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Systematique, évaluation et amélioration des connaissances taxonomiques sur la biodiversité

Maram Caesar

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Maram CAESAR

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**Systematique, évaluation et amélioration
des connaissances taxonomiques sur la biodiversité**

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Abstract

Systematic data are invaluable for biodiversity knowledge. They represent a unique source of information, because of their global taxonomic and spatial sampling. The thesis is aimed at studying and illustrating several important aspects around this subject. A first part focused on the review of taxonomic knowledge for a small taxonomic group, the Dictyoptera order (Insects) in a very large geographical area (the Middle East). I showed that the dynamics of knowledge was not simple but included different episodes of increase or stagnation, and that it was far from achieved. The two other parts of the thesis analyzed the quality, the representativeness and the significance of taxonomic data for all animals but in a smaller and very interesting geographical area, New Caledonia. First, data have been completed, validated and analyzed in term of representativeness and comparability of sampling effort. This first step has allowed to validate the hypothesis of strong micro-endemism in the fauna of New Caledonia, by distinguishing statistically micro-endemic from under-sampled species: this way, one species among ten has been showed to be distributed over less than 5.2 km². This analysis has also permitted to characterize the field sampling strategy of scientists and to reveal its most common biases. Finally, these data controlled for adequacy of sampling effort have been used to analyze which environmental parameters are the most correlated with the presence of micro-endemic species. Actually, the parameters describing the quality and the distribution of rainfall over the year appeared primarily important.

Keywords: Systematic data, fauna, Dictyoptera, Middle East, New Caledonia, distribution range, micro-endemism, environmental correlates.

Résumé

Les données systématiques apportent des connaissances indispensables sur la biodiversité. Elles sont les seules qui permettent de disposer d'une couverture globale en terme taxonomique et spatial. La thèse a permis d'étudier et d'illustrer plusieurs aspects importants autour de ce sujet. Un premier travail a permis de faire le bilan des connaissances taxonomiques pour un groupe zoologique restreint, l'ordre des Dictyoptères (Insectes) dans une zone géographique très étendue (le Moyen Orient). Il s'est avéré que la dynamique d'acquisition des connaissances n'était pas triviale, avec des phases d'accroissement et de stagnation, et qu'elle était loin d'être terminée. Les deux autres parties de la thèse ont analysé la qualité, la représentativité et la signification des données taxonomiques pour l'ensemble des animaux sur une aire géographique plus restreinte mais également très intéressante, la Nouvelle-Calédonie. En premier lieu, les données ont été complétées, validées et analysées en terme de représentativité et de comparabilité d'effort d'échantillonnage. Cette première étape a permis de valider l'hypothèse de forte proportion d'espèces réellement micro-endémiques dans la faune de Nouvelle-Calédonie, en les distinguant statistiquement des espèces rares parce que mal échantillonnées : une espèce sur 10 est ainsi répartie dans moins 5,2 km². Cette étape d'analyse a également permis de caractériser les stratégies de collectes des scientifiques et de révéler leur biais les plus communs. Enfin, ces données contrôlées ont permis d'analyser quels paramètres environnementaux sont le plus liés à la présence d'espèces micro-endémiques, à savoir des paramètres climatiques qui rendent compte de la qualité et de la répartition des précipitations sur l'année.

Mots-clés : données systématiques, faune, Dictyoptère, Moyen Orient, Nouvelle-Calédonie, aire de répartition, micro-endémisme, paramètres environnementaux.

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**A) Chapitre I -
Introduction à la Thèse
La Systématique, l'évaluation et l'amélioration des
connaissances taxonomiques sur la biodiversité**

Introduction

La Systématique, l'évaluation et l'amélioration des connaissances taxonomiques sur la biodiversité

La Systématique est la science qui a pour objet l'étude de la diversification et de la classification du Vivant. Dans ce but, elle réalise des descriptions de taxons (taxonomie) en rendant disponibles des noms qui permettent d'identifier des organismes et elle construit des hypothèses phylogénétiques de relations de parenté entre ces organismes (Minelli, 1993). L'ensemble de ces activités a pour résultat de fournir un système de référence sur la biodiversité pour l'ensemble de la science et de la société. Mais elle a aussi d'autres conséquences positives pour l'étude de la biodiversité que nous allons examiner tour à tour. Ce travail en amont apporte considérablement à l'organisation des bases des données (Minelli, 2003).

Ma thèse de doctorat a pour but de rendre compte de montrer, de valider et d'utiliser les connaissances taxonomiques dans le cas de deux zones géographiques bien différentes, le Moyen Orient et la Nouvelle-Calédonie.

1) Les données systématiques et leur contribution à la connaissance de la biodiversité

Les études de systématique et les recherches sur la classification du vivant ont généré d'énormes collections naturalistes qui représentent aujourd'hui une énorme source de données sur la biodiversité. Les centaines de millions de spécimens biologiques gardés dans des nombreuses collections, Muséums d'histoire naturelle ou Centres universitaires sont une ressource irremplaçable et indispensable à la connaissance du vivant, et représentent la pierre angulaire de la recherche biologique. Mais ces spécimens sont aussi très importants pour la communication et pour la sensibilisation de la société sur la diversité biologique, sa conservation face au phénomène de l'extinction (Funk 2003 ; Suarez & Tsutsui 2004).

En ce que concerne la recherche scientifique, les utilisations possibles des données systématiques et de spécimens de collections vont bien au delà des études taxonomiques (McLean et al., 2016). Leur quantité, leur diversité taxonomique, leur couverture spatiale et leur profondeur temporelle permettent de multiples emplois pour lesquels des voies de prospections s'ouvrent à chaque moment. Pour donner quelques exemples, l'étude des

spécimens en collections permet de tracer les routes et l'intensité des invasions biologiques (Muller, 2015), de définir les tendances des populations des pathogènes et parasites (Pinto *et al.*, 2010), de révéler l'histoire des maladies (Persing *et al.*, 1990; Marshal *et al.*, 1994), d'étudier les réponses des organismes aux changements environnementaux globaux (Robbirt *et al.*, 2011; Lister *et al.*, 2011), de construire des banques des graines (Muller, 2015), de documenter les changements phénotypique et génotypiques et ainsi étudier certains aspects de l'évolution (Holmes *et al.*, 2016). Dans cette perspective le spécimen de collection n'est pas simplement un porte-nom biologique. Il est surtout un exemplaire d'une réalité biologique qui porte des informations relatives non seulement à lui-même ou à ceux de son espèce, mais aussi relatives à l'espace et au temps où il a vécu, incluant ses parasites, ses maladies et les effets des facteurs environnementaux. Par exemple, des analyses de chimie isotopique sur des spécimens permettent aujourd'hui de contribuer à la caractérisation du climat passé ou des changements de niveaux de pollution (Britzke *et al.*, 2012 ; Pauli *et al.*, 2015).

Données systématiques d'occurrence

A la base, une donnée systématique d'occurrence inclut l'identification d'un organisme et la caractérisation d'un endroit où il été récolté. Normalement il s'agit d'un ensemble d'informations qu'on peut trouver associées aux spécimens dans des collections naturalistes. Parfois ces informations peuvent être complétées en reliant les étiquettes des spécimens avec des données gardées dans les carnets de terrain ou dans un journal de bord d'expédition.

Dans sa forme la plus simple, la donnée est donc composée d'un nom attribué a un spécimen et d'une information spatiale qui permet caractériser l'endroit où il a été récolté. Mais les données systématiques d'occurrence peuvent être riches d'information. Par exemple, le nom du (des) récolteur(s), la date d'échantillonnage, la méthode d'échantillonnage, ainsi que des informations relatives à l'habitat (type de forêt, caractéristique remarquable du relief ou du sol) ou au microhabitat (sur la canopée, sur l'écorce d'un arbre, dans la litière, etc.) sont couramment observés. L'étude de ces informations peut enrichir aussi notre connaissance sur le milieu dans un moment donné.

La quantité ainsi que la qualité de l'information relative a une donnée systématique d'occurrence peuvent être très diverses et varier selon les récolteurs, les régions, et surtout l'époque. Un exemple classique est la croissance de détails relatifs à la localisation

spatiale des spécimens. Pendant le XIX^{ème} siècle, l'information géographique était très vague, souvent restreinte à un pays ou à une grande région. Cette situation change vers la moitié du XX^{ème} siècle, quand des informations plus nombreuses ou plus précises sont conservées avec le spécimen, sur la localité de collecte, sur les collecteurs, etc.. Généralement ces informations permettent une bonne géolocalisation (souvent à la deuxième décimale), et permettent distinguer un village du plus proche où une montagne d'une région plus basse. De nos jours, on peut obtenir des données de géolocalisation GPS de très grande précision. Néanmoins, cela n'est pas nécessairement une panacée, du fait des erreurs possibles de transcription et requiert de conserver d'autres informations détaillées (toponymie, distances, etc.). Un autre exemple concerne la croissance de l'information biologique acquise et liée à un seul spécimen, incluant des données moléculaires, acoustiques, morphométriques, etc..

Pour conclure, la grande particularité des données systématiques d'occurrence est qu'elles ont été obtenues avec les buts les plus divers à l'origine. On essaie donc de les mettre ensemble pour répondre à des questions qui n'étaient pas nécessairement formulées auparavant et n'ont donc pas gouverné leur obtention. Le grand espoir des scientifiques est que leur grand nombre apporte une diversité suffisante et compense les carences des échantillonnages successifs pour permettre de détecter les principaux patrons et processus au sujet de la biodiversité. Mais de toute façon, la recherche basée sur des lots de données systématiques de collection doit comporter une part importante de contrôle des biais et des limites d'utilisation de ces données.

Sur les données de collections mises à disposition en ligne et quelques des leurs limites

Pendant plus de deux siècles, l'accès aux informations relatives aux spécimens de collection était restreint à des spécialistes. Ceux-ci voyageaient, visitaient des collections diverses ou importaient des spécimens pour réaliser leurs études. Cette situation a radicalement changé pendant les dernières décennies avec la révolution informatique et la banalisation de l'accès à l'internet. On a assisté à une vraie révolution en matière d'accès à l'information sur les données de collection, qui a commencé par la mise à disposition des données sur les spécimens-types puis s'est étendu à l'ensemble des spécimens de plusieurs collections, à des images des spécimens et des étiquettes associées. Le résultat est qu'aujourd'hui des centaines de millions de données peuvent être retrouvés en ligne, soit directement sur les sites internet de chaque institution, soit sur les sites des

agrégateurs de bases de données comme le Global Biodiversity Information Facility (GBIF).

Néanmoins, malgré leur énorme quantité, les données de collection mises à disposition en ligne comprennent plusieurs problèmes inhérents à leur nature propre. Comme nous l'avons déjà souligné, elles sont obtenues de manière erratique, ce qui amène à des extraordinaires agrégations spatiales, temporelles et taxonomiques et par voie de conséquence également à des énormes manques ou carences d'échantillonnage (e.g. Boakes et al., 2010). Il y a aussi des différences importantes entre les pays en ce qui concerne la disponibilité de ressources et l'informatisation des collections. Cela a des implications sur la quantité des données disponibles pour des différentes régions et, par conséquent, sur les estimations relatives de la richesse spécifique.

On peut aussi signaler l'occurrence d'erreurs non négligeables d'étiquetage et d'informatisation ou causées par des problèmes taxonomiques. Malgré l'effort du GBIF, par exemple, de croiser les informations et détecter certaines erreurs (absence du signe négatif dans les coordonnées concernant le sud de l'équateur et l'est de Greenwich, ajustement de coordonnées produites avec différents systèmes, etc.), certaines erreurs persistent. Dans le but de détecter ce genre d'erreur, de les corriger quand c'est possible, et de faciliter l'utilisation de ces données plusieurs outils ont été développés – des outils de géo référencement (e.g. Geolocate), de nettoyage de données (e.g. Biodatascreen.fr développé par l'ISYEB). Ces outils certainement facilitent l'utilisation des données en associant une localisation dans le même système de coordonnées géographiques, ou en détectant les données qui ne s'ajustent pas aux informations affichées. Mais ils ne résolvent pas les problèmes de manque d'information sur les étiquettes, des biais d'échantillonnage et des biais de mise à disposition. Par exemple, le bassin Amazonien est un des endroits les moins échantillonnés de la planète, et par voie de conséquence, la richesse spécifique évaluée à partir des données de collections est beaucoup plus basse que celle de plusieurs pays de l'Europe.

En ce que concerne le problème taxonomique, plusieurs référentiels taxonomiques ont été créés et rendus disponibles (e.g. TAXREF développé par l'INPN du MNHN pour la flore et la faune de France métropolitaine et outre-mer). Cela permet de faire correspondre une liste d'espèces avec un référentiel, de détecter les synonymes et les homonymes, et de réduire ainsi des erreurs dues à des noms différents.

Il reste néanmoins un problème très difficile à résoudre par des moyens automatisés : les changements taxonomiques ne sont pas forcément généralisés à l'ensemble des spécimens qui portent un nom à un moment donné. La taxonomie est un système très dynamique, et à la lumière de nouvelles études, de nouveaux critères, les changements de noms peuvent inclure l'ensemble des spécimens, une partie, ou encore regrouper plusieurs ensembles correspondant à des spécimens signalés comme appartenant à différentes espèces. La résolution de ce problème reste aujourd'hui très dépendante de l'activité ponctuelle des taxonomistes.

La littérature taxonomique, une source de données systématiques d'occurrence encore peu exploitée

La littérature taxonomique est une source très riche sur les données systématiques d'occurrence. Le grand avantage des données de littérature réside dans la question taxonomique, qui, traité par des spécialistes, est souvent bien résolu. Cela permet de prendre en compte une identification plus raisonnée des spécimens et, par conséquent, d'améliorer la nature du lien entre espèce et localité. Un autre avantage est que la littérature taxonomique comprend un travail en amont souvent minutieux de récupération des informations, incluant la lecture et la transposition des informations issues des étiquettes, des carnets de terrain, des ship-logs, etc, par le spécialiste qui a écrit l'article. Ce travail en amont apporte considérablement à l'organisation des bases des données.

Une des grandes difficultés lors du rassemblement de ce genre de données est que la littérature est vaste et hétéroclite, parfois avec des informations dans des ouvrages anciens retrouvés seulement dans quelques bibliothèques et qui ne sont pas forcément cités dans des moteurs de recherche comme Zoological Record. L'effort du Biodiversity Library Heritage (<http://www.biodiversitylibrary.org>) de scanner et rendre disponible une grande partie des livres anciens sur la biodiversité est en train de rendre malgré tout beaucoup plus facile ce genre de recherches. En ce que concerne la littérature plus récente, le problème principal reste lié à des noms très communs et similaires, ce qui rend difficile l'application des filtres et, par conséquent, les recherches automatisées.

Dans tous les cas, l'utilisation de ce type de données requiert une recherche exhaustive de la littérature concernée – elle peut être définie par un groupe taxonomique, par une région, etc., à partir de laquelle on rassemble les données (catalogage) et constitue les bases de données au niveau des spécimens avec les informations souhaitées.

Données de systématique et macroécologie

La macroécologie – science qui cherche à comprendre les patterns et procès relatifs à la distribution de la biodiversité sur la planète et à produire des informations nécessaires à sa conservation – est sans doute la discipline que a bénéficié le plus de la masse des données de biodiversité rendues disponible en ligne pendant les deux dernières décennies (Beck et al., 2012). Sans doute l'énorme quantité des données sur l'environnement présent, passé et future à très haute résolution (climat, sol, feu, probabilité de feu, concentration de chlorophylle, production primaire, etc.) en libre accès, et le développement des algorithmes pour l'analyse des big-data ont beaucoup facilité le développement de cette discipline. Néanmoins, l'arbre ne doit pas cacher la forêt. Cette masse de données ne doit pas empêcher le dépistage et la caractérisation des biais d'échantillonnage liés aux lacunes spatiales, temporaires, taxonomiques et écologiques.

2) Hotspots de Biodiversité

Les Hotspots, Points Chauds ou Points Sensibles de biodiversité sont des aires de la planète qui abritent une portion très importante de la diversité biologique et confrontées à de grands risques d'extinction. Cette classification est basée sur la richesse spécifique, surtout le nombre d'espèces de plantes vasculaires et de vertébrés endémiques, le rapport à la surface pour les plantes et animaux considérés ensemble, et la perte de habitat. Dans la définition la plus utilisée de Myers et al., (2000), un hotspot de biodiversité contient au moins 1500 espèces de plantes vasculaires endémiques, et a perdu au moins 70 % de sa végétation primaire. Sur cette base, Myers et al., (2000) ont caractérisé 25 hotspots, qui, dans leur ensemble, contenaient 44% des espèces de plantes et 35% des espèces de vertébrées. Mittermeier et al., (2004) ont identifié neuf autres régions, et Mittermeier et al., (2011) ont inclus encore un territoire dans cette liste. De ce fait, à nos jours il y a 34 hotspots de biodiversité. Ils ne couvrent plus que 2,3 % de la surface terrestre, mais abritent 42% des espèces de mammifères, oiseaux et amphibiens et 50% des plantes vasculaires (Fig. 1).

L'idée de hotspots de biodiversité est d'établir un critère pour définir des aires ou concentrer les efforts de conservation ou, malgré les risques, le gain en espèces protégées par rapport à l'aire serait énorme. Comme la destruction de habitats continue et la perte

de biodiversité n'est d'aucune manière en train d'être stoppée dans certaines régions, des auteurs ont alerté sur les risques d'investir dans la conservation d'espèces rares, endémiques et en danger de disparition (e.g. Possingham et al., 2002). Cela a provoqué l'émergence de propositions complémentaires pour la conservation, comme le fait de focaliser sur les coldspots de biodiversité (Kareiva & Marvier 2003 ; Davies & Cadotte 2011).

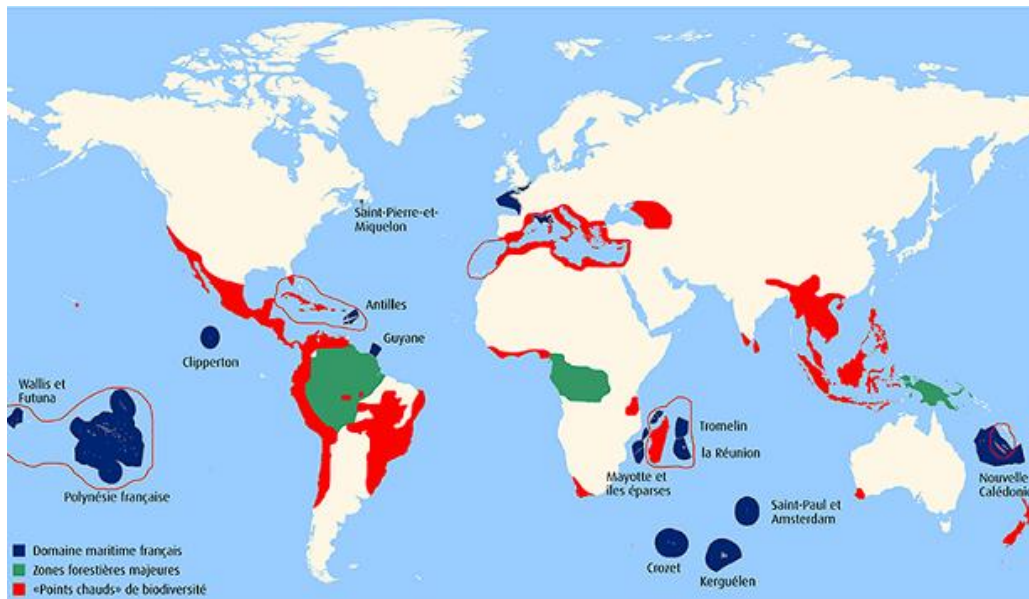


Figure 1 : Localisation de 34 points chauds de la biodiversité (d'après UICN et Commissariat général au développement durable).

3) Endémisme et micro-endémisme

Un critère majeur pour faciliter la caractérisation de l'importance d'une aire en termes de son contenu de biodiversité se trouve dans l'endémisme. L'endémisme caractérise la restriction géographique d'une espèce (e.g. *Amborella trichopoda* en Nouvelle-Calédonie), ou de n'importe quelle catégorie taxonomique (les Lémuriens à Madagascar) à une aire géographique. Les espèces endémiques s'opposent à celles avec des aires de répartition plus large, et représentent, par excellence, des organismes importants pour comprendre le rôle des facteurs environnementaux et historiques dans la diversité du vivant.

D'après Rabinowtiz (1981) l'aire de répartition des espèces est un des facteurs clés dans la détermination de la rareté. Les autres sont la diversité des habitats et la taille de la population (voir Tableau 1). Et même si ces facteurs sont indépendants, l'endémisme

et la rareté sont souvent très corrélés (Gaston, 1994), car il est difficile d'avoir des grandes tailles populationnelles quand l'aire de répartition est très petite.

Tableau 1. Les sept formes de rareté selon Rabinowitz (1981) et Krukeberg et Rabinowitz (1985). **A, E, C et G** sont des endémiques strictes, **B, C, F et G** sont des endémiques locales.

Taille des populations locales	Aire de distribution et spécificité de l'habitat			
	Aire vaste et habitat continu	Aire vaste et habitat discret	Aire restreinte et habitat continu	Aire restreinte et habitat discret
Grande, dominante dans certaines endroits	Localement abondante sur une vaste aire de distribution dans plusieurs habitats	Localement abondante sur une aire de distribution vaste dans des habitats discrets A	Localement abondante dans plusieurs habitats, mais restreinte géographiquement B	Localement abondante dans un habitat discret, mais restreinte géographiquement C
Petite, non dominante	Clairsemée continument sur une vaste aire de distribution dans des habitats divers D	Clairsemée continument sur une vaste aire de distribution dans des habitats discrets E	Clairsemée continument et restreinte géographiquement dans des habitats divers F	Clairsemée continument et restreinte géographiquement dans un habitat discret G

Le micro-endémisme évoque nécessairement un changement de l'échelle spatiale de l'aire de répartition (Médaille et al., 2012). Mais pas seulement. Il évoque aussi un changement d'échelle de risque d'extinction, qui s'approche de 100% avec la moindre perturbation des habitats où les espèces se trouvent, car les chances pour ces espèces de retrouver des conditions nécessaires et similaires sont très réduites. Pour cette raison, les espèces avec des aires de répartition plus petite que 10km² sont considérés comme « critically endangered » (catégorie CR) dans les critères IUCN (IUCN, 2012 ; Hartley & Kunin, 2003). Le micro-endémisme est la dénomination d'un patron de répartition très restreint, qui est souvent documenté par l'endroit précis de l'occurrence des espèces. Par exemple, une espèce micro-endémique peut être restreinte à la forêt de mousses du sommet du Mont Mou, ou restreinte au Pic du Grand Kaori.

Alors qu'au moins 35 aires de la planète sont connues pour avoir au moins 1500 espèces de plantes vasculaires endémiques (les hotspots mentionnés ci-dessus), les endroits avec de forts taux de micro-endémisme sont beaucoup plus rares. On a connaissance de l'importance du micro-endémisme dans la flore du Cap (par exemple, Richardson et al., 2001) ou en Nouvelle-Calédonie (par exemple, Pellens & Grandcolas,

2010). On connaît donc en fait peu de choses sur le micro-endémisme, soit en terme de taille d'aires de répartition correspondantes (mais voir Wulff et al., 2013), soit en terme de fréquence et de généralité au sein des différents groupes taxonomiques, ou encore en terme de déterminants environnementaux ou historiques qui peuvent expliquer ce patron de distribution. L'étude du micro-endémisme pourrait tirer profit aussi des études menées sur la biologie et la géographie de la spéciation. Ces dernières soulignent plusieurs processus intéressants, tels que le caractère récent des espèces micro-endémiques (Losos & Glor, 2003 ; Nattier et al., 2012).

4) Les zones biogéographiques étudiés dans cette thèse

Région méditerranéenne

La région méditerranéenne est une région biogéographique qui englobe les aires littorales du bassin Méditerranéen. Elle s'étend de l'Italie au Maroc (du nord au sud) et du Portugal à la Jordanie (d'ouest en est). Même si sa limite précise est objet de plusieurs controverses, on estime qu'elle couvre une surface de ca. 2.085,292 km², distribuées dans des portions plus au moins significatives de 15 pays en Europe, au Proche-Orient et en Afrique du nord (Fig. 2).

Il s'agit d'une des régions les plus riches au monde en termes de diversité animale et végétale (Myers et al., 2000). Cette région se caractérise par un climat où l'hiver est doux, humide et long, le printemps chaud et humide, et l'été est chaud et souvent très sec. Cet ensemble de conditions a donnée lieu à une énorme diversification de plantes, le groupe avec le plus fort taux d'endémisme. Adaptées à des conditions dures, ces plantes forment des végétations très particulières, comme les garrigues, les maquis, les pinèdes et les chênaies. Même si l'endémisme chez les plantes du bassin méditerranéen est le plus remarquable, il est important également chez les vertébrés, les insectes, et d'autres composantes de la faune (e.g. Médail & Quézel, 1997, 1999).

Les biomes du bassin Méditerranéen se trouvent dans plusieurs pays, avec des conditions politiques économiques et scientifiques très diverses; de ce fait, la connaissance de sa biodiversité est spatialement très hétérogène. Par conséquent, pour plusieurs groupes d'organismes, le point de départ de toutes les recherches de systématique, de biogéographie et de macroécologie dépend de l'organisation et du rassemblement des connaissances éparpillées dans de nombreuses études.

