o*	: ouldemé
k.	: kanouri	*p*	: podokwo
ko.	: kola	*t*	: tsinga
lè	: lémaudá	*ya*	: yambeta
m	: mouktélé	*yam*	: yambassa
ma	: mada	*yel*	: yelinda
mb	: mbokou	*yem*	: yembana
m-b-o.	: modelle-befang-obang	*wi*	: widikum
ma	: manguissa	*w.*	: woutè
me	: menemo	*z*	: zoulgogué

Annex 7. Principal ethnic groups of southern Cameroon, (Barbier JC, 1981)

Baudel Hélène

Evaluation des risques de transmission du virus Ebola des chauves-souris à l'homme : étude exploratoire sur les connaissances, les attitudes et les pratiques dans le Sud du Cameroun

L'écologie du virus Ebola (EBV) demeure méconnue, mais la détection d'ARN viral et d'anticorps anti-EBV chez des chauves-souris suggère qu'elles pourraient constituer un réservoir. Aujourd'hui, on connaît peu les interactions entre hommes et chauves-souris. L'objectif de ce travail était de mener une étude exploratoire pour préciser l'étendue et types de contacts entre hommes et chauves-souris dans le sud du Cameroun, zone à risque d'épidémie d'Ebola. Les résultats devraient contribuer à évaluer les risques de transmission des virus hébergés par les chauves-souris à l'homme. Des enquêtes ont été conduites sur la base de questionnaires semi-structurés dans 11 villages de 4 zones rurales, entre février et mai 2017. Les informations récoltées ont porté sur les pratiques liées à la chasse, la consommation de chauves-souris, les interactions enfants-chauves-souris, les contacts indirects, et la perception des dangers liés aux chauves-souris. Les réponses ont été analysées via des statistiques descriptives, test exact de Fisher et un modèle linéaire généralisé. 135 villageois, de 16 ethnies différentes et majoritairement cultivateurs de subsistance, dépendant de la viande de brousse, ont participé à l'étude.. Les résultats préliminaires montrent que la consommation de chauves-souris et par conséquent les contacts directs, varient significativement entre sites, de 0% (0/22) à 87% (34/39), et ethnie. La chauve-souris apparaît être une ressource occasionnelle de viande, avec une consommation médiane annuelle de 3. 22% des participants rapportent que leurs enfants attrapent les chauves-souris (essentiellement chez les participants qui les consomment). Les contacts indirects sont également fréquents : 55% des chasseurs s'abritent dans des grottes, 67% des personnes interrogées consomment des fruits croqués par les chauves-souris. La diversité géographique des contacts et perceptions vis-à-vis des chauves-souris au Cameroun souligne le besoin de mener des enquêtes à grande échelle afin d'identifier les populations à cibler pour des campagnes de santé et sensibilisation plus efficaces.

Mots-clés : Ebola, chauves-souris, pratiques, attitudes, Afrique centrale

Understanding Ebola risks in human-bats contacts: exploratory study on knowledge, attitudes and practices in Southern Cameroon

The ecology of Ebola virus (EBV) remains largely unknown, but the previous detection of viral RNA and anti-EBV antibodies in bats suggests that they might play a role in EBV reservoir. Today only little information is available on interactions between humans and bats. The objective of the present work was to carry out an exploratory study describing the extent and modes of contacts between humans and bats in southern Cameroon, an high-risk area regarding EBV outbreak. Results should contribute to assess the risk of transmission of bat viruses to humans. A survey was carried out in 11 villages of 4 rural areas, between February and May 2017. Data were collected using semi-structured questionnaires focusing on on bat bush-meat practices, children-bat interactions, indirect contacts, perception of bat-related diseases. Responses were analyzed using descriptive statistics, Fisher's exact test and generalized linear model.135 villagers from 16 different ethnic groups were involved in the study. Most of them were subsistence cultivators and relied on self-hunted bush-meat. Preliminary results showed that direct contact through consumption of bats varied significantly between regions from 0% (0/22) to 87% (34/39), ($p<10^{-10}$) and ethnic origin. Bat bush-meat appeared to be an occasional meat resource with a median yearly consumption of 3 (3^{rd} quantile=11). 30/135 (22%) respondents reported children catching bats, especially if respondent consume bats. Indirect contact is also common; 57% of hunters using caves as shelters and 67% of interviewees eat fruits munched by bats. Geographical diversity of contacts and perceptions regarding bats in Cameroun emphasizes the need to lead large-scale surveys in order to identify population to target for more efficient health and education campaigns.

Key words: Ebola, bats, practices, attitudes, Central Africa