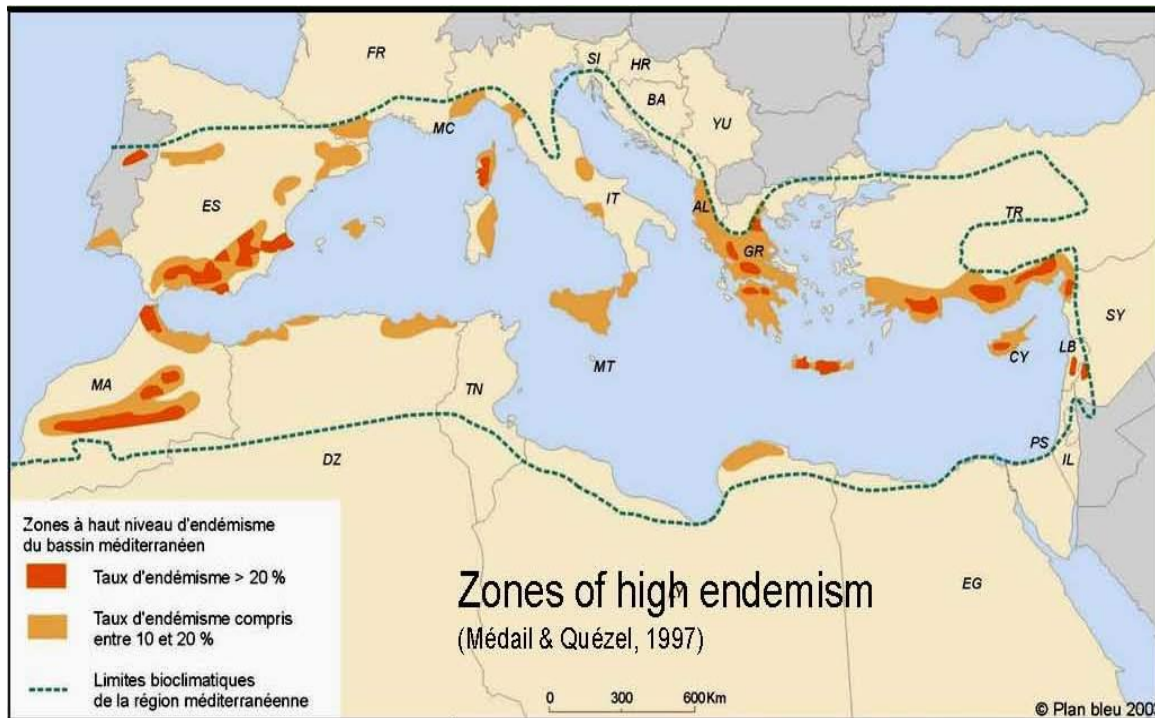


Figure 2 : Limites de la région méditerranéenne et principales zones d'endémisme (d'après Médail & Quézel, 1997).

La Nouvelle-Calédonie

La Nouvelle-Calédonie est un archipel océanique dans l'océan Pacifique, situé entre 18° - 23° S et 163° - 169° E. Le plus proche continent, l'Australie, est à environ 1500 km. L'archipel est composé d'une île principale (la Grande Terre), considérée comme la plus vieille île océanique (environ 37Ma), et de plusieurs îles plus petites et beaucoup plus récentes, le tout équivalant à une surface terrestre d'environ 18760 km². La Grande Terre est une île de forme allongée, orientée NW-SE, dont la surface est de 16372 km² (350 km de long and 50-70 km de large) (Fig. 3). Son paysage est caractérisé par un relief montagneux sur toute la longueur de l'île, avec seulement cinq sommets dépassant l'altitude de 1500 mètres and une série de petites montagnes aux pentes souvent raides et plus ou moins liées par un système de crêtes complexe. Elle est considérée comme un hotspot de biodiversité (Myers et al., 2000).



Figure 3 : Carte administrative de la Nouvelle-Calédonie (Atlas de la Nouvelle-Calédonie, ed. J. Mathieu-Daudé. Editions du Cagou, Nouméa).

5) Les objectifs et l'organisation de cette thèse

Cette thèse a pour objectif central d'investiguer la contribution des données de systématique à la connaissance de la biodiversité, en particulier à la caractérisation de l'endémisme et des facteurs qui peuvent déterminer son origine.

Elle est organisée en deux ensembles principaux.

Le premier est une étude sur l'obtention et l'organisation des données systématiques. Elle a été focalisée sur l'organisation de la connaissance taxonomique de la faune d'Insectes Dictyoptères (Blattaria, Isoptera et Mantodeae) de la région méditerranéenne. Le résultat de cette recherche est un catalogue de cette faune, publié dans le journal international *Zootaxa* (Caesar et al., 2015). Il est présenté dans le Chapitre II.

L'ensemble suivant comprend deux travaux plutôt focalisés sur l'utilisation des données systématiques, en regard de la caractérisation du micro-endémisme et de la compréhension des facteurs qui déterminent son origine et distribution en Nouvelle-Calédonie.

Dans le premier travail de ce second ensemble, on a caractérisé l'aire de répartition des espèces endémiques et non-endémiques de la Nouvelle-Calédonie afin d'étudier la fréquence des espèces avec des aires de répartition très restreintes, leur occurrence dans différents groupes taxonomiques, les variables d'effort d'échantillonnage qui permettent de contrôler pour la qualité des résultats concernant ces espèces, et l'apport de cette étude à une liste rouge des espèces de Nouvelle-Calédonie.

Le second travail de ce second ensemble a pour but de vérifier les facteurs qui déterminent le microendémisme et la richesse spécifique, une fois la part faite de la caractérisation et du contrôle des biais éventuels.

Ces résultats font partie de deux articles indépendants. Le premier vient d'être accepté dans la revue PlosOne et sera présenté ici dans le Chapitre III, tandis que le deuxième, qui constitue le Chapitre IV de cette thèse, sera soumis dans la revue Diversity and Distribution.

Dans dernier Chapitre je fais une discussion et conclusion générale en envisageant d'évaluer la contribution des études menées dans cette thèse à l'évaluation et l'amélioration des connaissances taxonomiques sur la biodiversité.

6) Références

Beck J, Ballesteros-Mejia L, Buchmann CM, Dengler J, Fritz SA, et al. (2012) What's on the horizon for macroecology? *Ecography* 35: 673-683.

Boakes EH, McGowan PJK, Fuller RA, Ding CQ, Clark NE, et al. (2010) Distorted Views of Biodiversity: Spatial and Temporal Bias in Species Occurrence Data. *Plos Biology* 8.

Britzke ER, Loeb SC, Romanek CS, Hobson KA, & Vonhof MJ (2012) Variation in catchment areas of Indiana bat (*Myotis sodalis*) hibernacula inferred from stable hydrogen ($\delta H-2$) isotope analysis. *Can J Zool* 90(10):1243-1250.

Caesar M, Roy R, Legendre F, Grandcolas P, Pellens R (2015) Catalogue of Dictyoptera from Syria and neighbouring countries (Lebanon, Turkey, Iraq and Jordan). *Zootaxa* 3948: 71-92.

Davies J, Cadotte MW (2011) Quantifying biodiversity: does it matter what we measure? In: Zachos FE, Habel JC, editors. Biodiversity hotspots: distribution and protection of conservation priority areas: *Springer*. pp. 43-60.

- Funk VA (2003) 100 uses for an herbarium (well at least 72). *American Society of Plant Taxonomists Newsletter* 17: 17-19.
- Gaston KJ (1994) *Rarity* (Chapman & Hall, London) 205p.
- Hartley S, Kunin WE (2003) Scale dependency of rarity, extinction risk, and conservation priority. *Conservation Biology* 17: 1559-1570.
- Hoffmann M, Hilton-Taylor C, Angulo A, Bohm M, Brooks TM, et al. (2010) The Impact of Conservation on the Status of the World's Vertebrates. *Science* 330: 1503-1509.
- Holmes MW, Hammond TT, Wogan GOU, Walsh RE, Labarbera K, et al. (2016) Natural history collections as windows on evolutionary processes. *Molecular Ecology* 25: 864-881.
- IUCN (2012) *IUCN Red List Categories and Criteria: Version 3.1. Second edition.*: Gland, Switzerland and Cambridge, UK: IUCN.
- Kareiva P, Marvier M (2003) Conserving Biodiversity Coldspots. *American Scientist* 91: 344-351.
- Kruckeberg A R, & Rabinowitz D (1985). Biological Aspects of Endemism in Higher Plants. *Annual Review of Ecology and Systematics* 16, 447-479.
- Lister AM, Grp CCR (2011) Natural history collections as sources of long-term datasets. *Trends in Ecology & Evolution* 26: 153-154.
- Losos JB, Glor RE (2003) Phylogenetic comparative methods and the geography of speciation. *Trends in Ecology and Evolution* 18: 220-227.
- Marshall WF, Telford SR, Rys PN, Rutledge BJ, Mathiesen D, et al. (1994) Detection of *Borrelia-Burgdorferi* DNA in Museum Specimens of *Peromyscus-Leucopus*. *Journal of Infectious Diseases* 170: 1027-1032.
- Mathieu-Daudé J, editor (1992) *Atlas de la Nouvelle-Calédonie*. Nouméa: Editions du Cagou.
- McLean BS, Bell KC, Dunnum JL, Abrahamson B, Colella JP, et al. (2016) Natural history collections-based research: progress, promise, and best practices. *Journal of Mammalogy* 97: 287-297.
- Médail F, Quézel P (1997) Hot-spots analysis for conservation of plant biodiversity in the Mediterranean basin. *Annals of the Missouri Botanical Garden* 84: 112-127.
- Médail F, Quézel P (1999) Biodiversity hotspots in the Mediterranean basin: Setting global conservation priorities. *Conservation Biology* 13: 1510-1513.
- Minelli A (1993) The species. *Biological Systematics*, (Springer, Netherlands), pp 62-86.

- Minelli A (2003) The status of taxonomic literature. *Trends in Ecology & Evolution* 18: 75-76.
- Mittermeier RA, Gil PR, Hoffman M, Pilgrim J, Brooks T, Mittermeier CG, Lamoreux J & da Fonseca GAB (2004) Hotspots revisited: earth's biologically richest and most endangered terrestrial ecoregions. *University of Chicago Press*, Chicago, IL
- Mittermeier RA, Turner WR, Larsen FW, Brooks TM, Gascon C (2011) Global biodiversity conservation: the critical role of hotspots. In: Zachos FE, Habel JC. (Eds.), *Biodiversity Hotspots: Distribution and Protection of Priority Conservation Areas*. Springer-Verlag, Berlin, pp. 3-22
- Muller S (2015) Intérêt des herbiers pour la connaissance des dynamiques spatio-temporelles des invasions biologiques. *Revue d'Ecologie (Terre Vie)* 70: 229-235.
- Myers N (2003) Biodiversity hotspots revisited. *Bioscience* 53: 916-917.
- Myers N, Mittermeier RA, Mittermeier CG, Fonseca GAB, Kent J (2000) Biodiversity hotspots for conservation priorities. *Nature* 403: 853-858.
- Nattier R, Grandcolas P, Elias M, Desutter-Grandcolas L, Jourdan H, et al. (2012) Secondary Sympatry Caused by Range Expansion Informs on the Dynamics of Microendemism in a Biodiversity Hotspot. *Plos One* 7.
- Pauli JN, Steffan SA, & Newsome SD (2015) It Is Time for IsoBank. *Bioscience* 65(3):229-230.
- Pellens R, Grandcolas P (2010) Conservation and management of the biodiversity in a hotspot characterized by short range endemism and rarity: the challenge of New Caledonia. In: Rescigno V, Maletta S, editors. *Biodiversity Hotspots*. New York: Nova Publishers. pp. 139-151.
- Persing DH, Telford SR, Rys PN, Dodge DE, White TJ, et al. (1990) Detection of *Borrelia burgdorferi* DNA in Museum Specimens of Ixodes-Dammini Ticks. *Science* 249: 1420-1423.
- Pinto CM, Baxter BD, Hanson JD, Mendez-Harclerode FM, Suchecki JR, et al. (2010) Using Museum Collections to Detect Pathogens. *Emerging Infectious Diseases* 16: 356-357.
- Possingham HP, Andelman S, Burgman MA, et al. (2002) Limits to the use of threatened species lists. *Trends Ecol Evol* 17: 503-507.
- Rabinowitz D (1981) Seven forms of rarity. In: Synge H, editor. *The Biological Aspects of Rare Plant Conservation*: John Wiley & Sons Ltd. pp. 205-217.
- Richardson JE, Weitz FM, Fay MF, Cronk QCB, Linder HP, Reeves G, and Chase, MW (2001) Rapid and recent origin of species richness in the Cape flora of South Africa. *Nature* 412, 181-183.

Robbirt KM, Davy AJ, Hutchings MJ, Roberts DL (2011) Validation of biological collections as a source of phenological data for use in climate change studies: a case study with the orchid *Ophrys sphegodes*. *Journal of Ecology* 99: 235-241.

Suarez AV, Tsutsui ND (2004) The value of museum collections for research and society. *Bioscience* 54: 66-74.

Wulff AS, Hollingsworth PM, Ahrends A, Jaffré T, Veillon JM, L'Huillier L, & Fogliani B (2013) Conservation Priorities in a Biodiversity Hotspot: Analysis of Narrow Endemic Plant Species in New Caledonia. *Plos ONE* 8, e73371.

**B) Chapitre II -
Catalogue of Dictyoptera from Syria and neighbouring
countries (Lebanon, Turkey, Iraq and Jordan)**



Catalogue of Dictyoptera from Syria and neighbouring countries (Lebanon, Turkey, Iraq and Jordan)

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Abstract

This study is a catalogue of Dictyoptera (Mantodea, Isoptera and Blattaria) from five Eastern Mediterranean countries (Syria, Lebanon, Turkey, Iraq and Jordan). There are 75 species of Dictyoptera known to occur in these countries. These species belong to 15 families (eight of Mantodea, four of Isoptera and three of Blattaria). Mantodea is by far the dictyopteran group with the highest richness with 43 species occurring in this region, followed by Blattaria, with 21, and Isoptera with 11. Turkey is the place with the highest number of Dictyoptera (34%), followed by Iraq (23%) then Syria (22%), Jordan (15%) and Lebanon (7%). An analysis of accumulated number of species along time shows that most of this biodiversity was described during the 20th century, and that Mantodea is the group with the highest number of species described more recently. If this curve is taken as an estimator of the increase of diversity with new prospections, this indicates that the number of Mantodea in this region would be much higher than presently known. Conversely, the local richness of Blattaria and Isoptera are likely to be close to the present numbers, as the curves remain steady for about 100 years. An accumulation curve of species described with occurrence restricted to these five countries shows that most of them were described at the beginning of the 20th century. An analysis of the number of references dealing with each of these species along time reveals that Mantodea is the dictyopteran group most studied in all periods except the second half of the 20th century, when Isoptera was more cited. The types of these species are distributed in 29 institutions, but are mainly concentrated in four major European collections.

Key words: Mantodea, Isoptera, Blattaria, species list, types, Mediterranean region, biodiversity assessment

Introduction

The Mediterranean Region is widely recognised as one of the world's Biodiversity Hotspots (Myers *et al.*, 2000). Its wonderful dry climate with diverse but harsh soil conditions gave rise to an enormous diversification of plants, the group with the highest rates of endemism, but also amongst vertebrates, insects, and many other organisms. However, the Mediterranean basin biomes (Mediterranean Grasslands and the Mediterranean Forests) are distributed in many countries and comprises several biodiversity hotspots (e.g. Medail & Quezel, 1997; 1999), and the present knowledge of the existing biodiversity and its present status is quite dissimilar from one place to another.

Blattaria, Mantodea and Isoptera are large groups of worldwide-distributed insects with an important diversity in the Mediterranean region. However, at present time it is hard to have an idea of the number of species and of their areas of distribution because the existing taxonomic data is spread in hundreds of documents demanding a huge effort each time we need information about species' occurrences, or distribution area. So, as a first step to systematize the present knowledge on the distribution of these three insect orders along the Mediterranean biomes, we prepared a catalogue of Dictyoptera (Mantodea, Isoptera and Blattaria) in five Eastern Mediterranean countries (Syria, Lebanon, Turkey, Iraq and Jordan), and we analysed the evolution of the knowledge about these groups along time.

Materials and methods

This study was based on a comprehensive search of the literature about Dictyoptera from Syria, Lebanon, Turkey, Iraq and Jordan. We started with a search in Zoological Records, 'Thomson Reuters' Web of Science, and Blattodea Species File, using the search: 'Blattaria' OR 'Blattodea' AND 'Syria', 'Blattaria' OR 'Blattodea' AND 'Turkey', 'Blattaria' OR 'Blattodea' AND 'Lebanon', 'Blattaria' OR 'Blattodea' AND 'Iraq', 'Blattaria' OR 'Blattodea' AND 'Jordan' (using both English and French orthography for country names). The same procedure was repeated for 'Isoptera' OR 'Termites', and for 'Mantodea'. In all cases we selected the options for finding these terms in "Titles" AND "Topics" AND "For All Years". This normally retrieves all information existing in these databases since 1900. To check if there were references that were missing in these databases, this search was complemented by searches in Google and Google Scholar with the same terms aligned, as, for instance, 'Blattaria' 'Blattodea' 'Syria'. In addition, we repeated the same procedure, but including the name of families that we expected to occur in this region as an additional option, as, for example, 'Blattaria' OR 'Blattodea' OR 'Polyphagidae' AND 'Syria'. From the resulting references we deleted all those dealing with fossil species.

This investigation was then complemented by exhaustive searches on the following comprehensive catalogues: Çiplak & Demirsoy, 1997; Ehrmann (2000, 2002, 2011), Otte & Spearman, 2005; Battiston *et al.*, 2010 for Mantodea; for Isoptera we used Krishna *et al.*, 2013, Engel *et al.*, 2009; and, finally, the Princis (1962-1971) catalogue for Blattaria. Once we had the list of species occurring in these countries, we went back to the same Web Databases using the species' names, to check if there were more references dealing specifically with them.

The localization of the type specimens was made with the help of the original publications, some published catalogues of types and recent internal databases of types and of specimens of the following institutions: Muséum national d'Histoire naturelle, Paris (Grandcolas, 2004-2007); Natural History Museum, London (Beccaloni, 2007); Naturhistorisches Museum in Vienna (Naturhistorisches Museum, Wien, 2007); the internal data base of Museum of Natural History of Geneva; the internal data base of Blattaria from the Zoologisches Institut der Martin-Luther Universität, Halle, Germany; Thunberg in Uppsala University (Wallin & Wallin, 2001).

The type specimens were characterized as Holotype, Allotype, Syntype, Paratype, Neotype, Lectotype or Paralectotype whenever this information was available in the publications or in the internal databases. We also mentioned the presence of specimens in some collections for which we had access to their database, indicating the presence of specimens in the collections even if they are not clearly identified as types.

The classification used in this paper follows Beccaloni & Eggleton (2013) modified from Princis (1962-1971) and Grandcolas (1996) for Blattaria; Engel *et al.*, (2009) for Isoptera; and Ehrmann (2000, 2002, 2011), with modifications for Mantodea.

Institutional Abbreviations

AMNH	American Museum of Natural History, New York, USA
ANSP	Academy of Natural Sciences, Philadelphia, USA
DZCU	Zoological Survey of India, Calcutta, West Bengal, India
FRI	Forest Research Institute, Dehradun, Uttarakhand, India
IEA	Institute of Agricultural Entomology, Portici, Italy
INHM	Iraq Natural History Museum, Baghdad, Iraq
IPUC	Istituto policeduca di Biologia animale, università di Catania, Italy
MHNG	Muséum d'Histoire Naturelle, Genève, Switzerland
MLUH	Martin-Luther-Universität Halle-Wittenberg, Institut für Zoologie und Zoologische Sammlung, Wittenberg, Germany
MNCN	Museo Nacional de Ciencias Naturales, Madrid, Spain
MNHN	Muséum National d'Histoire Naturelle, Paris, France
MRSN	Museo Regionale di Scienze Naturali di Torino, Italy
NHM	Natural History Museum of London, England—formerly known as British Museum of Natural History, or British Museum
NHMB	Naturhistorisches Museum, Basel, Switzerland
NHMW	Naturhistorisches Museum (Natural History State Museum in Vienna), Vienna, Austria
NMP	National History Museum Prague, Czech Republic

NTM	Museum of Plant Protection Department, Mustafa Kemal University, Ankara, Hatay, Turkey
RMNH	Naturalis Biodiversity Centre, Leiden, Netherlands
SANC	National Collection of Insects, Pretoria, South Africa
SMNK	Staatliches Museum für Naturkunde, Karlsruhe, Germany
SMNS	Staatliches Museum für Naturkunde, Stuttgart, Germany
UZI	Universitets Zoologiska Institut, Uppsala, Sweden
ZIHS	Zoötomiska Institute, Hogskolas, Stockholm, Sweden
ZIN	Zoological Institute of the Russian Academy of Sciences, St Petersburg, Russia (also cited as in the collection's of Leningrad)
ZMHB	Museum für Naturkunde der Humboldt- Universität zu Berlin, Germany (Zoological Museum, Berlin, Germany)
ZMUC	Zoological Museum, University of Copenhagen, Denmark
ZMUH	Zoological Museum of Hamburg, Germany
ZMUZ	Zoologisches Museum der Universität, Zürich, Switzerland
ZSM	Zoologische Staatssammlung München, Germany

Results and discussion

There are 75 species of Dictyoptera known from these five countries. These species belong to 15 families (eight for Mantodea, four for Isoptera and three for Blattaria). Mantodea is by far the dictyopteran group with the highest richness with 43 species and subspecies occurring in this region, followed by Blattaria, with 21, and Isoptera with 11. This is at odds with general trends of diversity within these groups, as globally Blattaria is the more specious, with more than 4000 species described (Princis, 1962–1971) and with a high number of new species at each new place sampled (Grandcolas, 1994a,c; 1997; Pellens, 2002; Pellens & Grandcolas, 2008; Grandcolas & Pellens, 2012); Isoptera has often low local species richness and includes a total of 3106 living and fossil species (Krishna *et al.*, 2013); and Mantodea has the lowest total number of known species (more than 2400 species) (Svenson & Whiting, 2004). These discrepancies suggest that, concerning the ratio between local and global number of species, Mantodea diversified more in these countries than the two others.

More species of Dictyoptera were recorded in Turkey (34%), followed by Iraq (23%) then Syria (22%), Jordan (15%) and Lebanon (7%). Roughly these results seem to be strongly associated with the size of the countries since Turkey is the largest one; Lebanon the smallest; and the three others have intermediate surfaces, and this diversity might reflect environmental diversity within each of them. However, other factors such as facility of access to natural sites, and the existence of local scientists interested in these groups might also play an important role in the knowledge of the existing fauna.

The species of Dictyoptera occurring in this region started to be studied in 1773, when *Bolivaria brachyptera* (Pallas, 1773) (Mantodea) was described, and the number of species increased at different paces for these three insect orders along time. Most of species of Blattodea and Isoptera are known from before 1950. For Mantodea, however, an important number of species (28%) were described more recently, and the accumulation curve (Figure 1A) suggests that the number of species in the region will still increase. For Isoptera all known species, except one, were described at the very beginning of the 20th century. For Blattaria, some species were described between 1937 and 1957, and never after this date.

Twenty-nine of these species (i.e., 38%) have so far been recorded only in these five countries (22 of Mantodea, one of Isoptera and six of Blattaria) and, as shown in Figure 1B, the greatest part of these species was described during the 20th century. It also shows that the total number of species is much smaller for (Figure 1 B).

In taxonomic studies, the number of times a species is cited reveals the dynamics of their study, as for example changes in nomenclature, reviews of the genera and resolution of synonymies. If we consider the number of times the species of Dictyoptera were cited along the time period comprised in this study, we can see that, as for many other taxonomic groups and in diverse scientific domains, it is above all from the beginning of the twentieth century they started to be more studied. Globally Mantodea is by far the dictyopteran group the most studied, with a total of 91 citations, and a significantly higher number of citations at each time period. But since 1958, Isoptera became more studied, being more cited than Mantodea in some decades (Figure 2). This information shows that

despite more studies of Isoptera from this region in the second half of the 20th century, only one new species was described (see Figure 1 B). This suggests that the present number of known species might be close to the real number of Isoptera species occurring in these countries.

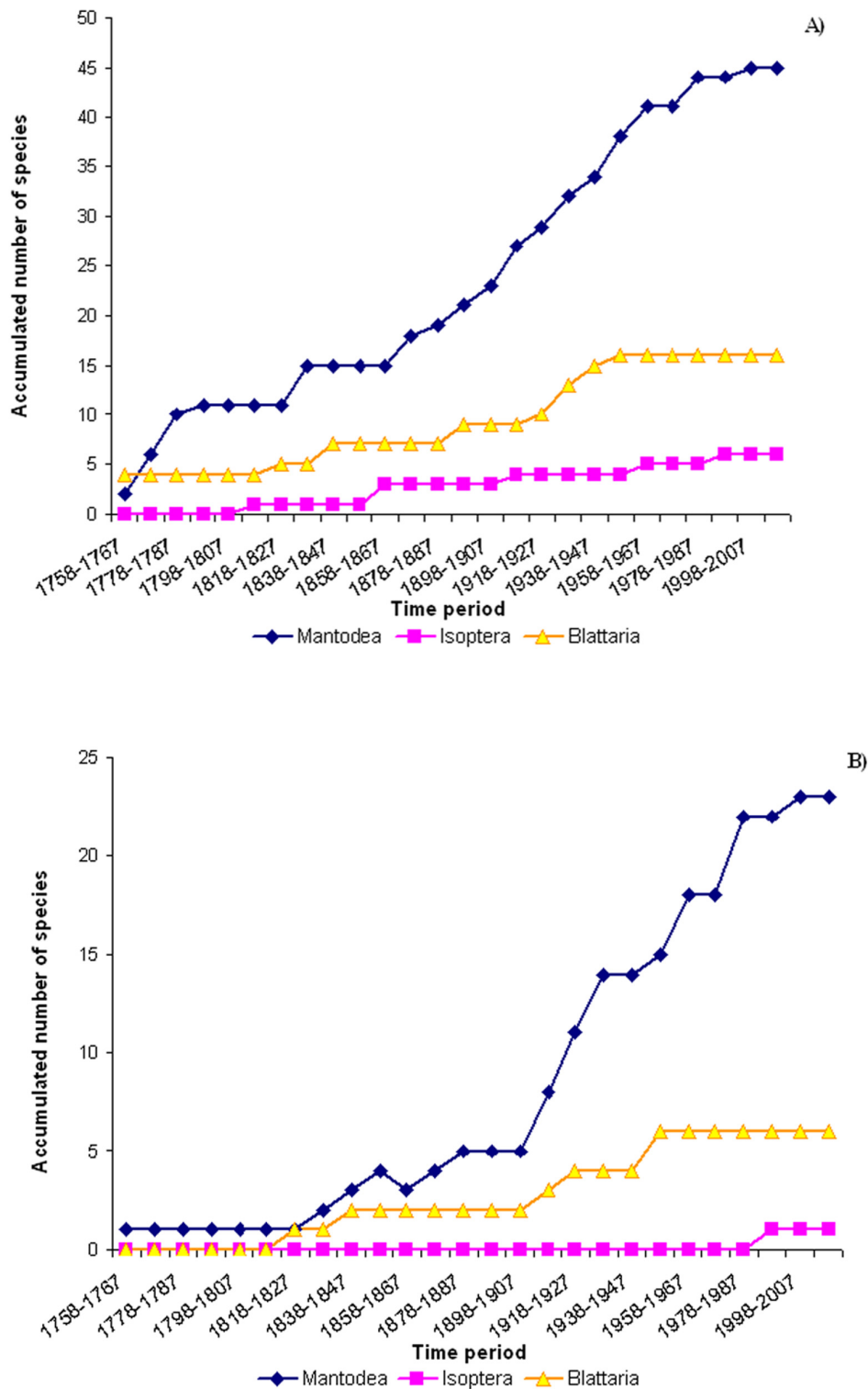


FIGURE 1. A) Accumulated number of species of Mantodea, Isoptera and Blattaria occurring in five Middle East countries (Syria, Lebanon, Turkey, Iraq and Jordan) described along time. **B)** Accumulated number of species of Mantodea, Isoptera and Blattaria known to occur **only** in these countries.

The 75 species with occurrence in these five countries are represented by 107 types or type series distributed in 29 institutions. Four of them (NHM, NHMW, MHNG, ZMHB) house 52% of the types, and each of them has between 13 and 15 types of these species. Seven other institutions house 35% of the types (MNHN, MLUH, UZIU, AMNH, MRSN, ZIN, IPUC), with between 4 and 7 types in each of them. The remaining 22 types (20%) are housed in 18 other institutions.

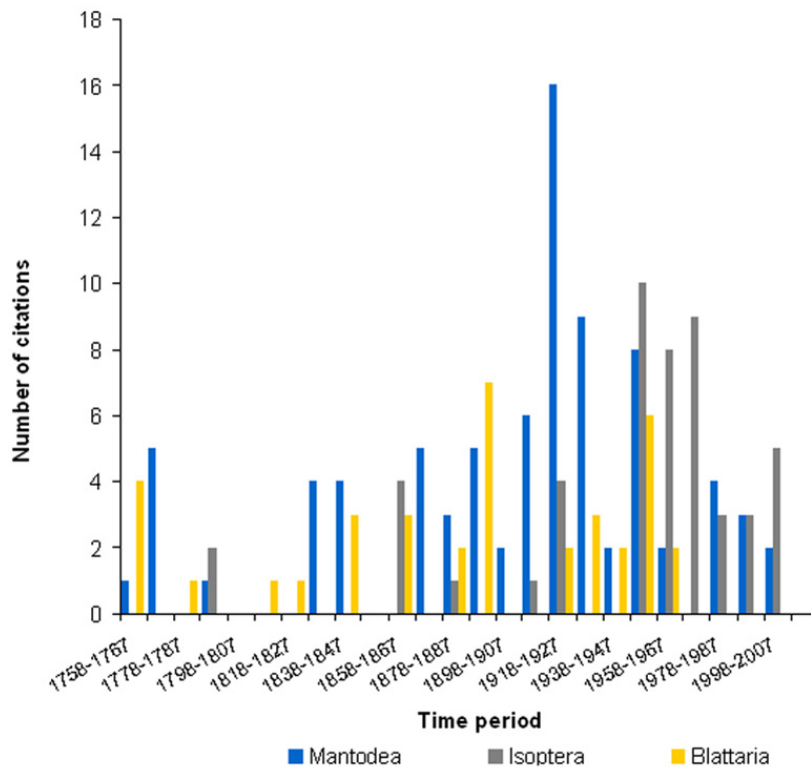


FIGURE 2. Number of citations of the species of Mantodea, Isoptera and Blattaria occurring in five Middle East countries (Syria, Lebanon, Turkey, Iraq and Jordan). The time period goes from the first species described (*Bolivaria brachyptera* (Pallas, 1773)—Mantodea) to 2007 when the last study concerning species from these groups was published.

Catalogue of Mantodea, Isoptera and Blattaria from Syria, Lebanon, Turkey, Iraq and Jordan

ORDER MANTODEA

Family: Amorphoscelidae

Amorphoscelis pantherina Roy, 1966

Amorphoscelis pantherina Roy, 1966: 268–270; Ehrmann, 2002: 62; 2011: 6; Otte & Spearman, 2005: 25.

Geographical records: Iraq.

General distribution: Iraq, Turkey-SE.

Type series: Holotype male ANSP. Type locality: Iraq: Arbil Liwa.

Family: Rivetinidae

Bolivaria brachyptera (Pallas, 1773)

Mantis brachyptera Pallas, 1773: 728.

Bolivaria brachyptera Giglio-Tos, 1927: 482; Ramme, 1951: 327; Çiplak & Demirsoy, 1997: 109; Ehrmann, 2002:

82; 2011: 9; Otte & Spearman, 2005: 226; Battiston *et al.*, 2010: 90.

Bolivaria kurda Ramme, 1951: 327–328; Çiplak & Demirsoy, 1997: 109; Ehrmann, 2002: 83; 2011: 9; Otte & Spearman, 2005: 227; Battiston *et al.*, 2010: 90.

Geographical records: Turkey.

General distribution: from Crete (Greece) to Mongolia.

Type series: Type male ZMHB (Alcohol). Type locality: Western Asia (Iraq, Iran): Iaikum; Turkey: Anatolia Silvan 700m.

Eremoplana infelix Uvarov, 1924

Eremoplana infelix Uvarov, 1924: 3–5; Ehrmann, 2002: 143; Otte & Spearman, 2005: 230; Battiston *et al.*, 2010: 103.

Geographical records: Lebanon.

General distribution: from Sudan to Lebanon.

Type series: Holotype male RMNH, Paratype female RMNH. Type locality: Egypt: Adair Wadi Hof.

Geomantis larvoides larvoides Pantel, 1896

Geomantis larvoides Pantel, 1896: 67–70; Otte & Spearman, 2005: 230 ; Battiston *et al.*, 2010: 104.

Geomantis larvoides larvoides Ehrmann, 2002: 156; 2011: 16.

Geographical records: Turkey.

General distribution: Mediterranean region from Portugal and Morocco to Turkey.

Type series: Holotype male MNHN, Allotype female MNHN. Type locality: Spain.

Microthespis dmitriewi Werner, 1908

Microthespis dmitriewi Werner, 1908: 120; Ehrmann, 2002: 224; Otte & Spearman, 2005: 233; Battiston *et al.*, 2010: 124.

Geographical records: Jordan, Iran, Oman, Saudi—Arabi, United Arab Emirates, Yemen.

General distribution: from Ethiopia, Somalia to Iran.

Type series: Holotype male ZIN, Paratype female ZIN. Type locality: Ethiopia: Djibuti, Harar.

Rivetina asiatica Mistshenko, 1967

Rivetina asiatica Mistshenko, 1967: 705–707; Ehrmann, 2000: 6; 2002: 310; 2011: 21; Otte & Spearman, 2005: 234; Battiston *et al.*, 2010: 148.

Kinzelbachia kinzelbachi Harz, 1988: 207–208; Ehrmann, 2000: 2.

Geographical records: Turkey.

General distribution: Turkey: Anatolia.

Type series: Holotype male ZIN, Allotype female ZIN, Paratype male, female ZIN, (Synonym: (*K.k.*) Neotype male, female, juv. SMNK). Type locality: Turkey: Anatolia.

Rivetina balcanica Kaltenbach, 1963

Rivetina balcanica Kaltenbach, 1963: 579–581; La Greca & Lombardo, 1982: 356; Ehrmann, 2000: 6; 2002: 311; 2011: 23; Otte & Spearman, 2005: 234; Battiston *et al.*, 2010: 150.

Geographical records: Turkey.

General distribution: Turkey: Anatolia.

Type series: Holotype female NHMW. Type locality: Turkey: Anatolia.

Rivetina byblica La Greca & Lombardo, 1982

Rivetina byblica La Greca & Lombardo, 1982: 368–369; Ehrmann, 2000: 6; 2002: 311; 2011: 24; Otte & Spearman, 2005: 234; Eid *et al.*, 2009: 23; Battiston *et al.*, 2010: 150.

Geographical records: Syria, Jordan, Turkey.

General distribution: from Jordan to Turkey.

Type series: Holotype male IPUC, Paratype male, female IPUC. Type locality: Jordan: Wadi Shu'elb.

Rivetina caucasica caucasica (Saussure, 1871a)

Iris (Fischeria) caucasica Saussure, 1871a: 110–112.

Fischeria caucasica: Bolívar, 1899: 587.

Eufischeriella caucasica: Giglio-Tos, 1927: 485.

Rivetina caucasica: Beier, 1935: 108.

Kinzelbachia ragnari Harz, 1988: 209; Ehrmann, 2000: 2.

Rivetina caucasica caucasica La Greca & Lombardo, 1982: 361; Ehrmann, 2000: 6; 2002: 311; 2011: 24; Otte & Spearman, 2005: 235; Battiston & Massan, 2008: 21–22; Battiston *et al.*, 2010: 150.

Geographical records: Syria, Turkey.

General distribution: Iran, Caucasus, Syria, Turkey.

Type series: Holotype male NHMW, Allotype female NHMW, Paratype male NHMW, (Synonym: (*K.r.*) Neotype male, female, juv. SMNK). Type locality: Caucasia.

Rivetina caucasica turcica Ramme, 1951

Rivetina turcica Ramme, 1951: 325–327.

Rivetina baetica: Uvarov, 1924: 40.

Rivetina caucasica turcica La Greca & Lombardo, 1982: 362; Ehrmann, 2000: 7; 2002: 311; Otte & Spearman, 2005: 237; Battiston *et al.*, 2010: 150.

Geographical records: Lebanon, Turkey.

General distribution: Lebanon: Beirut, Turkey-E: Anatolia.

Type series: Holotype female ZMHB. Type locality: Turkey: Anatolia-Ulukisla (Cilic. Taurus).

Rivetina excellens Beier, 1956

Rivetina excellens Beier, 1956: 73–74; La Greca & Lombardo, 1982: 374; Ehrmann, 2000: 7; 2002: 312; Otte & Spearman, 2005: 235.

Geographical records: Iraq.

General distribution: Iraq, Iran, Yemen, Emirates.

Type series: Holotype male SMNS.

Type locality: Iran-NS: Belutschistan, Iranshar 800 m im Trockental.

Rivetina laticollis La Greca & Lombardo, 1982

Rivetina laticollis La Greca & Lombardo, 1982: 388–390; Ehrmann, 2000: 7; 2002: 312; Otte & Spearman, 2005: 236.

Geographical records: Iraq.

General distribution: Iraq.

Type series: Holotype male IPUC. Type locality: Iraq: Kut.

Rivetina syriaca anatolica La Greca & Lombardo, 1982

Rivetina syriaca anatolica La Greca & Lombardo, 1982: 366.

Rivetina syriaca anatolica Ehrmann, 2000: 8; Ehrmann, 2002: 313; 2011: 25; Otte & Spearman, 2005: 236; Battiston *et al.*, 2010: 151.

Geographical records: Turkey.

General distribution: Turkey-E: Anatolia.

Type series: Holotype male IPUC, Allotype female IPUC, Paratype male, female IPUC. Type locality: Turkey: Foce F. Aksu, Fra Antalya Cahilar, Traüpan Acru.

Rivetina syriaca mesopotamica La Greca & Lombardo, 1982

Rivetina syriaca mesopotamica La Greca & Lombardo, 1982: 366–368; Ehrmann, 2000: 8; 2002: 313; Otte & Spearman, 2005: 236; Battiston *et al.*, 2010: 151.

Geographical records: Iraq.

General distribution: Iraq: Mesopotamia.

Type series: Holotype male IPUC, Allotype female IPUC, Paratype male IPUC, MRSN. Type locality: Iraq: Bagdad.

Rivetina syriaca syriaca (Saussure, 1869)

Iris syriaca Saussure, 1869: 65.

Rivetina syriaca syriaca Ehrmann, 2000: 8; 2002: 313; 2011: 25; Otte & Spearman, 2005: 236; Battiston *et al.*, 2010: 151.

Fischeria festae Giglio-Tos, 1916: 22; La Greca & Lombardo, 1982: 363–365.

Fischeria syriaca: Giglio-Tos, 1917: 153; Uvarov, 1922: 722–723.

Eufischeriella festae: Giglio-Tos, 1927: 485.

Rivetina festae Beier, 1935: 109.

Geographical records: Lebanon, Syria.

General distribution: Lebanon, Syria, Tadjikistan (Transcaspian: Utsh-Adzhi).

Type series: Holotype female MHNG, (Synonym: (*F.f.*) Holotype female MRSN). Type locality: Syria.

Family: Amelidae

Ameles heldreichi Brunner von Wattenwyl, 1882

Ameles heldreichi Brunner von Wattenwyl, 1882: 67; Bolívar, 1893: 7; Giglio-Tos, 1927: 163. Ehrmann, 2002: 59; 2011: 3; Otte & Spearman, 2005: 145; Battiston *et al.*, 2010: 74.

Geographical records: Turkey.

General distribution: from Greece to Libya and Cyprus.

Type series: Cotypus female ZMHB (Alkohol 2 male, female juv.). Type locality: Greece.

Ameles kervillei Bolívar, 1911

Ameles kervillei Bolívar, 1911: 1–2; Giglio-Tos, 1927: 161; Ehrmann, 2002: 59; Otte & Spearman, 2005: 145; Battiston *et al.*, 2010: 67.

Geographical records: Syria.

General distribution: Syria-W: Anti Lebanon bei Baalbeck=Heliopolis.

Type series: Holotype female MNCN, Type locality: Syria.

Ameles syriensis Giglio-Tos, 1915

Ameles syriensis Giglio-Tos, 1915: 150; 1927: 163; Ehrmann, 2002: 60; 2011: 6; Otte & Spearman, 2005: 146; Eid *et al.*, 2009: 23; Battiston *et al.*, 2010: 79.

Geographical records: Syria, Turkey, Jordan.

General distribution: Syria, Turkey, Jordan.

Type series: Holotype female MRSN. Type locality: Syria.

Family: Eremiaphilidae

Eremiaphila ammonita Uvarov, 1933

Eremiaphila ammonita Uvarov, 1933: 664–665; Ehrmann, 2002: 138; Battiston *et al.*, 2010: 171.

Geographical records: Jordan.

General distribution: Jordan.

Type series: Holotype female NHM. Type locality: Jordan: Amman.

Eremiaphila andresi Werner, 1910

Eremiaphila andresi Werner, 1910: 200–201; Ehrmann, 2002: 138; Otte & Spearman, 2005: 57; Battiston *et al.*, 2010: 171.

Geographical records: Iraq.

General distribution: Egypt, Libya, Iraq.

Type series: Holotype male NHMW, Allotype female NHMW. Type locality: Egypt: Dekela.

Eremiaphila braueri Krauss, 1902

Eremiaphila braueri Krauss, 1902: 53; Ehrmann, 2002: 138; Otte & Spearman, 2005: 58; Battiston *et al.*, 2010: 172.

Geographical records: Jordan.

General distribution: Yemen, Socotra, Jordan, Oman, Emirates.

Type series: Holotype male NHMW, Allotype female NHMW. Type locality: Arabia.

Eremiaphila cerisy Lefebvre, 1835

Eremiaphila cerisy Lefebvre, 1835: 484–486; Ehrmann, 2002: 139; Otte & Spearman, 2005: 59; Battiston *et al.*, 2010: 173.

Geographical records: Iraq.

General distribution: Egypt, Iraq, Iran, Oman, Saudi-Arabia, Emirates.

Type series: Holotype female MNHN. Type locality: "désert de Luxor (Haute-Egypte)".

Eremiaphila dagi Doganlar, 2007

Eremiaphila dagi Doganlar, 2007: 1–6; Battiston *et al.*, 2010: 173.

Geographical records: Turkey.

General distribution: Turkey.

Type series: Holotype female NTM, Allotype male NTM. Paratype female ZMUH, Paratype male and female SMNK, Paratype male and female ZSM. Type locality: Turkey: Antakya, Hatay.

Eremiaphila fraseri Uvarov, 1921

Eremiaphila fraseri Uvarov, 1921: 175–176; Ehrmann, 2002: 139; Otte & Spearman, 2005: 60.

Geographical records: Iraq.

General distribution: Iraq.

Type series: Holotype female NHM. Type locality: Iraq: Mesopotamia Anah am Euphrat.

Eremiaphila gene Lefebvre, 1835

Eremiaphila géné Lefebvre, 1835: 486–489; Ehrmann, 2002: 139; 2011: 13; Otte & Spearman, 2005: 60.

Eremiaphila généi: Saussure, 1871b: 250; Giglio-Tos, 1927: 52; Battiston *et al.*, 2010: 174.

Eremiaphila burmeisteri Giglio-Tos, 1927: 52.

Geographical records: Syria, Turkey, Jordan, Lebanon.

General distribution: from Egypt to Armenia.

Type series: Syntype male, female MRSN. Type locality: "Mont-liban".

Eremiaphila persica persica Werner, 1905

Eremiaphila persica persica Werner, 1905: 388–389; Otte & Spearman, 2005: 63.

Eremiaphila persica Ehrmann, 2002: 141; 2011: 14.

Geographical records: Turkey.

General distribution: Iran, Azerbaijan, Turkey-E: Anatolia.

Type series: Holotype male ZIN, Allotype female ZIN.

Eremiaphila turcica Westwood, 1889

Eremiaphila turcica Westwood, 1889: 29; Giglio-Tos: 1927, 53; Ehrmann; 2011: 14; Otte & Spearman, 2005: 64; Battiston *et al.*, 2010: 177.

Eremiaphila turica [sic], Ehrmann, 2002: 142.

Geographical records: Turkey, Iraq.

General distribution: Lebanon: Beirut, Turkey-E: Anatolia.

Type series: Syntype female NHM. Type locality: Turkey.

Eremiaphila typhon Lefebvre, 1835

Eremiaphila typhon Lefebvre, 1835: 499–500; Giglio-Tos: 1927, 47; Ehrmann, 2002: 142; Otte & Spearman, 2005:

64; Battiston *et al.*, 2010: 177.

Geographical records: Syria.

General distribution: from Algeria to Syria.

Type series: Holotype male ZMHB female juv. MNHN lost. Type locality: Egypt, désert près de la fontaine de Rhéan.

Eremiaphila uvarovi Bodenheimer, 1933

Eremiaphila uvarovi Bodenheimer, 1933: 79–80; Ehrmann, 2002: 142; Otte & Spearman, 2005: 65; Battiston *et al.*, 2010: 178.

Geographical records: Jordan.

General distribution: Jordan.

Type series: Holotype female NHM. Type locality: Jordan-S: Maan.

Family: Tarachodidae

Iris nana Uvarov, 1930

Iris nana Uvarov, 1930: 632; Ehrmann, 2002: 194; Otte & Spearman, 2005: 337.

Geographical records: Iraq.

General distribution: Afghanistan, Belutschistan, India, Iraq, Iran.

Type series: Holotype male NHM. Type locality: Iraq: Baghdad.

Iris oratoria (Linnaeus, 1758)

Gryllus (Mantis) oratorius Linnaeus, 1758: 426.

Mantis oratoria: Blanchard, 1840: 13.

Iris oratoria Giglio-Tos, 1927: 332; Çiplak & Demirsoy, 1997: 107; Ehrmann, 2002: 195; 2011: 18; Otte & Spearman, 2005: 338; Battiston *et al.*, 2010: 116.

Geographical records: Syria, Turkey.

General distribution: All Mediterranean region.

Type series: Holotype male, female UZIU. Type locality: Africa.

Family: Toxoderidae

Pareuthyphlebs palmonii (Uvarov, 1939)

Xenomantis palmonii Uvarov, 1939: 219–220; Ehrmann, 2002: 273; Otte & Spearman, 2005: 394; Battiston *et al.*, 2010: 137.

Geographical records: Jordan.

General distribution: Jordan.

Type series: Holotype female NHM. Type locality: am Fluss Jordan.

Sinaiella sabulosa Uvarov, 1939

Sinaiella sabulosa Uvarov, 1939: 552; Ehrmann, 2002: 319; Otte & Spearman, 2005: 245 Battiston *et al.*, 2010: 156.

Geographical records: Jordan.

General distribution: Saudi-Arabia, Jordan.

Type series: Holotype male NHM. Type locality: Saudi Arabia: Raushah, Alam, Shudhaib.

Family: Empusidae

Blepharopsis mendica (Fabricius, 1775)

Mantis mendica Fabricius, 1775: 275.

Empusa mendica: Blanchard, 1840: 10.
Blepharis mendica: Saussure, 1871a: 181; Westwood, 1889: 26; Bolívar, 1893: 8; Kirby, 1894: 138.
Blepharopsis mendica: Kirby, 1904: 315; Çiplak & Demirsoy, 1997: 105; Ehrmann, 2002: 79; 2011: 7; Battiston *et al.*, 2010: 87.
Blepharis monstrosa: Krauss, 1909: 112.
Blepharopsis mendica mendica Giglio-Tos, 1927: 645; Otte & Spearman, 2005: 43.
Geographical records: Lebanon, Turkey, Jordan, Syria.
General distribution: from Morocco to Syria.
Type series: 2males, 3females, 1 female juv. ZMHB. Type locality: Egypt: Alexandria.

***Empusa fasciata* Brullé, 1832**

Empusa fasciata Brullé, 1832: 83; Bolívar, 1893: 7; Giglio-Tos, 1927: 637; Çiplak & Demirsoy, 1997: 106; Ehrmann, 2002: 126; 2011: 10; Eid *et al.*, 2009: 23; Otte & Spearman, 2005: 46; Battiston *et al.*, 2010: 96.
Geographical records: Turkey, Jordan, Syria.
General distribution: from Greece and Algeria to India.
Type series: lost.

***Empusa longicollis* Ramme, 1951**

Empusa longicollis Ramme, 1951: 134–135; Roy, 2004: 9; Battiston *et al.*, 2010: 98.
Geographical records: Turkey.
General distribution: Turkey.
Type series: Holotype female ZMHB, Allotype male ZMHB. Type locality: Turkey: Anatolia.

***Empusa pennicornis pennicornis* (Pallas, 1773)**

Mantis pennicornis Pallas, 1773: 728; Linnaeus, *in* Gmelin, 1790: 2055; Olivier, 1792: 635, Otte & Spearman, 2005: 50.
Empusa pennicornis Giglio-Tos, 1927: 639; Çiplak & Demirsoy, 1997: 107.
Empusa orientalis Burmeister, 1838: 546–547.
Empusa attenuata Ramme, 1951: 135–136.
Empusa pennicornis pennicornis Ehrmann, 2002: 128; 2011: 12; Battiston *et al.*, 2010: 99.
Geographical records: Syria, Turkey.
General distribution: from Ukraine to China.
Type series: Syntype male ZMHB, (Synonym: (*E.a.*) Syntype male, female ZMHB, Paratype 4 males - 2 females ZMHB). Type locality: Syria: Caspium, (Paratype: Anatolia: Gebirge bei Malatia=Messina, Type: Aserbadsha=Bregli).

***Empusa uvarovi* Chopard, 1921**

Empusa uvarovi Chopard, 1921: 52–53; Ehrmann, 2002: 130; Otte & Spearman, 2005: 52; Battiston *et al.*, 2010: 100.
Geographical records: Iraq.
General distribution: Iraq, India.
Type series: Syntype male, female NHM. Type locality: Iraq: Mesopotamia Amara, Alhagi.

Family: Mantidae

***Armene robusta* Mistshenko, 1956**

Armene robusta Mistshenko, 1956: 652; Ehrmann, 2011: 6.
Geographical records: Turkey.
General distribution: Turkey, Afghanistan, Tadschikistan.
Type series: Holotype male ZIN. Type locality: Tadschikistan.

Hierodula transcaucasica Brunner von Wattenwyl, 1878

Hierodula transcaucasica Brunner von Wattenwyl, 1878: 88; Demirsoy, 1979: 262; Ehrmann, 2011: 17.

Geographical records: Turkey.

General distribution: Afghanistan, Iran, Caucasus, Turkestan, Turkey.

Type series: Holotype female NHMW?. Type locality: Iran-N: Astrabad.

Mantis religiosa religiosa (Linnaeus, 1758)

Gryllus (Mantis) religiosus Linnaeus, 1758: 426.

Mantis religiosa Linnaeus, 1767: 690; Çiplak & Demirsoy, 1997: 108; Ehrmann, 2002: 216; 2011: 19; Otte & Spearman, 2005: 186; Battiston *et al.*, 2010: 120.

Geographical records: Syria, Turkey.

General distribution: Africa, Western Asia, Europa, North-America (Introduced).

Type series: Holotype UZIU. Type locality: North Africa.

Sphodromantis trimacula (Saussure, 1870)

Hierodula trimacula Saussure, 1870: 233; Ehrmann, 2002: 324; Otte & Spearman, 2005: 262.

Hierodula (Sphodromantis) arabica Wood-Mason, 1882: 29.

Sphodromantis trimacula Kirby, 1904: 244.

Geographical records: Iraq.

General distribution: Egypt, Iraq, Iran, Saudi-Arabia, Oman: Muscat, Yemen.

Type series: Holotype female MHNG. Type locality: "Sina".

Sphodromantis viridis viridis (Forskål, 1775)

Gryllus viridis Forskål, 1775: 81; Audouin, 1827: 192.

Sphodromantis viridis viridis; Ehrmann, 2002: 325; 2011: 27–28; Otte & Spearman, 2005: 275; Battiston *et al.*, 2010: 160.

Mantis bioculata Burmeister, 1838: 537.

Sphodromantis bioculata: Rehn, 1903: 708.

Hierodula (Sphodromantis) viridis: Krauss, 1909: 112; Beier, 1935: 87.

Hierodula viridis Ramme, 1951: 416; Demirsoy, 1979: 261–262; Çiplak & Demirsoy, 1997: 105.

Geographical records: Syria, Turkey.

General distribution: from Algeria to Syria.

Type series: Syntype 3 males, 6 females ZMHB, (Synonym: (*St.v.*) female NHMB). Type locality: Egypt: Alexandria.

ORDER ISOPTERA

The information about Isoptera was taken from Krishna *et al.* (2013). Here we provide the list of species occurring in these five countries, indicating its occurrence and the institution where the type is hosted.

Family: Hodotermitidae

Anacanthotermes sawensis Al-Alawy, Abdul-Rassoul, & Al-Azawi, 1990

Geographical records: Iraq.

General distribution: Only know from Iraq.

Type: Holotype INHM. Paratype(s) INHM, DZCU.

Ref: Krishna *et al.*, 2013: 290.

Anacanthotermes septentrionalis (Jacobson, 1905)

Geographical records: Iraq.

General distribution: Also recorded in Afghanistan, Iran, Turkmenistan.
Type: Syntypes AMNH.
Ref: Krishna *et al.*, 2013: 289–290.

Anacanthotermes ubachi (Navás, 1911)
Geographical records: Turkey, Syria, Iraq, Jordan.
General distribution: Also recorded in Saudi Arabia.
Type: Syntypes (depository unknown).
Ref: Krishna *et al.*, 2013: 291.

Anacanthotermes vagans Hagen, 1858
Geographical records: Iraq.
General distribution: Also recorded in Afghanistan, Iran, Kuwait, Pakistan, Saudi Arabia.
Type: Syntype NHMW. Holotype NHMW.
Ref: Krishna *et al.*, 2013: 292.

Family: Kalotermitidae

Kalotermes flavicollis (Fabricius, 1793)
Geographical records: Syria, Turkey.
General distribution: Also recorded from Algeria to Egypt, Levant, NW Caucasus, France, Italy, Libya, Morocco, Portugal, Spain, Tunisia, Yugoslavia.
Type: Lectotype ZMUC.
Ref: Krishna *et al.*, 2013: 509–515.

Family: Rhinotermitidae

Reticulitermes clypeatus Lash, 1952
Geographical records: Iraq.
General distribution: Also recorded in Iran, Romania.
Type: Holotype AMNH. Paratypes AMNH, SANC, FRI.
Ref: Krishna *et al.*, 2013: 794.

Reticulitermes lucifugus lucifugus (Rossi, 1792)
Geographical records: Iraq, Turkey.
General distribution: Also recorded in Algeria, Austria, Azerbaijan, Cyprus, Bosnia, Herzegovina, Croatia and Yugoslavia, Egypt, France, Germany, Greece, Iran, Italy, Madeira Islands, Morocco, Portugal, Romania, Russia, Spain, Switzerland, Ukraine.
Type: Syntypes ZMHB.
Ref: Krishna *et al.*, 2013: 838–842.

Family: Termitidae

Amitermes corpulentus Al-Alawy, Abdul-Rassoul, & Al-Azawi, 1990
Geographical records: Iraq.
General distribution: Also recorded in Iran.
Type: Holotype INHM. Paratype INHM, BMNH, DZCU.
Ref: Krishna *et al.*, 2013: 2011.

Amitermes vilis (Hagen, 1858)

Termes vilis Hagen, 1858: 185–186, 240.

Geographical records: Iraq, Jordan.

General distribution: Also recorded in Yemen, Afghanistan, Iran, Oman, Saudi Arabia, Turkmenistan.

Type: Syntypes NHMW, AMNH, ZIHS.

Ref: Krishna *et al.*, 2013: 2058–2059.

Microcerotermes diversus Silvestri, 1920

Geographical records: Iraq.

General distribution: Also recorded in Yemen, North Yemen, South Yemen, Iran, Kuwait, Oman, Saudi Arabia.

Type: Syntypes IEA, AMNH.

Ref: Krishna *et al.*, 2013: 2196–2197.

Microcerotermes gabrielis Weidner, 1955

Geographical records: Iraq.

General distribution: Also recorded in Afghanistan, Iran, Saudi Arabia.

Type: Lectotype ZMUH. Paralectotypes ZMUH, AMNH.

Ref: Krishna *et al.*, 2013: 2207.

ORDER BLATTARIA

Family: Corydiidae

Subfamily: Corydiinae

Heterogamisca persica (Chopard, 1921)

Polyphaga persica Chopard, 1921: 763.

Arenivaga (Heterogamisca) persica (Chopard, 1921); Princis, 1962: 68.

Heterogamisca persica (Chopard, 1921); Grandcolas, 1994b: 157.

Geographical records: Iraq.

General distribution: Iran, Iraq, Afghanistan.

Type: Holotype NHM. Type locality: Iraq: (Perse, Quazvin, Mésopotamie).

Ref: Princis, 1961–1971: 68.

(<http://blattodea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=1178078>).

Heterogamisca simillima (Chopard, 1929)

Heterogamodes simillima Chopard, 1929: 313.

Arenivaga (Heterogamisca) simillima (Chopard, 1921); Princis, 1962: 68.

Geographical records: Jordan.

General distribution: From Jordan to the Mediterranean Sea.

Type: Holotype NHM. Type locality: Jordan: Transjordanie.

Ref: Princis, 1961–1971: 68.

(<http://blattodea.speciesfile.org/common/basic/taxa.aspx/Taxa.aspx?TaxonNameID=1178079>)

Heterogamodes ursina (Burmeister, 1838)

Heterogamia ursina Burmeister, 1838: 489.

Heterogamia africana Brunner de Wattenwyl, 1865: 357.

Heterogamia syriaca Krauss, 1890: 241.

Heterogamia livida Giglio-Tos, 1893: 3.

Heterogamodes ursina (Burmeister, 1838); Princis, 1962: 56; Grandcolas, 1994b: 157.

Geographical records: Syria.

General distribution: Syria; Egypt; Libya; Tunisia; Algeria; Morocco; Africa (Sahara).

Type: MLUH. Type locality: Syria, Egypt.

Ref: Princis, 1962: 56.

(<http://blattodea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=1178086>)

There are specimens identified as *ursina* in the MHNG Collection, but they are not indicated as types or as part of a type series.

Polyphaga aegyptiaca (Linnaeus, 1758)

Blatta aegyptiaca Linnaeus, 1758: 424.

Polyphaga aegyptiaca (Linnaeus, 1758); Princis, 1962: 48; Grandcolas, 1994b: 157.

Geographical record: Syria, Turkey, Iraq.

General distribution: Turkmenistan; Caucasus Mountains; Iran; Iraq; Turkey; Syria; Cyprus; (Crete Island); Greece; Croatia; (south), Italy; (Sicily), Italy; Algeria; Tunisia; Libya; Egypt; Eritrea; Saudi Arabia.

Type: UZIU. Type locality: Syria, Egypt.

Specimens of *aegyptiaca* MNHN, ZMHB, NHMW. Type locality: Syria, Turkey, Iraq.

Ref: Princis, 1962: 48–51.

Remarks: Domestic species

(<http://blattodea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=1178117>)

There are specimens identified as *aegyptiaca* in MLUH, but they are not indicated as types or as part of a type series.

Hemelytrobatta africana (Linnaeus, 1758)

Blatta africana Linnaeus, 1758: 424.

Blatta scutata minor Seba, 1765: 87.

Heterogamia ursine Burmeister, 1838: 1011.

Heterogamia africana Saussure, 1893: 312.

Heterogamia conspersa Brunner de Wattenwyl, 1865: 358.

Polyphaga syriaca Saussure, 1864: 346.

Arenivaga (Psammoblatta) africana (Linnaeus, 1758); Princis, 1962: 66.

Hemelytrobatta africana (Linnaeus, 1758); Grandcolas, 1994b: 157.

Geographical records: Syria.

General distribution: From Egypt to Syria, probably more abundant in Syria and surrounding countries (Chopard, 1929: 304).

Type: UZIU. Type locality: Africa.

Specimens of *africana* in Syria and Lebanon in MLUH, MNHN, NHMW, NHM, ZMUZ.

of *ursine* and *syriaca* in MHNG.

Ref: Princis, 1961–1971: 66; Chopard, 1929: 301–305.

(<http://blattodea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=1177349>)

There are specimens identified as *africana* in MHNG, but they are not indicated as types or as part of a type series.

Hemelytrobatta ebneri (Chopard, 1929)

Heterogamodes ebneri Chopard, 1929: 305–306.

Arenivaga (Psammoblatta) ebneri (Chopard, 1929); Princis, 1962: 67.

Hemelytrobatta africana (Linnaeus, 1758); Grandcolas, 1994b: 157.

Geographical records: Turkey, Syria.

General distribution: Turkey, Syria, Rhodos.

Type: NHMW. Type locality: Turkey: Taurus: Makri.

Ref: Princis, 1961–1971: 67.

There are specimens identified as *ebneri* in MHNG, but they are not indicated as types or as part of a type series.

Hemelytrobatta latifrons (Chopard, 1929)

Heterogamodes latifrons Chopard, 1929: 319.

Psammoblatta persica Chopard, 1929: 316.
Arenivaga (Psammoblatta) latifrons (Chopard, 1929); Princis, 1962: 66.
Geographical record: Iraq.
General distribution: Iraq, Iran, Pakistan.
Type: MNHN. Type locality : Perse: Bender-Bouchir.
Ref: Princis, 1961–1971: 66.
(<http://blattodea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=1178047>)
(http://isyeb.mnhn.fr/IMG/pdf/Types_Blattaria_MNHN_modif.pdf)

Hemelytroblatta livida (Brunner de Wattenwyl, 1865)
Heterogamia livida Brunner de Wattenwyl, 1865: 359.
Arenivaga (Psammoblatta) livida (Brunner de Wattenwyl, 1865); Princis, 1962: 62.
Geographical records: Iraq, Turkey, Syria, Jordan.
General distribution: Cyprus, Greece, Asia Minor.
Type: Paratype NHMW. Type locality: Chypre.
Ref: Princis, 1961–1971: 62, Giglio-tos, 1893: 3.
A recent list of types in NHMW confirms its presence in this institution.

Hemelytroblatta marismortui (Janson, 1891)
Heterogamia (Polyphaga) maris-mortui Janson, 1891: 184.
Arenivaga (Psammoblatta) maris-mortui (Janson, 1891); Princis, 1962: 65.
Hemelytroblatta africana (Linnaeus, 1758); Grandcolas, 1994b: 157.
Geographical records: Iraq, Syria.
General distribution: Syria, Iraq, Sinaï (Egypt).
Type: NHM. Type locality: Egypt: Sinaï.
Ref: Princis, 1961–1971: 65.
(<http://blattodea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=1178051>)
Although the original publications mention NHM as the depository institution, recent institutional lists do not confirm its presence.

Family: Ectobiidae

Subfamily: Ectobiinae

Arbiblatta syriaca (Bey-Bienko, 1938)
Phyllodromica (Arbiblatta) syriaca Bey-Bienko, 1938: 232.
Hololampra brevipennis Ramme, 1951: 415.
Geographical records: Syria.
General distribution: Syria.
Type: NHMW in the Brunner von Wattenwyl's collection; Paratype in the former Zoological Institute, Leningard, now ZIN. Type locality: Syria
Ref: Princis, 1961–1971: 1108.
(<http://blattodea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=1175944>)

Ectobius vittiventris (Costa, 1847)
Blatta vittiventris Costa, 1847: 111.
Ectobius neolividus Fruhstorfer, 1921: 13, 18, 56, 58, 63, 78.
Geographical records: Turkey.
General distribution: Switzerland; Sicily, Italy; Yugoslavia; Romania; Bulgaria; Turkey; Caucasus mountains.
Type: Syntype ZMHB. Type locality: Switzerland.
Ref: Princis, 1961–1971: 1050–1052; Baur & Corey, 2004: 615.

(<http://nmbe-xen25.unibe.ch/sites/default/files/uploads/pubinv/2120.pdf>)

There are specimens identified as *vittiventris* in MHNG, but they are not indicated as types or as part of a type series.

Luridiblatta beybienkoi Maran, 1957

Phyllodromica beybienkoi Maran, 1957: 165.

Geographical records: Turkey.

General distribution: Turkey.

Type: Holotype NMP. Type locality: Turkey: Karapinar, Toros.

Ref: Maran, 1957: 165.

Phyllodromica brevipennis (Fischer, 1853)

Blatta brevipennis Fischer, 1853: 102.

Alphebia carpetana (nec Bolívar, 1873) Giglio-tos, 1893: 3.

Geographical records: Syria, Turkey, Lebanon.

General distribution: Austria; Italy; Yugoslavia; Hungary; Albania; Bulgaria; Turkey; Syria.

Type: NHMW in the Brunner von Wattenwyl's collection. Type locality: Italy: Istria.

Ref: Princis, 1971: 1103; Giglio-tos, 1893: 3.

(<http://blattodea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=1176174>)

There are specimens identified as *brevipennis* in MHNG, but they are not indicated as types or as part of a type series.

Phyllodromica marginata (Schreber, 1781)

Blatta marginata Schreber, 1781: 88.

Geographical records: Turkey.

General distribution: (Sardinia Island), Italy; (Sicily), Italy; Austria; Yugoslavia; Albania; Greece; Bulgaria; Hungary; Romania; Ukraine; Crimea; Turkey.

Type: MLUH. Type locality: Italy.

Ref: Princis, 1971: 1091–1093.

(<http://blattodea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=1176252>)

There are specimens identified as *marginata* in MHNG, but they are not indicated as types or as part of a type series.

Phyllodromica megerlei Fieber, 1853

Blatta megerlei Fieber, 1853: 94.

Hololampra f. erythronota Ramme, 1951: 324.

Phyllodromica megerlei ssp. asiatica Bey-Bienko, 1950: 232.

Geographical records: Syria, Turkey.

General distribution: Germany; Switzerland; Slovakia; Czech Republic; Austria; Italy; Slovenia; Croatia; Serbia; Bosnia and Herzegovina; Hungary; Romania; Moldova; Republic of Ukraine.

Type: According to Vidlicka & Majzlan (1997), the type is missing.

Ref: Princis, 1961–1971: 1094–1096; Vidlicka & Majzlan, 1997: 165.

(<http://blattodea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=1176209>)

There are specimens identified as *megerlei* in MHNG, but they are not indicated as types or as part of a type series.

There are specimens of *asiatica* in Syria and Turkey in ZMHB.

Phyllodromica pallida (Brunner von Wattenwyl, 1882)

Aphlebia pallida Brunner von Wattenwyl, 1882: 42.

Geographical records: Turkey.

General distribution: Greece; Yugoslavia; Turkey.

Type: NHMW. Type locality: Greece.

Ref: Princis 1971: 1104.

(<http://blattodea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=1176247>)

There are specimens identified as *pallida* in MHNG, but they are not indicated as types or as part of a type series.

Phyllodromica znojkoii Bey-Bienko, 1938

Phyllodromica znojkoii Bey-Bienko, 1938: 230.

Geographical records: Turkey.

General distribution: Transkaukasia: Ordubad; Turkey: Anatolia.

Type: NHMW. Type locality: Transkaukasia.

Ref: Princis, 1971: 1104.

Subfamily: Blattellinae

Blattella germanica (Linnaeus, 1767)

Blatta germanica Linnaeus, 1767: 688.

Geographical records: Sincanköy-Ankara (Turkey).

General distribution: cosmopolitan, probably of East Asian origin.

Type: Holotype NHM in the collection of the Linnean Society.

Ref: Princis, 1962–1971: 807–841.

Remarks: domestic species cosmopolitan.

There are specimens identified as *germanica* in MLUH and UZIU one, but they are not indicated as types or as part of a type series.

Loboptera decipiens (Germar, 1817)

Loboptera (Blatta) decipiens Germar, 1817: 249.

Geographical records: Lebanon.

General distribution: Madeira Island; Portugal; Canary Islands, Spain; Corsica, France; Sardinia Island, Italy; Sicily, Italy; Crete Island, Greece; Yugoslavia; Albania; Bulgaria; Romania; Crimea; Caucasus Mountains; Morocco; Algeria; Tunisia; Libya; Lebanon; Asia.

Type: MHNG (Neotype from Harz, 1977: 33–34, probably not valid). Type locality: unknown

Ref: Princis, 1961–1971: 850, Giglio-tos, 1893: 3.

(<http://blattodea.speciesfile.org/Common/basic/Taxa.aspx?TaxonNameID=1175303>)

There are specimens identified as *decipiens* in NHM, but they are not indicated as types or as part of a type series.

Family: Blattidae

Subfamily: Blattinae

Blatta orientalis Linnaeus, 1758

Blatta orientalis Linnaeus, 1758: 724.

Geographical records: Ankara-Baraj, Anatolia (Turkey), Syria.

General distribution: cosmopolitan in temperate regions [southern Russian origin].

Type: Lectotype, Paralectotype NHM in the collection of the Linnean Society; Neotype MHNG, Marshall, 1983: 390.

Ref: Princis, 1962–1971: 475–507; Marshall, 1983: 390; Giglio-tos 1893: 3.

Remarks: Domestic species. Cosmopolitan

There are specimens identified as *orientalis* in MLUH, but they are not indicated as types or as part of a type series.

The congeneric *Blatta furcata* (Karny, 1908) could be probably found in the region as well (Bohn, 1984).

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References

- Al-Alawy, S.A., Abdul-Rassoul, M.S. & Al-Azawi, A.F. (1990) Description of new species of termites (Insecta, Isoptera) from Iraq. *Bulletin of the Iraq Natural History Museum*, 8 (3), 25–33.
- Audouin, J.V. (1827) Explication sommaire des planches d'Insectes de l'ouvrage de la commission d'Égypte et de la Syrie, Publiées par J.C.Savigny, in : *Description de l'Égypte ou recueil des observations et des recherches qui ont été faites en Égypte pendant l'expédition de l'armée française*, Paris, pp. 192. [439]
- Battiston, R. & Massa, B. (2008) The Mantids of Caucasus (Insecta Mantodea). *Atti della Accademia --Roveratana degli Agiati*, Series 8, 8, 21–22.
- Battiston, R., Picciau, L., Fontana, P. & Marshall, J. (2010) *Mantids of the Euro-Mediterranean Area. WBA Handbooks 2*. World Biodiversity Association, Verona, 240 pp.
- Baur, H. & Coray, A. (2004) A revision of the Blattodea, Ensifera and Caelifera described by H. Fruhstorfer. *Revue Suisse de Zoologie*, 111 (3), 611–630.
- Beccaloni, G.W. (2007) Blattodea Species File Online. Version 1.0/3.0. World Wide Web electronic publication. Available from: <http://Blattodea.SpeciesFile.org> (accessed 1 May 2014)
- Beccaloni, George W. & Eggleton Paul. (2013) Order Blattodea. In: Zhang, Z.-Q. (Ed.), *Animal biodiversity: An outline of higher-level classification and survey of taxonomic richness*. *Zootaxa*, 3703 (1), 46–48. <http://dx.doi.org/10.11646/zootaxa.3703.1>
- Beier, M. (1935) *Mantodea. Fam. Mantidae. Subfam. Mantinae. Genera Insectorum* de P. Wystman, 203^{me} fascicule. Desmet-Verteneuil, Bruxelles, 146 pp.
- Beier, M. (1956) Mantiden aus dem Iran 1954 (Orthopt.). *Ergebnisse der Entomologischen Reisen Willi Richter, Stuttgart, im Iran 1954 und 1956, Nr. 2. Jahreshefte des Vereins für vaterländische Naturkunde in Württemberg*, 111 (1), 68–75.
- Bey-Bienko, G.Ya. (1938) On some new or interesting Asiatic Blattodea. *Annals and Magazine of Natural History*, 1, 230–238. <http://dx.doi.org/10.1080/00222933808526759>
- Bey-Bienko, G.Ya. (1950) *Fauna of the USSR. Insects. Blattodea*. Institute of Zoology, Academy of Sciences URSS, Moscow, 342 pp.
- Blanchard, M.E. (1840) Histoire naturelle des Insectes Orthoptera. *Orthoptères*, 3, 1–44. [P. Duménil, Paris]
- Bodenheimer, F.S. (1933) Eine neue Eremiaphila-Art, (Orthoptera-Mantodea). *Mitteilungen der Schweizerischen Entomologischen Gesellschaft*, 4, 79–80.
- Bohn, H. (1984) *Blatta furcata* (Karny), the nearest relative of the oriental cockroach *Blatta orientalis* L. (Insecta: Blattodea: Blattidae). *Journal of Zoology*, 33, 39–50.
- Bolívar, I. (1893) Liste des Orthoptères recueillis en Syrie par le Dr Théod. Barrois, par le professeur I. Bolívar de Madrid. *Revue biologique du nord de la France*, 1893, 3–16.
- Bolívar, I. (1899) Orthoptères du voyage de M. Martinez Escalera dans l'Asie Mineure. *Annales de la société entomologique de Belgique*, 43, 583–607.
- Bolívar, I. (1911) Description de cinq espèces nouvelles d'Orthoptères. (Quatre trouvées par M. Henri Gadeau de Kerville en Syrie et Perse). *Bulletin de la Société des amis des sciences naturelles de Rouen*, 1911, 1–3.
- Brunner de Wattenwyl, C. (1865) *Nouveau système des Blattaires*. G. Braumüller, Vienna, 426 pp. <http://dx.doi.org/10.5962/bhl.title.8507>
- Brunner von Wattenwyl, K. (1878) Nutwissenschaftliche Beitrage zur Kenntnis der Kaukasuslaender auf Grund seiner Sammelbeute. *Naturwissenschaft beitrage Kaukasus*, 1878, 87–90.
- Brunner von Wattenwyl, K. (1882) *Prodromus der europäischen Orthopteren*. Engelmann, Leipzig, xxxii + 466 pp. [Leipzig, W. (Ed.), pp. 54–71.]
- Brullé, A. (1832) Expedition Sci. de Morée. *Zoologie - Orthoptera - Mantodea*. Levrault, Paris, 400 pp.
- Burmeister, H.C. (1838) Handbuch der Entomologie. Fangschrecken. *Handbuch der Entomologie*, 2, 469–552.
- Çiplak, B. & Demirsoy, A. (1997) Mantodea (Insecta) Fauna of Malatya vicinity (Turkey) and some remarks on the Mantises of Anatolia. *Journal of Orthoptera Research*, 6, 105–111. <http://dx.doi.org/10.2307/3503542>
- Costa, A. (1847) Pecie nuove o rare d'Insetti delle Montagne del Matese. "Annali dell'Accademia degli aspiranti naturalisti", Series 2, 1, 111. [Napoli]
- Chopard, L. (1921) Report on the Orthoptera of Mesopotamia and Persia. *Journal of the Bombay Natural History Society*, 27, 759–771.
- Chopard, L. (1929) Orthoptera palaeartica critica. VII. Les Polyphagiens de la faune paléarctique. *Eos, Revista Espanola de*

- Entomologia*, 5, 223–358.
- Demirsoy, A. (1979) Die Fangheuschreckenfauna Anatoliens. *Entomologische Mitteilungen aus dem Zoologischen Museum Hamburg*, 6 (106), 253–265.
- Doganlar, M. (2007) A new species of the genus *Eremiaphila* Lefebvre, 1835 (Mantodea: Eremiaphilidae) from Turkey. *Australian Journal of Basic and Applied Sciences Research*, 1 (1), 1–6.
- Ebner, R. (1919) Prof. Dr. Franz Tölg Ergebnisse einer zoologischen Forschungsreise nach Kleinasien. VI. Orthopteren aus Kleinasien. *Archiv für Naturgeschichte*, 85 (8), 148–176.
- Ehrmann, R. (2000) *Rivetina* Berland & Chopard 1922, eine interessante Gattung der Ordnung Mantoptera (Insecta: Mantoptera: Familie: Mantidae, Subfamilie: Mantinae, Tribus: Miomantini). *Arthropoda*, 8 (1), 2–9. [Wernigerode]
- Ehrmann, R. (2002) *Mantodea. Gottesanbeterinnen der Welt*. Natur und Tier-Verlag GmbH (NTV Wissenschaft), Münster, 519 pp.
- Ehrmann, R. (2011) Mantodea from Turkey and Cyprus (Dictyoptera: Mantodea). *Articulata*, 26 (1), 1–42.
- Eid, E., Katbeh-Bader, A., Al-Otoom, M. & Othman, Y. (2009) Contribution to the Entomofauna of Dibe'en Forest Reserve in Jordan. *Centre for Entomological studies Ankara*, 49, 19–41.
- Engel, M.S., Grimaldi, D.A. & Krishna, K. (2009) Termites (Isoptera): their phylogeny, classification, and rise to ecological dominance. *American Museum Novitates*, 3650, 1–27.
<http://dx.doi.org/10.1206/651.1>
- Fabricius, J.C. (1775) *Systema Entomologiae sistens Insectorum*. Kortii, Flensburgi et Lipsiae, 12 pp. [pp. 268–279]
- Fabricius, J.C. (1793) *Entomologia systematica emendata et aucta. Secundum: classes, ordines, genera, species. adjectis: synonymis, locis, observationibus, descriptionibus. Vol. 2*. Christ. Gottl. Proft, Copenhagen, pp. 8 + 519. [12–25]
- Fieber, F.X. (1853) Synopsis der europäischen Orthopteren, mit besonderer Rücksicht auf die in Böhmen vorkommenden Arten als Auszug aus dem zum Drucke vorliegenden Werke. In: "Die europäischen Orthopteren". Prag, pp. 95.
- Fischer, L.H. (1853) Orthoptera Europaea. Mantodea. *Orthoptera Europaea*, 1853, 127–129. [sumtibus G. Engelmann., Leipzig]
- Forskål, P. (1775) Descriptiones animalium avium Insectorum. Orthoptera - Mantodea. *Havniae, Carsten Niebuhr, Moeller*, Kopenhagen, 4, 81–83.
- Fruhstorfer, H. (1921) Die Orthopteren der Schweiz und der Nachbarländer auf geo-graphischer sowie oekologischer Grundlage mit Berücksichtigung der fossilen Arten. *Archiv für Naturgeschichte*, 87 (5), 1–262.
- Germar, E.F. (1817) *Reise durch Oesterreich, Tyrol nach Dalmatien und in das Gebiet von Ragusa*. Brockhaus, Leipzig, 1–2 + 323 pp.
- Giglio-Tos, E. (1893) Viaggio del D.r E. Festa in Palestina, nel Libano e regioni vicine. *Bollettino dei Musei di Zoologia. Università di Torino*, 8 (164), pp. 3.
- Giglio-Tos, E. (1915) Mantidi esotici. Generi e specie nuove. *Bollettino della Società Entomologica Italiana*, 46, 134–200.
- Giglio-Tos, E. (1916) Mantidi esotici. Generi e specie nuove. *Bollettino della Società Entomologica Italiana*, 47, 3–44.
- Giglio-Tos, E. (1917) Note al Catalogo dei Mantidi di Kirby. *Bollettino della Società Entomologica Italiana*, 48, 139–163.
- Giglio-Tos, E. (1927) *Das Tierreich 50. Orthoptera Mantidae*. Walter de Gruyter & Co., Berlin & Leipzig, XL+707 pp.
- Grandcolas, P. (1994a) Les Blattes de la forêt tropicale de Guyane Française: structure du peuplement (Insecta, Dictyoptera, Blattaria). *Bulletin de la société Zoologique de France*, 119, 59–67.
- Grandcolas, P. (1994b) Phylogenetic systematics of the subfamily Polyphaginae, with the assignment of *Cryptocercus* Scudder, 1862 to this taxon (Blattaria, Blaberoidea, Polyphagidae). *Systematic Entomology* 19, 145–158.
- Grandcolas, P. (1994c) Blattaria (Insecta: Dictyoptera) of Saudi Arabia: a preliminary report. In: Büttiker, W. & Krupp, F. (Eds.), *Fauna of Saudi Arabia. Vol. 14*. NCWCD, Pro Entomologia, Riyadh, Basle, pp. 40–58.
- Grandcolas, P. (1996) The phylogeny of cockroach families: a cladistic appraisal of morpho-anatomical data. *Canadian Journal of Zoology*, 74, 508–527.
<http://dx.doi.org/10.1139/z96-059>
- Grandcolas, P. (1997) Systématique phylogénétique de la sous-famille des Tryonicinae (Dictyoptera, Blattaria, Blattidae). In: Najt, J. & Matile, L. (Eds.), *Zoologia Neocaledonica. Vol. 4. Mémoires du Muséum national d'Histoire naturelle* 171, Paris, pp. 91–124.
- Grandcolas, P. (2004–2007) Muséum National d'Histoire Naturelle. Available from <http://www.mnhn.fr/mnhn/oseb/grandcolas.htm> (accessed 1 May 2014)
- Grandcolas, P. & Pellens, R. (2012) Capitulo 27. Blattaria. In: Rafael, J.A., Rodrigues de Melo, G.A., Barros de Carvalho, C.J., Casari, S.A. & Constantino, C.J. (Eds.), *Insetos do Brasil. Diversidade e Taxonomia*. Ribeirão Preto, Holos Editora, pp. 333–346.
- Hagen, H.A. (1858) Monographie der Termiten. *Linnaea Entomologica*, 12, 4–342 + 459. [Iraq, Turkey]
- Harz, K. (1977) *Loboptera decipiens* (Germ.) in Deutschland gefunden (Blattoptera). *Articulata*, 16, 33–34.
- Harz, K. (1988) Eine neue Gattung der Mantidae mit zwei neuen Arten aus der Türkei. *Articulata*, Steinsfeld., pp. 207–213.
- Jacobson, G. (1905) Zur Kenntnis der Termiten Russlands. *Annuaire du Musée Zoologique de l'Académie Impériale des Sciences de St.-Petersbourg*, 9 [1904], 57–107.
- Janson, O. (1891) *Some Account of the fauna and flora of Sinai*. Petra and Wady 'Arabah, London, 2 pp. [pp. 182–183]
- Kaltenbach, A.P. (1963) Kritische Untersuchungen zur Systematik, Biologie und Verbreitung der europäischen Fangheuschrecken. *Zoologische Jahrbücher, Systematik*, 90, 521–598.

- Kirby, W.F. (1894) The Zoology of the Afghan Delimitation Commission. *The Transactions of the Linnean Society of London, Zoology*, 5 (2), 53–142.
- Kirby, W.F. (1904) *A synonymic Catalogue of Orthoptera. I. Orthoptera Euplexoptera, Cursoria et Gressoria*. British Museum, Natural History, London, x + 501 pp.
- Krauss, H.A. (1890) Erklärung der Orthopteren-Tafeln J.C. Savigny's in der Description de l'Égypte. *Verhandlungen der Zoologisch-Botanischen Gesellschaft in Wien*, 40, 3–48. [pp. 227–272]
- Krauss, H.A. (1902) Diagnosen neuer Orthopteren aus Südarabien und von der Insel Sokotra. *Anzeiger der Akademie der Wissenschaften in Wien*, 39 (7), 53–59.
- Krauss, H.A. (1909) Zoologische Ergebnisse zweier in den Jahren 1902 und 1904 durch die Sinai-halbinsel Botanischen Studiereisen. In: Kneucher, A. (Ed.), *Verhandlungen des Naturwissenschaftlichen Vereins in Karlsruhe*, 21, pp. 99–199.
- Krishna, K., Grimaldi, D.A., Krishna, V. & Engel, M.S. (2013) Treatise on the Isoptera of the World. *Bulletin of the American Museum of Natural History*, Number 337, 1–2704.
- Lash, J.W. (1952) A new species of *Reticulitermes* (Isoptera) from Jerusalem, Palestine. *American Museum Novitates*, 1575, 1–7.
- La Greca, M. & Lombardo, F. (1982) Le Specie Mediterranee e dell'Asia occidentale del gen. *Rivetina* Berland & Chopard. (Insecta, Mantodea). *Animalia (Catania)*, 9, 345–393.
- Lefebvre, A. (1835) Nouveau Groupe d'Orthoptères de la Famille des Mantides. *Annales de la Société entomologique de France*, 4, 449–508.
- Linnaeus, C. (1758) *Systema naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis. Tomus I, editio decima, reformata*. Holmaie, Laurentii Salvii, Stockholm, 824 pp. [pp. 424–426]
- Linnaeus, C. (1767) *Systema Naturae Editio duodecima reformata, Stockholm*. Holmiae, Laur. Salvius., Stockholm, 5 pp. [pp. 687–691]
- Linnaeus, C. (1790) *Systema naturae*, 13 Aufl. In: Gmelin, J.F. (Ed.), *Insecta*, 1 (4), pp. 1517–2224. [Beer, Lipsiae]
- Maran, J. (1957) Wissenschaftliche Ergebnisse der zoologischen Expedition des Nationalmuseums in Prag nach der Türkei. 21. Blattoidea. *Acta Entomologica Musei Nationalis Pragae*, 31, 163–165.
- Marshall, J.A. (1983) The orthopteroid insects described by Linnaeus, with notes on the Linnaean collection. *Zoological Journal of the Linnean Society*, 78, 375–396.
<http://dx.doi.org/10.1111/j.1096-3642.1975.tb02266.x>
- Medail, F. & Quezel, P. (1997) Hot-spots analysis for conservation of plant biodiversity in the Mediterranean basin. *Annals of the Missouri Botanical Garden*, 84 (1), 112–127.
<http://dx.doi.org/10.2307/2399957>
- Medail, F. & Quezel, P. (1999) Biodiversity hotspots in the Mediterranean basin: Setting global conservation priorities. *Conservation Biology*, 13 (6), 1510–1513.
<http://dx.doi.org/10.1046/j.1523-1739.1999.98467.x>
- Mistshenko, L.L. (1956) *Entomology Oborz. Vol. 35. USSR, Tadzhikistan, Kondara, Varzob River valley*, 6 pp. [pp. 652–657]
- Mistshenko, L.L. (1967) New species of the genus *Rivetina* Berland & Chopard. From Kazakhstan, Turkomania and Asia minor. *Entomological Review USSR*, 46 (3), pp. 699–711. [Moskau]
- Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B. & Kent, J. (2000) Biodiversity hotspots for conservation priorities. *Nature*, 403, 853–858.
<http://dx.doi.org/10.1038/35002501>
- Naturhistorisches Museum, Wien (2007) *Blattoidea types in the collection*. Unpublished list, 36 pp.
- Navás, R.P.L. (1911) Algunos Ortopteros y Neuropteros de Palestina. *Revista Montserratana*, 5, 120–121. [Barcelona]
- Olivier, A.G. (1792) Histoire Naturelle. Insectes (Mantodea). *Encyclopédie Méthodique, Dictionnaire des Insectes*. Panckoucke, Paris, pp. 616–642.
- Otte, D. & Spearman, L. (2005) Mantida Species File. *Catalogue of the Mantids of the world*, Publication Number 1, 1–489. [Insect Diversity Association]
- Pallas, P.S. (1773) Reise durch verschiedene Provinzen des Russischen Reiches in den Jahren 1768–1774. *Akademie Buchhandlung*, 2, 728.
- Pantel, J. (1896) Notes Orthoptérologiques. Teil 4–5. *Geomantis larvoides* nov. spec. *Anales de la Sociedad española de Historia Natural*, 5 (25), 47–118. [Madrid]
- Pellens, R. (2002) *Fragmentação florestal em Mata Atlântica de Tabuleiros: os efeitos da heterogeneidade da paisagem sobre a diversidade de artrópodos edáficos*, Phd thesis in Departamento de Geografia, Programa de Pós-Graduação em Geografia. Universidade Federal do Rio de Janeiro, Rio de Janeiro, 198 pp.
- Pellens, R. and Grandcolas, P. (2008) Catalogue of Blattaria (Insecta) from Brazil. *Zootaxa*, 1709, 1–109.
- Princis, K. (1961–1971) Blattariae. Pars 3, 4, 6, 7, 8, 11, 13, 14. *Orthopterorum Catalogus*. M. Beier. Junk's-Gravenhage, The Hague, 1224 pp.
- Ramme, W. (1951) Zur Systematik, Faunistik und Biologie der Orthopteren von Süd–Ost–Europa und Vorder Asien. *Mitteilungen aus dem Zoologischen Museum in Berlin*, 27, 1–431.
- Rehn, J.A.G. (1903) Studies in old world Mantidae (Orthoptera). *Proceedings of the Academy of Natural Sciences of Philadelphia*, 55, 701–718.

- Rossi, P. (1792) *Mantissa insectorum, exhibens species nuper in Etruria collectas: adjectis faunae etruscae illustrationibus, ac emendationibus, Fauna Etrusca*. Pisis Ex typ. Polloni, 148 pp.
- Roy, R. (1966) A new species of *Amorphoscelis* from Iraq (Mantodea: Amorphoscelididae). *Entomological News*, 77 (1), 267–270.
- Roy, R. (2004) Réarrangements critiques dans la famille des Empusidae et relations phylogénétiques [Dictyoptera, Mantodea]. *Revue française d'Entomologie*, New Series, 2004, 26 (1), 1–18.
- Saussure, H. de (1864) Blattarum novarum species aliquot. *Revue et Magasin de Zoologie*, 16, 305–349.
- Saussure, H. de (1869) Essai d'un Système des Mantides. *Mittheilungen der Schweizerischen entomologischen Gesellschaft*, 3 (2), 49–73.
- Saussure, H. de (1870) Additions au Système des Mantides. *Mittheilungen der Schweizerischen entomologischen Gesellschaft*, 3 (5), 221–244.
- Saussure, H. de (1871a) Mélanges Orthoptérologiques. III^{me} Fascicule. IV. Mantides. *Mémoires de la Société de Physique et d'Histoire naturelle de Genève*, 21 (2), 1–214.
- Saussure, H. de (1871b) Mélanges Orthoptérologiques. Supplément au III^{me} Fascicule. IV. Mantides. *Mémoires de la Société de Physique et d'Histoire naturelle de Genève*, 21 (1), 239–337.
- Saussure, H. de (1893) Révision de la tribu des Hétérogamiens. *Revue Suisse de Zoologie*, 1, 289–318.
- Seba, A. (1765) *Rerum Naturalium thesauri Académie accurata descriptio. Vol. 4*. Amsterdam, 87 pp, Index 33 pp.
- Schreber, W.L. (1781) Beschreibungen merkwürdiger Insekten. Erstes Stück. *Der Naturforscher*, 15, 87–95.
- Silvestri, F. (1920) A new termite from Mesopotamia. *Annals and Magazine of Natural History*, Series 9, 6 (53), 477–479.
<http://dx.doi.org/10.1080/00222932008632468>
- Svenson, G.J. & Whiting, M.F. (2004) Phylogeny of Mantodea based on molecular data: evolution of a charismatic predator. *Systematic Entomology*, 29, 359–370.
<http://dx.doi.org/10.1111/j.0307-6970.2004.00240.x>
- Uvarov, B.P. (1921) *Eremiaphila fraseri*, sp. n., a new mantid from Mesopotamia. *The Entomologist's monthly magazine*, 57, 175–176.
- Uvarov, B.P. (1922) Records and descriptions of Orthoptera from S. W. Asia. *Journal of the Bombay Natural History Society*, 28, 719–725.
- Uvarov, B.P. (1924) Some new and interesting Orthoptera in the collection of the Ministry of Agriculture, Cairo. *Ministry of Agriculture, Egypt Technical & Scientific Service Bulletin*, 41, 1–40.
- Uvarov, B.P. (1930) Notes on Palearctic Mantidae (Orthoptera). *Annals and Magazine of Natural History*, 5 (10), 631–633.
<http://dx.doi.org/10.1080/00222933008673176>
- Uvarov, B.P. (1933) Notes on new and little-known Orthoptera from Palestine. *Annals and Magazine of Natural History*, 11 (10), 663–672.
<http://dx.doi.org/10.1080/00222933308673740>
- Uvarov, B.P. (1939) New and less-known Palestinian Orthoptera. *Annals and Magazine of Natural History*, 11 (20), 216–221.
<http://dx.doi.org/10.1080/00222933908526986>
- Vidlicka, L. & Majzlan, O. (1997) Revision of the megerlei-group of the cockroach genus *Phyllodromica* Fieber (Blattaria: Blattellidae, Ectobiinae). *Entomologica Scandinavica*, 28, 163–173.
<http://dx.doi.org/10.1163/187631297X00033>
- Wallin, L. & Wallin, H. (2001) *Catalogue of type specimens. 1. C. P. Thunberg (1743–1828), Insecta*. Uppsala University, Museum of Evolution - Zoology Section, Uppsala, unpublished list. 65 pp.
- Weidner, H. (1955) Eine neue Termitenart aus Vorderasien. *Infsectes Sociaux*, 2 (1), 63–68.
<http://dx.doi.org/10.1007/BF02223438>
- Werner, F. (1905) Ergebnisse einer zoologischen Forschungsreise nach Ägypten und dem ägyptischen Sudan. I. Die Orthopterenfauna Ägyptens mit besonderer Berücksichtigung der Eremiaphila. *Sitzungsberichte der mathematisch-naturwissenschaftlichen Klasse der Akademie der Wissenschaften Wien*, 114 (5), 357–436.
- Werner, F. (1908) Die Mantodeen Abessyniens. Nach dem Material des St. Petersburger akademischen Museums. *Annuaire du Musée zoologique de l'Académie Impériale des Sciences de Saint-Petersbourg*, 13, 108–128.
- Werner, F. (1910) Une nouvelle espèce d'Eremiaphile d'Égypte (Orthopt.). *Bulletin de la société Entomologique d'Égypte*, 2, 200–201.
- Westwood, J.O. (1889) *Revisio Insectorum Familiae Mantidarum, speciebus novis aut minus cognitis descriptis et delineatis*. Gurney and Jackson, London, 54 + III p., 14 pl.
- Wood-Mason, J. (1882) On new and little known Mantodea (5). *Journal of the Asiatic Society of Bengal*, 51 (2), 21–36.

**C) Chapitre III -
Outstanding microendemism in New Caledonia: more than
one out of ten animal species has a very restricted range of
distribution**

Outstanding microendemism in New Caledonia: more than one out of ten animal species has a very restricted range of distribution

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Abstract

New Caledonia is a biodiversity hotspot with extremely high number of endemic species with narrow distribution range, and in high risk of extinction due to open-cast nickel mining, invasive species and seasonal man-induced fires. Mentions of microendemism permeate the literature on the biota of this archipelago. But so far there is specific research about this subject bearing on a diversity of animal groups, making impossible to disentangle microendemism from data deficiency. The aim of the present study is to clarify this issue, and evaluate the area, the frequency, and the extent microendemism is common to several groups of organisms. We studied a dataset issuing from Zoologia Neocaledonica, with 1149 species, and 86% endemic to New Caledonia. The number of dates and the number of collectors by species were the variables of sampling effort best correlated with the distribution range, and highly intercorrelated. The median of sampling dates was used to establish a cutoff for characterizing adequately sampled species. We showed that, although only 52% of these species were adequately sampled to state about their distribution range, the number of species with very narrow distribution range is still high. Among the endemics from New Caledonia, 12% (116 species) have ranges $\leq 5.2 \text{ km}^2$ and 3.9% (38) have ranges between 23 and 100 km^2 . Microendemic species were the most frequent species in 18 out of 20 orders studied. These results allow for revising the IUCN red list of species in this archipelago, indicating that at least 116 species are probably critically endangered. Surprisingly, a similar trend was observed for the non-endemic species: 22% in area $\leq 5.2 \text{ km}^2$, and 8% in areas $\geq 23 \text{ km}^2$ and $\leq 100 \text{ km}^2$, suggesting that environmental dissimilarity may play an important role in species' distribution.

Keywords: Microendemism, narrow endemism, rarity, sampling effort, islands, Zoologia Neocaledonica, restricted distribution range

Introduction

Microendemism, short-range endemism, narrow endemism, restricted distribution range are terms commonly and interchangeably used to describe very short geographical distribution ranges. This is a common form of rarity [1, 2], and the literature is plenty of examples of microendemic species and of sites that harbor exceptional rates of them as well [3-5]. Despite of its commonness, the quantification of microendemism is quite challenging, particularly because the very characterization of distribution range can be obscured by scaling effects [6] and by differential sampling efforts in space and time, which might lead to confusions between microendemicity and data deficiency.

The massive destruction and transformation of natural habitats [7] is leading to one major crisis in the history of life on Earth [8]. So, characterizing species that are microendemic and sites that harbor important rates of them is fundamental for establishing adequate conservation strategies for reducing major biodiversity losses and assuring several important and vulnerable functions in the ecosystem [9]. From a conservation perspective, the principal particularity of microendemicity is that the population size is often very small (even when the density is locally high). As a consequence, species' survival is highly dependent on the long-term permanence and integrity of very localized habitats.

Although microendemic species can be found virtually everywhere, they are particularly abundant in some regions known for their rich and original biota due to local evolution and diversification (e.g., the Cape flora, mammals or frogs in Madagascar). These local diversification bursts lead to numbers of species with very restricted geographical ranges or with marked differences in the way they exploit the resources [3-5,10].

Among these remarkable regions of the world, New Caledonia is not only famous for its exceptional regional endemism [11] but also for its extremely high local microendemism [11-14]. New Caledonia is the oldest oceanic island [15,16]. It is considered a world's biodiversity hotspot due to a magnificent flora and fauna

characterized by a the high number of locally endemic species facing threats due to nickel mining, repeated fires, and invasive species [10, 17- 21]. Mentions of microendemism permeate the literature on the New Caledonian fauna and flora. For instance, local insect diversifications showed most endemic species allopatric or secondary sympatric on different small mountains [22-25]. Most of the species of the largest monophyletic animal group (Insecta Trichoptera) were confined to one single creek [26]. A new harvestman species was found at each new locality explored [27]. Forty eight percent of the land-snails studied [28] were found in a single locality; for the geckos from the genus *Dierogecko*, all species were restricted to only one site, sometimes very near from the one with a different species or isolated without a visible geographical barrier [29]. Twenty one percent of the flora were microendemic species [30].

The repeated documentation of microendemism in several components of New Caledonia biota shows a clear need of a synthesis aimed at understanding not only its frequency, range and main drivers, but also the extent it is actually common to different groups of organisms. A first study in this direction was done by [30], bringing a first contribution to the understanding of microendemism in the New Caledonian flora. However, despite of the diversity and richness of the local fauna already documented by many taxonomic studies e.g. [14, 31-32], nothing was yet done to advance in the knowledge of its distribution. In order to contribute to this task we designed a study for characterizing the extent microendemism is common in New Caledonian fauna, and to disentangle microendemic from poorly sampled species. More specifically, we explored (1) the area of what can be called microendemism in New Caledonia, (2) the frequency of species in different distribution ranges, (3) a set of variables expressing sampling effort with the purpose of finding that (or those) that were more likely to have implications in the variations of specie's distribution range; and (5) verified that microendemism significantly occurred in a set of well-sampled species from diverse taxonomic groups composing this fauna. As our dataset also comprised species non-endemic from New Caledonia, we compared the results with the objective of exploring how much these distributional patterns result from local evolution.

Material and Methods

Study site

New Caledonia is an oceanic archipelago in the Pacific Ocean located between 18° - 23° S and 163° - 169° E. It is about 1500 km far from Australia, the nearest continent. It is formed by a main island (Grande Terre), considered the oldest oceanic island (37Ma) [15-16], and several smaller and much more recent islands, making a total land surface of about 18,760 km². The Grande-Terre is a long island oriented northwest-to-southeast with 16,372 km² (350km in length and 50-70 in width). Its landscape is characterized by a mountain range running the length of the island, with five peaks over 1,500 meters and complex series of more or less connected small mountains that rises with very steep slopes.

The dataset

We based this research on the species studied in *Zoologia Neocaledonica*, an ongoing series of 8 volumes about taxonomy of New Caledonian fauna published by Paris Museum from 1988 to 2014, [31-38] the period with the highest number of publications in systematics of New Caledonia [25]. *Zoologia Neocaledonica* is especially dedicated to the description of species, revision of genera, and to reporting on the natural history of terrestrial and freshwater animals occurring in New Caledonia. It comprised 105 chapters, which represented 25% of the publications about this subject in the same period (Fig. 1).

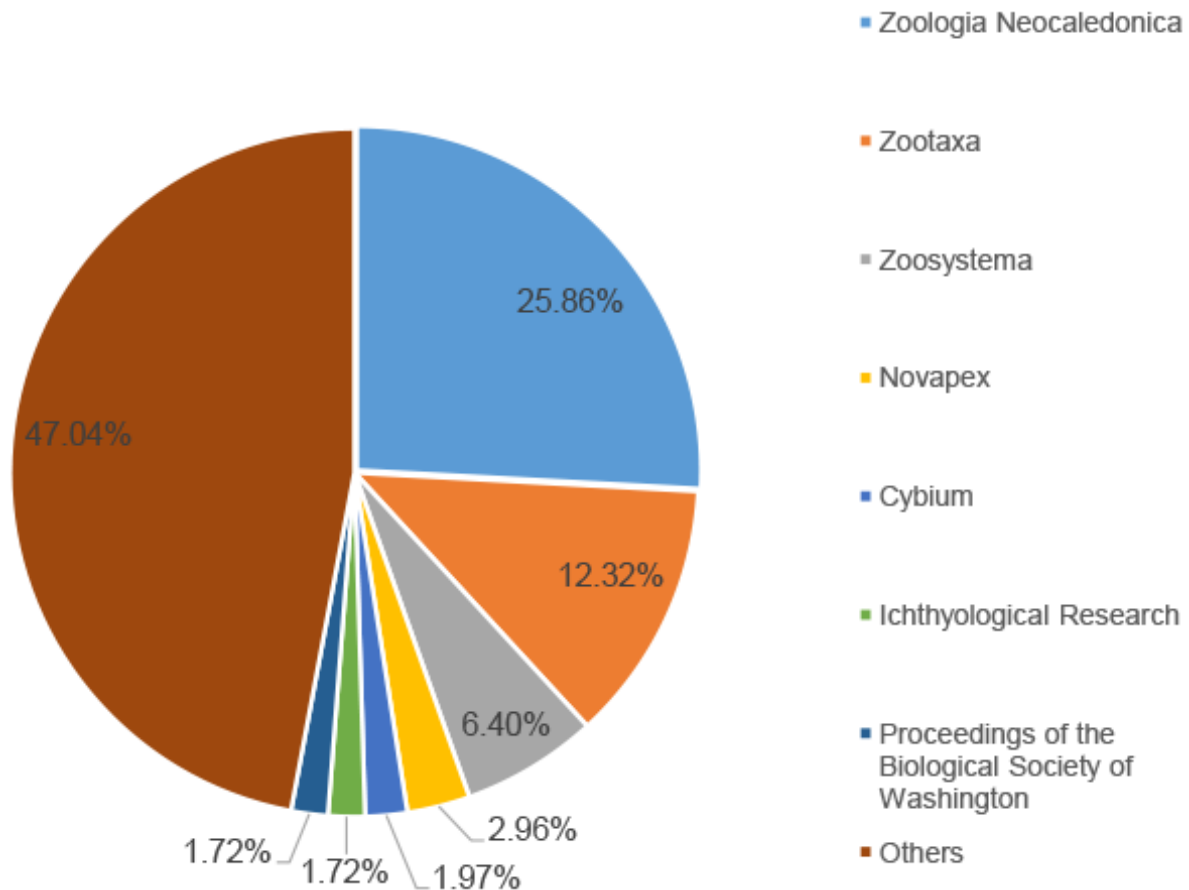


Figure 1. Number of papers on taxonomy, systematics and natural history of New Caledonia's fauna published between 1988 and 2014 in *Zoologia Neocaledonica* and in all other journals.

We built a database with 9818 entries, in which we recorded all information available about the taxonomy (Order, Family, Genus, Species and changes in names and classification along time), occurrence (geographical coordinates, locality, altitude, type of ecosystem, soil, other environmental characteristics) and to time and collectors (sampling dates, name of each collector) to each specimen. This dataset was then completed with an exhaustive search with the name of the species (using all names and combinations when there were taxonomic changes) Web of Science, Zoological Records, Google Scholar using the following Query terms: Topic: 'new species' AND Topic: 'new caledonia' OR Topic: (new genus) AND Publication Name: (new caledonia) NOT Topic: 'plant*' NOT Title: 'bryophyte' NOT Topic: 'moss' NOT Title: 'fungi' NOT Topic: 'bacteria' NOT Publication Name: 'Memoires du Museum National d'Histoire Naturelle' NOT Topic: 'tree*' NOT Title: 'annonaceae' NOT Title: 'lagoons' NOT Title: deep water NOT Title:

marine NOT Publication Name: 'Systematic Botany' NOT Publication Name: 'New bryophyte' Timespan: 1988-2014. This was complemented with a search in Google Scholar and Google using the name of the species and New Caledonia.

When the information about sampling effort was absent we assumed the existence of one collector, and one date for each sample. For specimens collected with Malaise traps or other long-staying methods of capture we assigned only one date, independently of the number of days the trap was active.

Estimating distribution range, sampling effort and accessing conservation status

The distribution range of each species was calculated using the Convex Hull using ArcGis 10.2. Convex Hull calculates the minimum convex polygon encompassing all records available for a species. It was used for all species with three records in different points or more. For species with only one point of occurrence we assigned a value of 1/3 of the smallest area estimated with Convex Hull. For those with two points, the area inferred was 1/3 of the smallest convex hull, multiplied by the inverse of the distance between the two points. This allowed considering the distance between the points in the estimate of area.

For 130 species that had at least 15 distinct records of occurrence, we also estimated the area using MaxEnt 3.3.3 [39], using a polygon of the New Caledonia archipelago as a mask. Climate data were obtained in WORLDCLIM Version 1.4 database (<http://www.worldclim.org>; [40]), on 30-arcsec resolutions. The analyses were made with 19 Bioclim variables plus altitude. A comparison of the area estimated with the two methods showed that the areas estimated with MaxEnt were much smaller ($t=16.51$, $df=131.58$, $p\text{-value} < 2.2e-16$). For this reason, and also considering that minimum convex polygon is the method using for IUCN for defining the Area of Occurrence AOO, or the extent of occurrence EOO, we based our analysis on the data from Convex Hull [41]

Six variables were examined in order to assess their implications in the estimates of distribution range. The three first ones reported on the sampling effort really employed for the sampling of each species: the number of dates the species was sampled; the number of collectors that sampled the species; and the number of specimens by species. The three other represented inferences of the possibility of being collected: the number of dates the collectors that collected the species were in the field; the number of points

sampled by the species' collectors; the mean area of the polygons sampled by the species collectors.

Threat status was accessed in IUCN redlist searched at <http://www.iucnredlist.org> in December 27th 2016 [42].

Results

a) *Characterization of the dataset*

Our dataset was composed by 1149 species, belonging to 352 genera, 91 families, and 20 orders (11 of insects and 9 of very far related organisms such as Squamata, Araneae, and Mollusca). Forty four percent of the genera and 59% of the species were new. For the species, 78% of the total and 90% of the newly described were only known from *Zoologia Neocaledonica* without any other mention in the literature. Almost the totality (98%) of the new species was only known from New Caledonia. This sampling involved 358 collectors, 41289 specimens, and 1803 different sampling points (Table 1). The distribution range of the species accessed varied from a single point to 11,500 km². Despite of differences in total numbers, the species with small ranges are the most frequent in the dataset (Fig. 2).

Table 1. Characterization of the dataset.

Number of genera	352	
Number of new genera	154	44%
Total number of species	1149	
Number of new species	674	59%
Number of species cited only in <i>Zoologia Neocaledonica</i>	893	78% ^a
Number of species also cited in another publication	257	22% ^a
Number of new species cited only in <i>Zoologia Neocaledonica</i>	604	90% ^b
Number of species endemic to New Caledonia	982	86% ^a
Number of species also found elsewhere – Non Endemic	167	14% ^a
Number of new species endemic to New Caledonia	660	98% ^b
Number of specimens	41289	
Number of points	1803	
Number of collectors	358	

^a – values based on the total number of species; ^b values based on the number of new species.

b) Main trends of species endemic and non-endemic to New Caledonia

982 (86%) species were known only from the New Caledonian archipelago, so characterized as regionally endemic, whereas 167 (14%) were also recorded elsewhere. In average, the distribution area was significantly lower (less than half) for species endemic to New Caledonia, but the sampling effort was quite similar for the two sets of species (Table 2). It shows that differences in area were not related to differential sampling effort. A point common to both sets of species is that the median was consistently much lower than the mean, indicating that distribution area and sampling effort are highly skewed to the lowest values. In other words, although the range is enormous, for the great majority of species, distribution area and sampling effort were very low.

c) Relationship between distribution range and sampling effort

The main patterns of relationship between area and sampling effort were very similar for species endemic and non-endemic from New Caledonia. In all cases, the *r-values* of the correlation between the area and sampling effort were low. In spite of this, a clear separation of the two sets of variables of sampling effort was observed. On the one hand were those describing the way species were sampled (number of collectors by species and number of dates each species was collected), which were significantly correlated with area. The number of specimens by species was an exception. On the other hand were the variables associated with the possibility of being collected, for which we did not detect any correlation with area (Table 3).

d) Choosing a variable to characterize the sampling effort in the dataset

The two variables with significant correlations with distribution range (number of dates of collection and number of collectors) were only slightly correlated when considering all species together ($r=0.0576$, $p=0.05$), ($r=0.0312$, $p=0.328$ for endemic) and ($r=0.1314$, $p=0.090$ for non-endemic). This confirms, as expected, their independence. Nevertheless, the frequency of species in different classes of sampling effort was highly correlated ($r=0.964$, $r=0.897$, $r=0.966$, for endemic, non endemic and all species together, respectively, and $p < 0.00001$ in all cases). This shows that, no matter the variable considered, there is an extremely high frequency of species poorly sampled and then a marked decrease in frequency in the subsequent classes (Fig. 3).

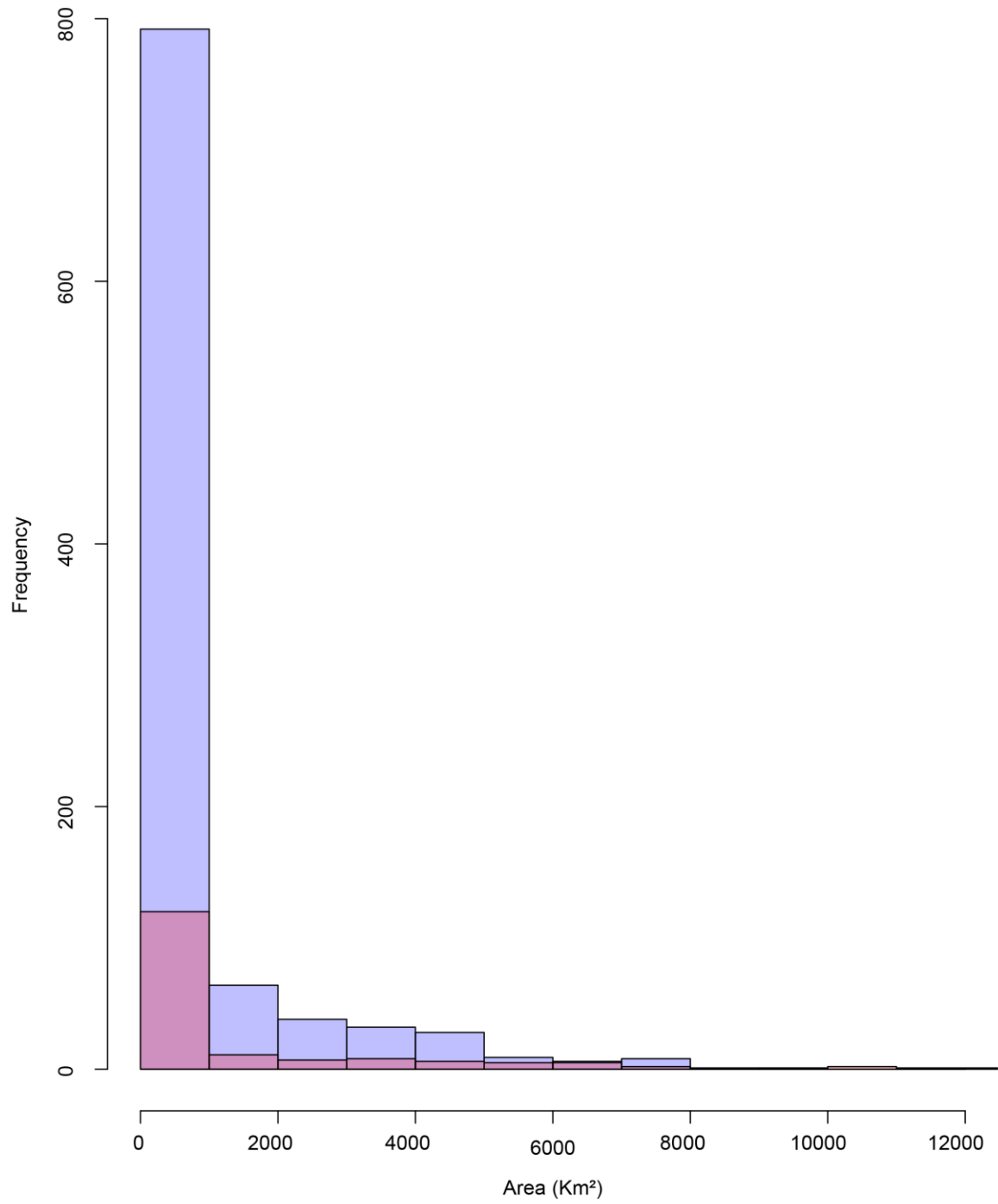


Figure 2. Distribution range and frequency of endemic (violet) and non-endemic (light pink) species.

Table 2. Area of distribution and values of different variables of sampling effort for species endemic from New Caledonia and species also recorded in other places. ^aThe mean is calculated for each species; ^b Values calculated to all points in the dataset.

	Endemic Mean ±SE	Median	Non-Endemic Mean ±SE	Median	Test T	All species Mean ±SE	Median
Area (Km ²)	693 ±46	0.349	1338 ±185	0.830	t = -3.3694 p < 0.0001	820 ±50	0.396
Number of collectors by species	4.645 ±0.29	2	5.281 ±0.94	2	t = -0.6463 p=0.518	4.739 ±0.28	2
Number of dates each species was collected	6.7 ±0.4	3	6.7 ±0.7	3	t = 0.1068 p= 0.9	7.7 ±0.4	4
Number of specimens by species	37.5 ±5.5	7	26.39 ±4.46	7	t= 1.5771 p=0.1152	35.93 ± 4.74	7
Number of dates the species' collectors were in the field	105 ±4	44	89 ±9	32	t=1.5851 p=0.1143	103 ±3.8	27
Number of points sampled by species' collectors	62.8 ±2.52	31	56.3 ±5.23	31	t = 1.1175 p= 0.264	61.9 ±2.28	31
Mean of area prospected by species' collectors (Km ²)	3,853 ±120	3	4,595 ±382	3,594	t = -1.8492 p= 0.0659	3,961 ±117	3

Table 3. Results of Pearson correlation between area and different variables expressing sampling effort. Significant correlations are indicated in bold.

	Endemic	Non-endemic	Total
<i>Variables derived from the information of collection of each species</i>			
Number of collectors	r= 0.1707 p≤ 0.0001	r= 0.13725 p= 0.077	r= 0.16250 p≤ 0.0001
Number of days of collections	r= 0.21071 p≤ 0.0001	r= 0.26089 p= 0.0007	r= 0.21562 p≤ 0.0001
Number of specimen by species	r=0.0172 p=0.591	r=0.0776 p=0.319	r= 0.020 p= 0.495
<i>Variables inferring to the possibility of being collected</i>			
Number of dates the species' collectors were in the field	r=0.0045 p=0.885	r=0.4031 p=0.648	r=0.013 p=0.654
Number of points sampled by species' collectors	r= -0.0113 p= 0.7248	r= 0.02209 p= 0.7769	r= -0.0066 p= 0.8231
Mean of area prospected by species' collectors (Km ²)	r= -0.0187 p= 0.5589	r= 0.02437 p= 0.761	r= 0.02085 p= 0.4802

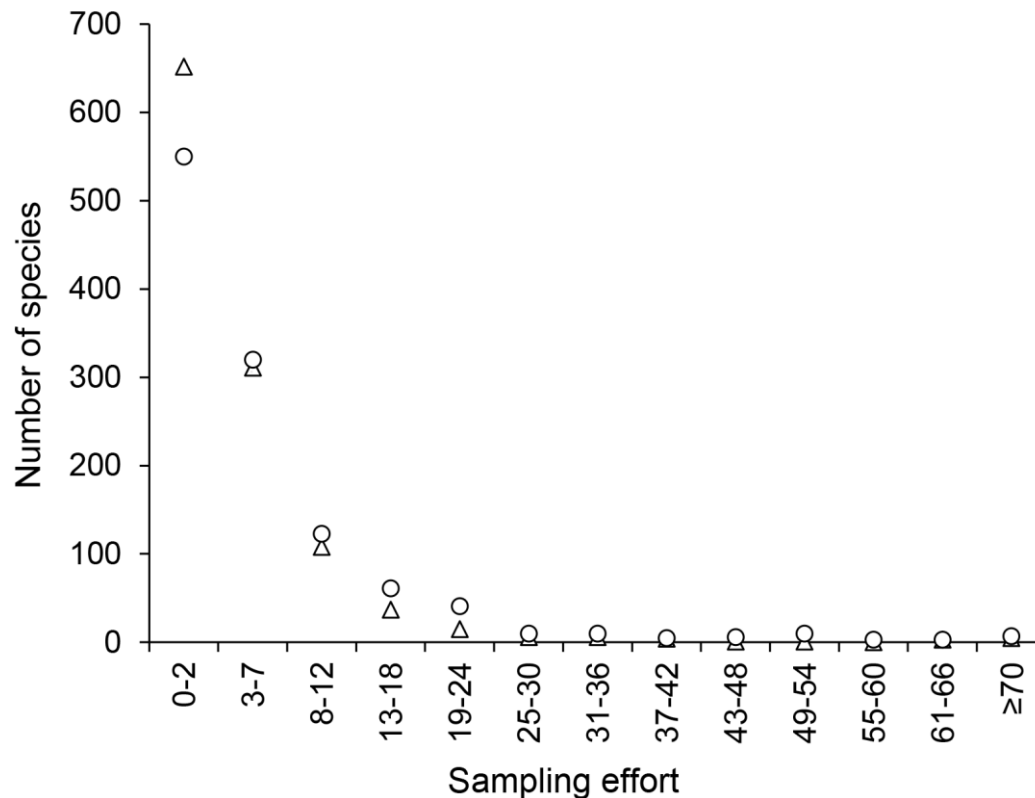


Figure 3. Number of species collected in different classes of sampling effort: triangles= number of collectors; circles = number of dates (n=1149).

Based on it, and considering that the r -values for relationship with area were higher, we used the number of dates as a measure of sampling effort in the analysis hereafter. In addition to this, we used the median number of dates in the entire dataset (=3) as a cutting off point to establish the adequacy of sampling for the inference of distribution range. That is, a species was considered adequately sampled if it was collected in at least 3 different dates (Fig. 4).

The relationship between distribution range and number of sampling dates roughly describes a triangular shape. This shows a high number of species collected with very low sampling effort in all classes of distribution range, a high number of species with small distribution range in all classes of sampling effort, and a markedly reduced number of species between these two extremes (Fig. 4). In fact, it confirms what we showed with the median values in table 2.

e) Distribution range of adequately sampled species

56% of the endemic species and 57% of the non-endemic were sampled a number of dates equal to or higher than the median (i.e. in ≥ 3 dates). The frequency of these adequately sampled species in different classes of distribution range is presented in Fig. 5. This shows that, despite the differences in total numbers, species with small distribution range are far the most frequent in the two datasets. Concerning the species endemic to New Caledonia, 12% have distribution area $\leq 5.2 \text{ km}^2$, and 3.9% have distribution area $\geq 23 \leq 100 \text{ km}^2$. The percentage of non-endemic species with small distribution range in New Caledonia is surprisingly much higher (22% have distribution area $\leq 5.2 \text{ km}^2$, and 8% $\geq 23 \text{ km}^2$ and $\leq 100 \text{ km}^2$).

Another point to be remarked is that although the range of distribution of the set of species examined is very wide (see table 2) there are major gaps in this continuum, with some classes of area without any species (see Fig. 4). So, these cutoffs were established taking in advantage the existence of these gaps. This is how we arrived to the value of $\leq 5.2 \text{ km}^2$ for microendemic species. Following the same procedure, the next group of species has ranges of distribution varying from 23 km^2 to 89 km^2 , which we synthetize as between ≥ 23 and $\leq 100 \text{ km}^2$.

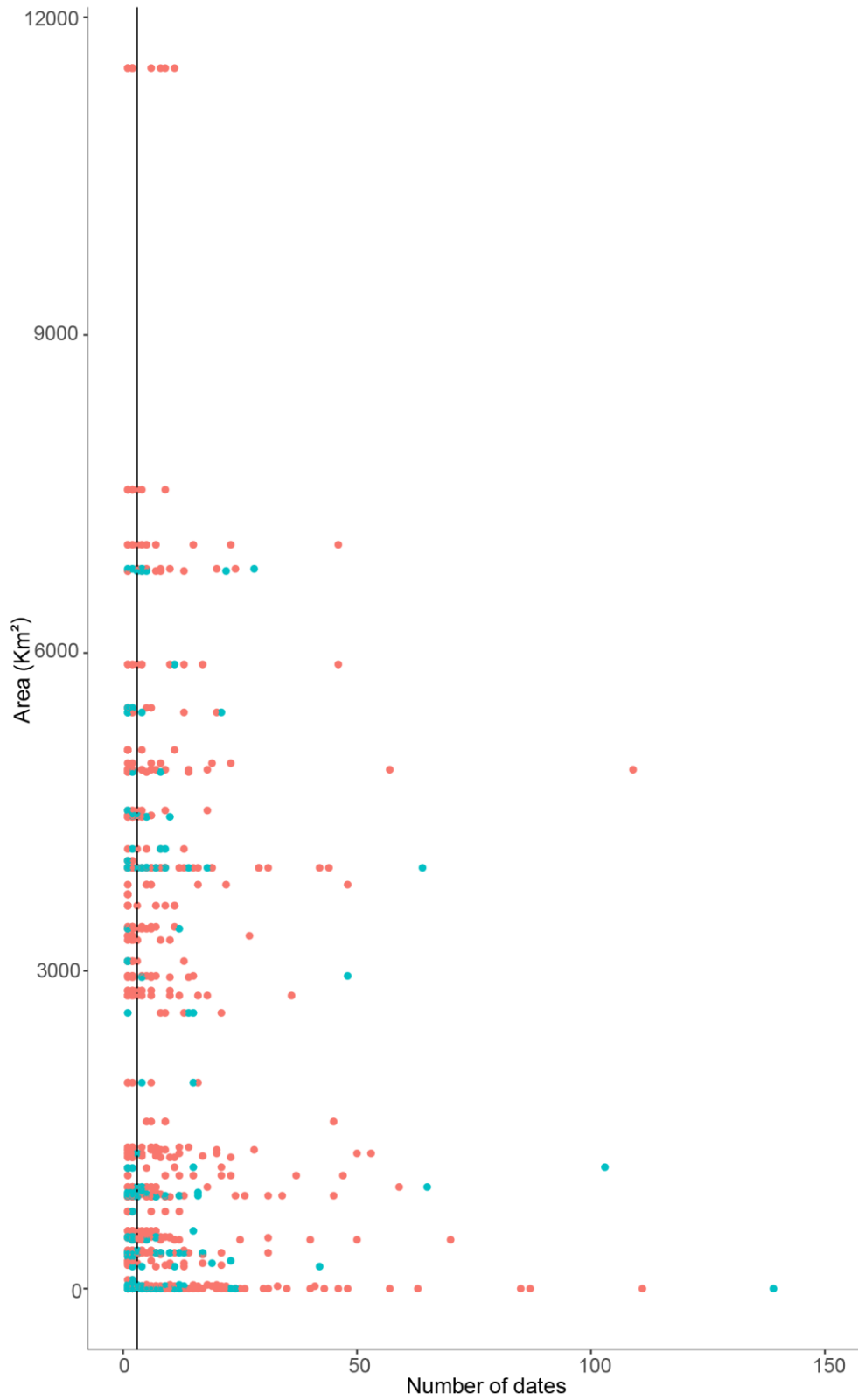


Figure 4. Distribution range in relation with the number of dates the species was sampled for species endemic to New Caledonia (red) and non-endemic (blue). The black line indicates the median of sampling dates (n=3), used to establish a cutting off point between the species assumed correctly sampled and data deficient.

f) *Contribution of organisms from different orders*

From the 20 animal orders composing this dataset, Diptera with 419 species, is by far the most diverse, followed by Coleoptera, Collembola and Squamata. All orders had at least one, but often several, species endemic to New Caledonia, whereas the non-endemic species studied belonged to only 10 orders. Diptera is also the richest in terms of species endemic to New Caledonia, followed by Coleoptera, Squamata and Hemiptera. Among non-endemic Diptera, Collembola and Crustacea have also a high number of species studied, while the others are poorly represented or absent. The rate of species endemic to New Caledonia is very high for all groups, with major departures only for Crustacea (43%) and Collembola (57%).

Despite the marked differences in total numbers, the rate of species sampled 3 dates or more is quite high for several orders for both endemic (51% of the total) and non-endemic species (56% of the total) (Table 4).

Figure 6 shows the frequency of the most abundant endemic species in different classes of distribution range. This shows that the high frequency in the classes of very small distribution range is common to almost all orders (except Myriapoda and Orthoptera). In addition to this, this figure also shows that only Diptera had species with the maximum distribution range estimated in this dataset (11,519km²). Squamata (7020km²) and Coleoptera (7020km²) also had species with large distribution ranges. For species of all other orders the distribution range was never higher than 5500km².

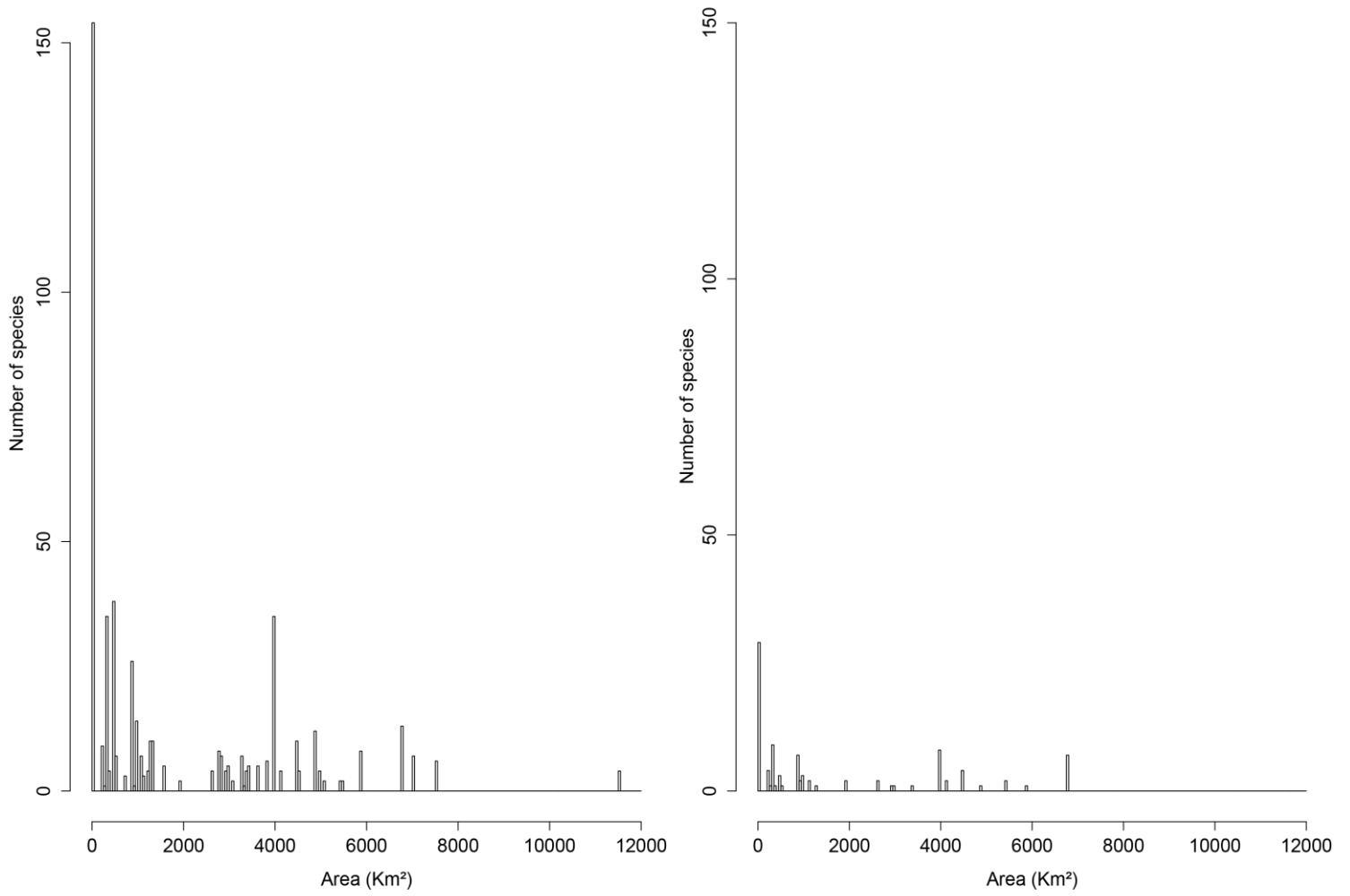


Figure 5. Number of endemic (A) and non-endemic (B) species sampled in at least 3 dates in different classes of distribution range.

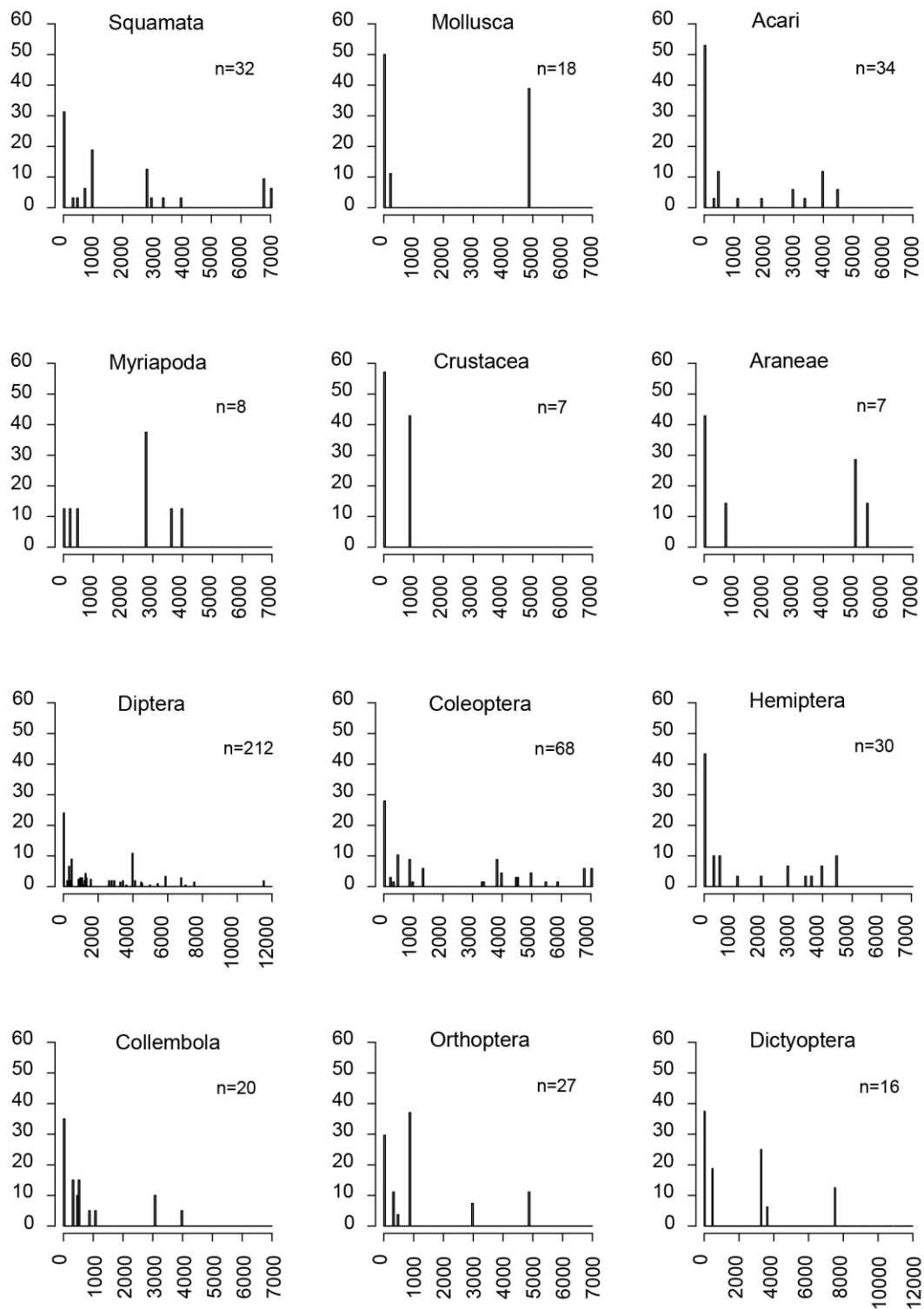


Figure 6. Number (%) of species endemic to New Caledonia in different classes of distribution range according to the order they belong.

Order	Total	Endemic	Non-Endemic	Sampled at least 3 dates		
				Total	Endemic	Non-Endemic
Acari	60	52-86% (5%)	8 (13%) (5%)	38	35-67% (7%)	3-37% (3%)
Araneae	36	36-100% (3%)	0	7	7-19% (1%)	0
Myriapoda	22	18-82% (2%)	4 -18% (2%)	11	8-44% (1%)	3-75% (3%)
Mollusca	27	27-100% (3%)	0	18	18-67% (3%)	0
Crustacea	37	17-43% (2%)	21-56% (12%)	16	7-41% (1%)	9-42% (9%)
Coleoptera	141	132-93% (14%)	9-6% (5%)	72	67-50% (13%)	5-55% (5%)
Collembola	87	57-65% (6%)	29-34% (17%)	36	20-35% (4%)	16-55% (17%)
Dictyoptera	34	34 (3%)	0	16	16-47% (3%)	0
Phasmatodea	14	11-78% (1%)	3-21% (2%)	8	5-45% (1%)	3-100% (3%)
Diptera	419	353-84% (36%)	67-16% (40%)	249	210-50% (42%)	39-58% (41%)
Hemiptera	79	65-82% (7%)	13-18% (8%)	38	29-45% (6%)	9-69% (9%)
Homoptera	14	14-100% (1%)	0	8	8-57% (1%)	0
Lepidoptera	34	34-100% (3%)	0	2	2-6% (0.3%)	0
Orthoptera	45	45-100% (5%)	0	27	27-60% (5%)	0
Neuroptera	1	1-100% (0.1%)	0	1	1-100% (0.1%)	0
Trichoptera	5	5-100% (0.5%)	0	3	3-60% (0.5%)	0
Opiliones	13	13-100% (1%)	0	5	5-38% (1%)	0
Tricladida	1	1 (0.1%)	0	1	1-100% (0.1%)	0

Table 4. Number of species of different taxonomic orders according to distribution range and sampling effort. Percentage values in parenthesis are based on total of the corresponding column.

Teleostei	9	1-11% (0.1%)	8-88% (5%)	5	0	5-62% (5%)
Squamata	71	66-93% (7%)	5-7% (3%)	36	33-50% (6%)	3-60% (3%)
Total	1149	982 (85%)	167 (15%)	597	502 (43%)	95 (57%)

g) *Conservation status in IUCN red list*

The investigation in the IUCN's red list shows that the number of species already assessed is very low (only 76 out of the 1149) and very aggregated in terms of organisms represented (Crustacea, Teleostei and Squamata). In addition, only the species of Squamata have an assessment with detailed information. Those of Crustacea and Teleostei are classified only as LC or DD (Table 5).

Table 5. Number of species in different categories of extinction risks in the IUCN red list according to the adequacy of samples established in this study and the distribution range estimated. We present these estimates for the only three orders with species of the present dataset listed in the IUCN assessment. DD= data deficient; LC= least concern; NT= near threatened; VU= vulnerable; EN= endangered; CR= critically endangered.

			DD	LC	NT	VU	EN	CR	Listed IUCN	Total this study	
Sampled in 1 or 2 dates	Crustaceae	11	-	-	-	-	-	-	11	21	
	Teleostei	1	2	-	-	-	-	-	3	4	
	Squamata	6	1	6	3	4	4	24	36		
Sampled in ≥ 3 dates	≤ 5.2 km ²	Crustaceae	-	-	-	-	-	-	-	1	
		Teleostei	2	-	-	-	-	-	2	2	
		Squamata	2	2	1	-	1	2	8	10	
	≥ 23 ≤ 100 km ²	Crustaceae	1	6	-	-	-	-	7	8	
		Teleostei	-	-	-	-	-	-	-	-	-
		Squamata	-	-	-	-	-	-	-	-	1
	> 100 km ²	Crustaceae	-	4	-	-	-	-	4	4	6
		Teleostei	-	2	-	-	-	-	2	2	3
		Squamata	-	2	3	3	3	4	15	15	24

Discussion

Although microendemicity of the New Caledonian fauna was often reported in studies on the natural history and evolution of different groups of organisms [10, 12, 14, 21, 24-25, 29] the present research is the first specifically designed to quantify its distribution

range, estimate its frequency, and to appreciate the extent the findings can be common to several taxonomic groups. It is also the first time that the distribution range of this fauna is analyzed taking the sampling effort into account.

The dataset we used was certainly incomplete in terms of the species covered. But it had the advantage of including a large number of orders, comprising organisms with different life habits, sizes and natural histories, allowing the verification of the extent the patterns observed are common to the diverse fauna inhabiting this island. In addition, it included a high number of species that were new to science. The main benefit of using this dataset, however, was in that the identifications and definitions of species were done in a taxonomic framework. This means that scientific names and occurrence were based on the work of experts, which is undoubtedly much preferable than using second hand faunistic compilations or natural history collection databases that often include uncertain taxonomic treatments and doubtful identifications.

Variables of sampling effort and their implications in the patterns observed

Among the variables of sampling effort examined, only the number of dates the species was sampled and the number of collectors was correlated with area. This puts in evidence the importance of diversity in the way sampling to increase the probability of finding species in a wider range. This result is in accordance to the topography and distribution of the remnants of different forests in New Caledonia, marked by important discontinuities. The relief formed by a central chain divided into a series of groups of small mountains with steeply slopes certainly constrains fieldworkers' mobility. This makes difficult to enlarge the area prospected without moving from one slope to the other, or from one mountain to the next, which requires long walks or driving for accessing the sampling sites by other slopes. So, often researchers focus on near spots in a same date, and attack by a different flank in another. The fact that some remnants of forest are distributed in several scattered patches also contributes to this limitation, favoring the search in several dates. As expected from previous studies on the collector's effect, accessibility constraints play an important role regarding the estimation of specific richness [43, 44].

The fact that the number of specimens by species was not correlated with area was not a surprise, as the number of specimens is often a choice of the collectors. However, the low number of specimens by species suggests that in general the densities are low,

which is in accordance with our (PG, RP) observations in the field and repeated remarks in the literature [14]. But more studies on population ecology are necessary to confirm the extent this is common to several organisms.

Contrary to the case of variables of sampling effort discussed above, the relationship between variables inferring the possibility of being collected and area brought a surprising result. Intuitively, one could expect that the more the collectors capable to find a species sampled the territory the higher the chances to find the species in its entire range of occurrence. So, our interpretation for the lack of relationship between area and these variables (number of dates, number of points, or area sampled by all collectors that captured the species) is that it confirms that, for many species, the distribution range estimated might be very close to the reality and not a mere sampling artifact.

Another important question in this analysis was the definition of a cut-off point above which the sampling would be considered adequate. We chose to use the median sampling effort. Although arbitrary, this allows for comparisons between different datasets.

Rate, frequency and extent of microendemism

Our results show that the rate of microendemism is indeed extremely high. If we had based our inferences on the entire dataset, 22% of the species endemic to New Caledonia could be considered as very narrow endemic (with distribution range not larger than 5.2km²). This figure is quite similar to the estimates of [30] showing that 21.7% of the plants in New Caledonia were found in at least three different points and in less than 10km².

The consideration of sampling effort allowed for refining these estimates and driving considerations about the nature of the distribution of this fauna. On the one hand, we found that a much smaller set were sampled well enough to allow a sound statement about their distribution range. This brings the rates of confirmed microendemism (i.e., among the well sampled species) to 12%, (116 species with area ≤ 5.2 km²) and another set of 3.9% with area ≥ 23 and ≤ 100 km².

Then, as a main result, our study showed that one species among ten in many different groups of organisms had an extremely small distribution area, not larger than a few kilometers and another one less than 100 km². The microendemism often mentioned or

even assessed in some groups especially well-studied actually represents a general characteristic of the New Caledonian fauna, consistently with the previous assessment concerning the flora [30]. The extreme scale of this microendemism is also remarkable as it probably involves extremely small populations, given both the low densities and the small areas of a few kilometers. In addition, previous case studies on varied groups showed that these species are well-differentiated from a morphological, molecular or behavioral point of view [22-25]. Therefore, microendemism is occurring in cases of normal evolutionary differentiation equivalent to other highly diverse with less microendemic faunas.

What about the non-endemic species?

A surprising result in this study concerns the species non-endemic to New Caledonia. Even if in average they had larger distribution areas (table 2), an important fraction had very restricted ranges (22% in area $\leq 5.2 \text{ km}^2$, and 8% in areas $\geq 23 \text{ km}^2$ and $\leq 100 \text{ km}^2$). Several hypotheses might explain these localized distributions. The most likely could be a) the clumped nature of their niches in the island, or 2) that some of them are occasional species, which is often found in low abundances and with different habitat requirements [45]. Considering the present dataset, some of these species would be classified as common-rare-rare by [1], meaning that, although they are found in places very wide apart, the total distribution is due several, but very localized populations. More data on their distribution ranges could clarify this point. But it highlights the difficulty of estimating the range and, consequently, of defining categories of threats to species with this pattern of distribution (see [41] for a discussion about this topic).

As a perspective for future research, this result should help to interpret the correlates and then the origin of microendemism in local species. If non-endemic species have equally restricted distribution areas, it could mean that distribution is primarily controlled by environmental parameters and their small-scale variation in a patchy landscape.

Conservation status

As already claimed by [30] concerning the flora, our results indicate that the IUCN red list needs an urgent re-assessment concerning the endemic fauna of New Caledonia. Our results give indications of distribution range that will facilitate revising the classification

of species from at least 12 different orders. Considering that most the present pressure and destruction of several habitats in New Caledonia [10, 17-21], that all the species with distribution range $<10 \text{ km}^2$ occur in a single locality, and that frequently population sizes are very small, a great number of these microendemic species are very likely to be Critically Endangered.

In conclusion, our study shows that New Caledonia biota are composed of very narrowly distributed species, one among ten could be said microendemic and found on less than 5.2 km^2 and near 4% on less than 100 km^2 . This result is consistent with previous numerical assessment focusing on the flora. By controlling for sampling effort, we were able to show that these distributional patterns are not a spurious effect of undersampling and rarity in a constraining landscape. This study sets up the basis for a global study of microendemism, which should look further for the environmental parameters that possibly determined its evolution. Such an account should be an invaluable source for further phylogeographic studies or establishing land management policies.

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References

1. Rabinowitz D (1981) Seven forms of rarity. In: Synge H, editor. *The Biological Aspects of Rare Plant Conservation*: John Wiley & Sons Ltd. pp. 205–217.
2. Gaston KJ (1994) *Rarity*. London: Chapman & Hall. 205 p.
3. Richardson JE, Weitz FM, Fay MF, Cronk QCB, Linder HP, et al. (2001) Rapid and recent origin of species richness in the Cape flora of South Africa. *Nature* 412: 181–183.
4. Wilme L, Goodman SM, Ganzhorn JU. (2006) Biogeographic evolution of Madagascar's microendemic biota. *Science* 312: 1063–1065.
5. Vences M, Wollenberg KC, Vieites DR, Lees DC (2009) Madagascar as a model region of species diversification. *Trends in Ecology & Evolution* 24: 456–465.
6. Peterson AT, Watson DM (1998) Problems with areal definitions of endemism: the effects of spatial scaling. *Diversity and Distributions* 4, 189–194.
7. Mace GM, Masundire H, Baillie JEM (2005) *Millennium Ecosystem Assessment: current states and trends Biodiversity*. Washington, DC. 77–121 p.
8. Barnosky AD, Matzke N, Tomiya S, Wogan GOU, Swartz B, et al. (2011) Has the Earth's sixth mass extinction already arrived? *Nature* 471: 51–57.
9. Mouillot D, Bellwood DR, Baraloto C, Chave J, Galzin R, et al. (2013) Rare species support vulnerable functions in highdiversity ecosystems. *Plos Biology* 11(5): e1001569.
10. Pellens R, Ahrends A, Hollingsworth PM, Grandcolas P (2016) Assessing hotspots of evolutionary history with data from multiple phylogenies: An analysis of endemic clades from New Caledonia. In: Pellens R, Grandcolas P, editors. *Biodiversity Conservation and Phylogenetic Systematics: Preserving Our Evolutionary Heritage in an Extinction Crisis* pp. 237–262.
11. Kier G, Kreft H, Lee TM, Jetz W, Ibisch PL, et al. (2009) A global assessment of endemism and species richness across island and mainland regions. *Proceedings of the National Academy of Science USA* 106: 9322–9327.
12. Chazeau J (1993) Research on New Caledonian terrestrial fauna: achievements and prospects. *Biodiversity Letters* 1: 123–129.
13. Morat P, Jaffré T, Veillon JM (1999) Menaces sur les taxons rares et endémiques de la Nouvelle-Calédonie. *Bulletin de la Société Botanique du Centre-Ouest (SBCO)*, 19: 129–144.

14. Grandcolas P, Murienne J, Robillard T, Desutter-Grandcolas L, Jourdan H, Guilbert E, Deharveng L (2008) New Caledonia: a very old Darwinian island? *Philosophical Transactions of the Royal Society of London, B* 363: 3309–3317.
15. Grandcolas P (2016) Ten false ideas about New Caledonia biogeography. *Cladistics*, in press. doi:10.1111/cla.12176
16. Nattier R, Pellens R, Robillard T, Jourdan H, Legendre F, Caesar M, Nel A, Grandcolas P (2016) Old Clades on Oceanic Islands: Updating the Dating of New Caledonia Biodiversity, *Scientific Reports*. (accepted with modifications).
17. Bouchet P, Jaffré T, Veillon JM (1995) Plant extinction in New Caledonia: protection of sclerophyll forest urgently needed. *Biodiversity and Conservation* 4: 415–428.
18. Myers N, Mittermeier RA, Mittermeier CG, Fonseca GAB, Kent J (2000) Biodiversity hotspots for conservation priorities. *Nature* 403: 853–858.
19. Beauvais ML, Coléno A, Jourdan H, editors (2006) *Les espèces envahissantes dans l'archipel néocalédonien. Un risque environnemental et économique majeur*. Paris: IRD editions. 259 p. + CD.
20. Pascal M, Richer de Forges B, Le Guyader H, Simberloff D (2008) Mining and other threats to the New Caledonia biodiversity hotspot. *Conservation Biology* 22: 498–499.
21. Pellens R, Grandcolas P (2010) Conservation and management of the biodiversity in a hotspot characterized by short-range endemism and rarity: the challenge of New Caledonia. In: Rescigno V, Maletta S, editors. *Biodiversity Hotspots*. New York: Nova Publishers. pp. 139–151.
22. Murienne J, Grandcolas P, Piulachs MD, Bellés X, D'Haese C, Legendre F, Pellens R, Guilbert E (2005) Evolution on a shaky piece of Gondwana: is local endemism recent in New Caledonia? *Cladistics* 21: 2–7.
23. Murienne J, Pellens R, Budinoff RB, Wheeler WC, Grandcolas P (2008) Phylogenetic analysis of the cockroach *Lauraesilpha* endemic to New Caledonia. Testing competing hypotheses for the diversification of the biota. *Cladistics* 24: 802–812.
24. Nattier R, Grandcolas P, Elias M, Desutter-Grandcolas L, Jourdan H, et al. (2012) Secondary sympatry caused by range expansion informs on the dynamics of microendemism in a biodiversity hotspot. *PLoS ONE* 7(11): e48047.
25. Nattier R, Grandcolas P, Pellens R, Jourdan H, Couloux A, et al. (2013) Climate and soil type together explain the distribution of microendemic species in a biodiversity

- hotspot. PLoS ONE 8(12): e80811.
26. Espeland M, Johanson KA (2010) The effect of environmental diversification on species diversification in New Caledonian caddisflies (Insecta: Trichoptera: Hydropsychidae). *Journal of Biogeography* 37: 879–890.
 27. Sharma P, Giribet G (2009) A relict in New Caledonia: phylogenetic relationships of the family Troglonidae (Opiliones: Cyphophthalmi). *Cladistics* 25: 279–294.
 28. Haase M, Bouchet P (1998) Radiation of crenobiontic gastropods on an ancient continental island: the *Hemistomia*-clade in New Caledonia (Gastropoda: Hydrobiidae). *Hydrobiologia* 367: 43–129.
 29. Bauer AM, Jackman T, Sadler RA, Whitaker AH (2006) A Revision of the *Bavayia validiclavis* group (Squamata: Gekkota: Diplodactylidae), a clade of New Caledonian Geckos Exhibiting Microendemism. *Proceedings of the California Academy of Sciences* 57: 503–547.
 30. Wulff AS, Hollingsworth PM, Ahrends A, Jaffré T, Veillon JM, L'Huillier L, Fogliani B (2013) Conservation Priorities in a Biodiversity Hotspot: Analysis of Narrow Endemic Plant Species in New Caledonia. *PLoS ONE* 8(9): e73371.
 31. Najt J, Grandcolas P, editors (2002) *Zoologia Neocaledonica* 5. Systématique et endémisme en Nouvelle-Calédonie. *Mémoires du Muséum National d'Histoire Naturelle*, 187: 1–283.
 32. Guilbert E, Robillard T, Jourdan H, Grandcolas P, editors (2014) *Zoologia neocaledonica*: 8. Biodiversity studies in New Caledonia. *Mémoires du Muséum National d'Histoire Naturelle*, 206: 1–315.
 33. Chazeau J, Tillier S, editors (1991) *Zoologia Neocaledonica* 2. *Mémoires du Muséum National d'Histoire Naturelle*, 149: 1–358.
 34. Grandcolas P, editor (2008) *Zoologia Neocaledonica* 6: Biodiversity studies in New Caledonia. *Mémoires du Muséum National d'Histoire Naturelle*, 197: 1–326.
 35. Grandcolas P, editor (2009) *Zoologia Neocaledonica* 7: Biodiversity studies in New Caledonia. *Mémoires du Muséum National d'Histoire Naturelle*, 198: 1–440.
 36. Najt J, Matile L, editors (1997) *Zoologia Neocaledonica* 4. *Mémoires du Muséum National d'Histoire Naturelle*, 171: 1–399.
 37. Tillier S, editor (1988) *Zoologia Neocaledonica* 1. *Mémoires du Muséum national d'Histoire naturelle*, 142: 1–158.
 38. Tillier S, editor (1993) *Zoologia Neocaledonica* 3. *Mémoires du Muséum National*

d'Histoire Naturelle, 157: 1–218.

39. Phillips S, Dudík M, Schapire RE (2004) A Maximum Entropy approach to species distribution modeling In Proceedings of the twenty-first international conference on Machine learning, ACM, Banff, Alberta, Canada: 655–662.
40. Hijmans RJ, Cameron SE, Parra JL, Jones PG, Jarvis A (2005) Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology* 25: 1965–1978.
41. Hartley S, Kunin WE (2003) Scale dependency of rarity, extinction risk, and conservation priority. *Conservation Biology* 17: 1559–1570.
42. IUCN (2012) IUCN Red List Categories and Criteria: Version 3.1. Second edition. Gland, Switzerland and Cambridge, UK: IUCN.
43. Crisp MD, Laffan HP, Linder HP, Monro A (2001) Endemism in the Australian flora, *Journal of Biogeography* 28: 183–198.
44. Schulman L, Ruokolainen K, Junikka L, Saaksjarvi IE, Salo M, et al. (2007) Amazonian biodiversity and protected areas: Do they meet? *Biodiversity and Conservation* 16: 3011–3051.
45. Magurran AE, Henderson PA (2003) Explaining the excess of rare species in natural species abundance distributions. *Nature* 422: 714–716.

**D) Chapitre IV -
Correlates of microendemic specie's distribution in New
Caledonia**

Correlates of microendemic specie's distribution in New Caledonia

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Abstract

New Caledonia is a biodiversity hotspot characterized by important species richness, high rates of endemism and strong risk of extinction. However, this archipelago is especially remarkable by the local microendemism, with high number of species of the fauna and the flora with extremely small distribution ranges. In a previous study we characterized the range, the frequency and how microendemism is distributed in different taxonomic groups. We showed that 116 adequately sampled species endemic to New Caledonia have very narrow distribution ranges, and that this trend is pervasive to the majority of the faunal groups. In this paper we aim to verify the correlates of this pattern of distribution. For this we considered the richness of non-microendemic species, two variables related to sampling effort (number of collectors and road density, which informs about the facility of accessing the study sites) and 12 environmental variables. The results indicate a major importance of the richness of other species and sampling effort in bounding the distribution of microendemic species. Landuse and soils were the most discriminant environmental variables, as microendemic species are mainly found in forests and dominate in areas with ultramafic soils, but they are not predictors of the distribution of microendemism. The most predictive feature were the precipitation of the wettest and driest quarter, and the slope. It suggests that despite of the small size of New Caledonia, and the buffer oceanic effect, local distribution of humidity strongly shaped by E/W aspect, along with slope, play a central role in shaping biodiversity distribution.

Introduction

The biodiversity of New Caledonia has three distinctive characteristics of the hotspots, namely species richness, endemism and threat (Myers et al., 2000). But the tree hides the forest: the kind of endemism commonly put forward for hotspots is regional endemism (Kier et al., 2009), therefore with species that are located only in the island and nowhere else. Actually, New Caledonia is also especially remarkable, like other famous place such as the Cape flora or Madagascar's biota, by the very high local micro-endemism, therefore with species that are occur in very small areas inside the territory (Grandcolas et al., 2008; Richardson et al., 2001; Vences et al., 2009).

This pattern was already described as very common to the flora of New Caledonia with species apparently rare because they are limited to very narrow areas of a few square kilometers (e.g., Wulff et al., 2013). Traditionally, local endemism was related to the notion of refuges or relicts where species were supposed to differentiate or to diversify (centers of endemism or o-diversity) or stay during inhospitable times, such as relicts in refuges (Grandcolas et al., 2014; Grandcolas, 2016). However, detailed case studies have shown its relation with recent speciation, resulting from the splitting of ancestral populations into adjacent sister-species within the very dissected landscape (Murienne et al., 2005, 2008; Nattier et al., 2012, 2013).

We have recently shown that this pattern is pervasive in many different taxonomic groups of animals (Caesar et al., 2017). This appeared as a real and well-characterized pattern, a true kind of rarity characterized with adequate sampling effort (Rabinowitz, 1981). We now question the environmental correlates of this pattern of microendemism, aiming to understand its origin, and to provide elements for inferring which other places in New Caledonia are likely to harbor exceptionally high rates of microendemic species. From the point of view of the environment, it was considered as related to favorable microclimates (high rainfall) under possible control by orography. This conception was mainly mentioned in plants (Pintaud et al., 2001; Wulff et al., 2013; Pouteau et al., 2015), and it was mainly studied according to species or environmental factors selected a priori. The present study is aimed at analyzing this question in animals with a wider scope by considering all micro-endemic species known from our large data set and a diverse series of environmental parameters. We expect to characterize the main factors related to the distribution of microendemic species, to determine if micro-endemic species from

different groups actually cluster in the same areas of the island and which parameters or combination of parameters actually explain their distribution.

Material and Methods

Study site

New Caledonia is an oceanic archipelago in the Pacific Ocean located between 18° - 23° S and 163° - 169° E, located at about 1500 km far from Australia, the nearest continent. It is formed by a main island (Grande Terre), considered the oldest oceanic island (37Ma), and several smaller and much recent islands, making a total land surface of about 18,760 km². The Grande Terre is a long island oriented northwest-to-southeast with 16,372 km² (350km in length and 50-70 in width). Its landscape is characterized by two main mountain ranges, and some discrete mountains, running the length of the island, with five peaks over 1,500 meters.

The climate is tropical, with important spatial, seasonal and interannual variations in temperature and precipitation. The mean annual temperature is 22.4°C, with an average variation between 19.2°C in July and August and 25.9°C in February. The total annual rainfall varies markedly between places. In the Grande Terre it varies from more than 4000mm in the east coast exposed to the humid trade winds, to less than 700mm in the dry leeward west, which leads to important variations in climate stability and climate thresholds. In the smaller islands, as the relief is much less variable, so is the climate. T annual rainfall is around 1700 mm, and temperatures. Three main types of substrate are distributed over New Caledonia: ultramafic, volcano-sedimentary and calcareous soils. The natural vegetation cover results from the interplay of altitudinal gradients, aspect, and soils.

Dataset

We based this research on the species studied in *Zoologia Neocaledonica*, an ongoing series of 8 volumes about taxonomy of New Caledonian fauna published by Paris Museum from 1988 to 2014. *Zoologia Neocaledonica* is especially dedicated to the description of species, revision of genera, and to reporting on the natural history of terrestrial and freshwater animals occurring in New Caledonia.

Our initial database had 9818 entries. To each specimen we recorded all information available about the taxonomy (Order, Family, Genus, Species and changes in names and

classification along time), occurrence (geographical coordinates, locality, altitude, type of ecosystem, soil, other environmental characteristics), dates of sampling and name of collector (s). This information was completed with a search in Web of Science and in Google for each species. It comprised 982 (86%) species endemic from New Caledonia and 167 (14%) species also found in another spots.

For the present study we kept only species that satisfied the following conditions: 1) being endemic from New Caledonia's archipelago; 2) having been sampled at least 3 dates (the minimum sampling effort to allow for stating about specie's distribution; and 3) the information for geolocalisation allowed for a spatial accuracy of $\pm 500\text{m}$ or less (see Caesar et al., 2017 for details about method and characterization of minimum sampling effort). This restrained this sample to 502 species, with 116 (23%) with distribution area smaller than 10km^2 , hereafter called microendemic, and 386 species (77%) with larger distribution range. For convenience we will refer to this last set as "non-microendemic species".

Mapping specie's distribution range

The number of occurrence data for non-microendemic species varied from 1 to 1683 and this required adjusting the method for calculating their distribution range. For species with occurrence data ≤ 2 we assigned their presence directly to the grid cell that included their coordinates. For those with occurrence data $= 3$ and ≤ 14 we used Convex Hull performed in ArcGis desktop 10.2. As the convex hull was constrained to the land areas, when a species occurred in several islands, a convex hull was built for each. In case of species with only one or two points in an island, we assigned their occurrence to the corresponding cell.

For species with occurrence data ≥ 15 we used MaxEnt 3.3.3.k, with settings and logistic output (Phillips et al 2004; 2006). The environmental variables were the 18 Bioclim plus altitude, obtained in WorldClim.org. MaxEnt's predictions are presented in a continuous cumulative probability field. We transformed this probability field to a binary map of "suitable" versus "unsuitable", using non-fixed 10th percentile training as threshold, as recommended by Liu et al., (2005).

Data analysis

Analyses were based on a grid containing 1066 cells of 25 km² (5x5 km) covering the entire land surface of New Caledonia (Fig. 1 A, B). The number of microendemic species was calculated by counting the species occurrences in each grid cells. For the other species, we summed the polygons that were overlaid on each cell and added the species directly assigned to a single polygon. Fifteen variables were used to access the factors related to the distribution of microendemic species. These variables were selected to give an estimate of sampling effort, environmental diversity, environmental stability, and environmental threshold (Table 1).

For estimating the area prospected by collectors and counting the number of collectors to each grid cell we employed exactly the same procedure employed to species.

Table 1. The 15 variables used in this study with their corresponding description, the type of values extracted to the grid-cells, the unit, and the source of data.

Acronym	Variable Description	Values Extracted to the grid	Unit	Source
Species Richness	Species Richness	Sum	-	Zool. Neocaledonia
<i>Sampling Effort, Infrastructure</i>				
Nb_ Collectors	Number of Collectors	Sum	-	Zool. Neocaledonica
RoadDensity	Road Density ¹	Mean	m/km ²	DITTT
<i>Environmental Diversity</i>				
Altitude	Altitude ²	Mean	m	DITTT
Slope	Slope ²	Maximum	%	DITTT
Soil	Main Soil Categories	Majority	-	DITTT
LandUse	Land Use	Majority	-	DITTT
<i>Environmental Stability</i>				
Bio1	Mean annual temperature	Mean	°C	WorldClim 1.4
Bio3	Isothermality	Mean	-	WorldClim 1.4
Bio15	Precipitation seasonality	Mean	-	WorldClim 1.4
<i>Environmental Threshold</i>				
Bio12	Annual rainfall	Mean	mm	WorldClim 1.4
Bio16	Precipitation of the wettest quarter	Mean	mm	WorldClim 1.4
Bio17	Precipitation of the driest quarter	Mean	mm	WorldClim 1.4
Bio6	Minimum temperature of the coldest month	Mean	°C	WorldClim 1.4
Bio5	Maximum temperature of the warmest month	Mean	°C	WorldClim 1.4

DITTT= Direction des Infrastructure, de la Topographie et des Transports Terrestres of New Caledonia. ¹ rasterized from the road network shapefile, including all road types ; ² rasterized from the altitudinal contour shapefile 250m.

Climate variables interpolated at 30 arc-seconds were obtained in WorldClim 1.4 (Hijmans et al., 2005). We preferred to use this instead of local climate dataset because it also provides data on seasonality and on different ways of interpreting environmental

thresholds, which are very important for understanding limits of species distribution (Zimmerman et al., 2009). The altitude, road density, soil and land use data were rasterized from fine resolution shape files provided by DITTT. Soils were grouped in three main classes: Ultramafic, Volcano-Sedimentary and Calcareous. Landuse was aggregated in 7 general classes: E: Fresh and salt water including, rivers, creeks, lakes, wetlands marshes and swamps; F: Forests, meaning all types of forests; M: Mangrove, salt marsh, beaches, dunes, sand; S: Savannas, including savannas and maquis; H: Transformed areas, including any kind of continuous or discontinuous urban surfaces, land occupied by agriculture and pastures, areas transformed by opencast mining; A: Sclerophyllous vegetation; V: Sparsely vegetated areas.

We used Random Uniform Forest (RUF) in as performed in R package <http://cran.r-project.org/package=randomUniformForest> to assess variable importance in predicting the distribution of microendemic species. This is a machine learning algorithm designed for classification, regression and unsupervised learning. It builds many unpruned and randomized binary decision trees, using random cut-points to grow the tree, and bootstrap and subsampling (Ciss, 2015). RUF is non-parametric and thus can be used on data with a large number of variables of various types. Its application in ecology (e.g. Cuttler et al., 2007) and forest management (e.g. Oliveira et al., 2012) suggests that it can be very powerful for characterizing variable importance, particularly when non-linear trends exist. Here, RUF was employed for assessing global variable importance and variable importance based on interactions. In order to explore how these variables could be assessed in other multiple variables assessment we also used Global Linearized Model, also performed in R (R Core Team, 2014).

Results

A list with the 116 microendemic species considered in this study, the estimated distribution range, and the respective values of the environmental variables in the places they occur is presented in Table 2. These species correspond to 15 taxonomic orders or classes, including a majority of invertebrates, but also some species of Squamata. Their distribution range varies from a single locality (0.043km²) to 5.2 km².

Table 2. The 116 microendemic species considered in this study, with respective values of distribution range, and of 13 environmental variables in the places they were recorded. See table 1 for the definition of variables.

	Species	Distribution range (km ²)	RoadDensity (m/km ²)	Altitude (m)	Slope (%)	Bio1 (°C)	Bio5 (°C)	Bio6 (°C)	Bio12 (mm)	Bio16 (mm)	Bio17 (mm)	Bio3 (°C)	Bio15 (mm)	Soil	LandUse
Coleoptera	<i>Achorius parvioculis</i>	0.043	513	343	15	248	216	204	238	749	213	247	49	VS	F
Orthoptera	<i>Adenopterus amiensis</i>	0.043	581	613	15	235	199	185	226	662	240	232	42	UM	F
Myriapoda	<i>Allopauropus macropygus</i>	0.043	391	969	30	221	185	171	211	591	183	218	44	VS	F
Myriapoda	<i>Allopauropus tillierae</i>	0.043	350	969	30	222	186	170	212	590	182	217	43	UM	F
Dictyoptera	<i>Angustonicus boucheti</i>	0.043	347	462	15	246	208	194	236	817	332	242	35	UM	F,V
Coleoptera	<i>Anomalodermus proclivis</i>	0.043	596	700	20	239	201	187	229	773	313	235	34	UM	F
Diptera	<i>Anomalomyia</i> sp.	0.043	347	462	15	246	208	194	236	817	332	242	35	UM	F
Hemiptera	<i>Anorhinosia anomala</i>	0.043	423	349	10	251	220	207	242	752	212	250	48	VS	F
Diptera	<i>Antyx pallidiventris</i>	0.043	106	544	5	242	205	190	232	528	172	239	40	UM	F
Coleoptera	<i>Aralius dispar</i>	0.043	596	700	20	239	201	187	229	773	313	235	34	UM	F
Collembola	<i>Boudinotia prima</i>	0.043	490	387	15	246	208	194	235	750	310	242	34	UM	F
Coleoptera	<i>Brachida stilifera</i>	0.043	347	462	15	245	208	194	236	817	332	241	35	UM	F
Orthoptera	<i>Bullita fusca</i>	0.043	596	700	20	239	201	187	229	773	313	235	34	UM	F
Orthoptera	<i>Bullita transversa</i>	0.043	691	613	15	235	199	185	226	662	240	232	42	UM	F
Orthoptera	<i>Bullita unicolor</i>	0.043	681	610	15	235	195	182	224	660	236	230	40	UM	F
Dictyoptera	<i>Rothisilpha panie</i>	0.043	347	462	15	246	208	194	236	817	332	242	35	UM	F
Crustacea	<i>Caledonillo bruneum</i>	0.043	679	1075	15	219	180	166	208	801	316	215	34	UM	F
Crustacea	<i>Caledonillo tillierorum</i>	0.043	337	1206	30	215	181	168	205	733	187	212	50	VS	F
Hemiptera	<i>Caledonisia bolanus</i>	0.043	449	436	20	245	206	192	234	629	256	241	34	VS	F
Hemiptera	<i>Caledonisia crypta</i>	0.043	453	577	15	239	202	188	228	709	258	236	42	VS	F
Hemiptera	<i>Caledonisia monsmollis</i>	0.043	350	812	30	232	194	179	222	789	313	229	35	UM	F
Hemiptera	<i>Caledonisia theophane</i>	0.043	648	436	20	245	206	192	234	629	256	241	34	VS	F
Diptera	<i>Scaptodrosophila loxostyla</i>	0.043	425	416	30	243	212	199	234	581	142	242	54	VS	F,E
Orthoptera	<i>Koghiella bouleti</i>	0.043	543	884	5	224	186	172	213	653	225	220	40	VS	F
Phasmatodea	<i>Gigantophasma bicolor</i>	0.043	655	812	30	232	194	179	222	789	313	229	35	UM	F,S
Orthoptera	<i>Caltathra chopardi</i>	0.043	511	818	5	232	193	179	221	849	333	228	36	VS	F
Orthoptera	<i>Caltathra</i> spp.	0.043	456	613	15	234	199	185	225	662	240	232	43	UM	F
Orthoptera	<i>Caltathra areto</i>	0.043	607	612	15	235	199	185	226	630	217	231	42	UM	F
Myriapoda	<i>Hemipauropus melanesicus</i>	0.043	756	57	5	260	223	208	249	550	210	256	34	VS	F
Hemiptera	<i>Cephalidiosus sineoræ</i>	0.043	337	1206	30	215	181	168	205	733	187	212	50	VS	F
Hemiptera	<i>Cephalidiosus thy</i>	0.043	688	773	30	237	199	185	227	755	305	234	34	VS	F
Diptera	<i>Chasmia bozennae</i>	0.043	347	462	15	246	208	194	236	817	332	242	35	UM	F
Homoptera	<i>Chazeauana gahniae</i>	0.043	651	400	10	248	210	196	237	672	270	243	35	UM	F
Diptera	<i>Styringomyia bidentata</i>	0.043	645	583	15	239	203	189	229	666	240	236	42	UM	F
Diptera	<i>Corindia flaviscuta</i>	0.043	844	636	15	237	201	187	227	655	232	234	42	VS	F
Hemiptera	<i>Corinthus plumensis</i>	0.043	512	372	15	250	212	198	239	622	249	246	35	UM	F
Collembola	<i>Pyrtulina dubia</i>	0.043	756	359	10	248	211	196	237	688	288	244	34	UM	F,A
Diptera	<i>Cydistomyia brachypalpus</i>	0.043	225	160	15	258	220	205	248	398	155	254	36	UM	F
Diptera	<i>Cydistomyia massali</i>	0.043	561	524	15	244	207	193	234	687	225	241	42	VS	F

	Species	Distribution range (km ²)	RoadDensity (m/km ²)	Altitude (m)	Slope (%)	Bio1 (°C)	Bio5 (°C)	Bio6 (°C)	Bio12 (mm)	Bio16 (mm)	Bio17 (mm)	Bio3 (°C)	Bio15 (mm)	Soil	LandUse
Coleoptera	Cypha lancea	0.043	197	42	5	257	225	212	248	621	184	257	47	VS	F
Diptera	Cysteoichila cubans	0.043	250	139	10	259	221	207	248	651	262	255	35	VS	F
Diptera	Scaptodrosophila sp. 10	0.087	648	436	20	245	206	192	234	629	256	241	34	VS	F
Diptera	Dasybasis norae	0.087	347	462	15	246	208	194	236	817	332	242	35	UM	F
Hemiptera	Distantiana stylirecta	0.087	540	226	20	256	225	212	247	545	130	254	57	VS	F
Coleoptera	Dracophyllius marginicollis	0.087	998	812	30	232	194	179	222	789	313	229	35	UM	F
Diptera	Ectonura koumac	0.087	250	313	10	253	222	208	244	520	187	252	54	C	F
Diptera	Scaptodrosophila sp. 12	0.087	487	138	30	255	223	210	246	913	239	254	53	UM	F,S
Collembola	Ectonura parolata	0.096	596	700	20	239	201	187	229	773	313	235	34	UM	F
Collembola	Ectonura proxima	0.096	596	700	20	239	201	187	229	773	313	235	34	UM	F
Collembola	Ectonura pulchra	0.107	645	583	15	239	203	189	229	666	240	236	42	UM	F
Collembola	Elytroteinus geophilus	0.110	670	507	10	242	211	198	234	578	138	241	55	C	F
Diptera	Empis nondouensis	0.110	636	118	15	260	222	207	249	638	256	256	35	UM	F
Diptera	Senostoma flavipes	0.110	645	583	15	239	203	189	229	666	240	236	42	VS	F
Araneae	Encyocrypta berlandi	0.141	393	669	20	236	201	188	226	624	191	234	45	VS	F
Diptera	Encyocrypta cagou	0.141	347	462	15	246	208	194	236	817	332	242	35	UM	F
Diptera	Encyocrypta colemani	0.141	596	700	20	239	201	187	229	773	313	235	34	UM	F
Opiliones	Troglosiro brevifossa	0.164	570	296	15	251	214	199	241	693	289	247	34	UM	F
Opiliones	Troglosiro oscitatio	0.164	391	969	30	221	185	171	211	591	183	218	44	UM	F
Opiliones	Troglosiro raveni	0.186	464	545	5	244	206	192	233	498	166	240	41	UM	F
Diptera	Encyocrypta koghi	0.186	596	700	20	239	201	187	229	773	313	235	34	UM	F
Hemiptera	Suvarisia caudafurcata	0.191	612	44	10	258	227	214	249	705	250	257	48	C	F
Trichoptera	Xanthochorema christinae	0.235	225	91	10	258	224	210	248	525	174	256	45	VS	F,E
Diptera	Encyocrypta kritscheri	0.235	525	349	10	249	213	199	239	626	215	246	43	VS	F
Squamata	Phoboscincus bocourti	0.274	347	462	15	246	208	194	236	817	332	242	35	UM	F
Coleoptera	Lomaglossina domina	0.341	464	545	5	244	206	192	233	498	166	240	41	UM	F
Diptera	Parentia webbi	0.341	461	541	10	239	201	193	235	496	163	241	41	UM	F
Crustacea	Paratya typa	0.341	1002	812	30	232	194	179	222	789	313	229	35	UM	F
Homoptera	Ueana desserti	0.341	594	468	20	249	217	204	240	712	211	248	48	VS	F
Diptera	Neoplatyura lyraefera	0.043	425	416	30	243	212	199	234	581	142	242	54	VS	F
Diptera	Toxorhina juvenca	0.043	688	957	20	227	189	174	217	704	267	224	36	UM	F
Squamata	Nannoscincus exos	0.043	525	349	10	249	213	199	239	626	215	246	43	UM	F
Coleoptera	Tremellia aptera	0.047	240	488	20	249	213	198	239	709	258	246	43	VS	F
Coleoptera	Exocelina nehoue	0.048	300	413	20	251	219	205	242	775	200	249	54	VS	F
Hemiptera	Fennahsia cafana	0.065	596	700	20	239	201	187	229	773	313	235	34	UM	F
Hemiptera	Fennahsia matuta	0.065	393	669	20	236	201	188	226	624	191	234	45	VS	F
Hemiptera	Fennahsia perioflata	0.065	543	884	5	224	186	172	213	653	225	220	40	VS	F
Collembola	Folsomides insularis	0.075	561	524	15	244	207	193	234	687	225	241	42	VS	F
Diptera	Caledonileia pusilla	0.087	394	221	15	245	207	193	234	678	285	241	34	C	F,V
Diptera	Geron aaptis	0.087	756	57	5	260	223	208	249	550	210	256	34	C	F
Hemiptera	Glyptodonisia tomyris	0.087	596	700	20	239	201	187	229	773	313	235	34	C	F

	Species	Distribution range (km ²)	RoadDensity (m/km ²)	Altitude (m)	Slope (%)	Bio1 (°C)	Bio5 (°C)	Bio6 (°C)	Bio12 (mm)	Bio16 (mm)	Bio17 (mm)	Bio3 (°C)	Bio15 (mm)	Soil	LandUse
Diptera	Lapita cudo	0.087	425	416	30	243	212	199	234	581	142	242	54	VS	F
Coleoptera	Sternotropa multiplex	0.043	543	884	5	224	186	172	213	653	225	220	40	VS	F
Diptera	Lapita expirata	0.043	431	613	15	235	199	185	226	662	240	232	42	UM	F
Diptera	Leptotarsus glabristylus	0.043	596	700	20	239	201	187	229	773	313	235	34	UM	S,E
Diptera	Lapita laniensis	0.043	449	1092	20	217	178	164	207	363	128	213	34	UM	F
Diptera	Lapita schlingereri	0.341	441	462	15	246	208	194	236	817	332	242	35	UM	F
Diptera	Nervijuncta vicina	0.479	451	900	30	215	181	168	205	733	187	212	50	VS	F
Diptera	Lapita semita	0.479	337	1206	30	215	179	173	207	723	187	213	55	VS	F
Diptera	Leia delobeli	0.482	870	61	5	256	222	208	246	688	242	253	38	VS	F,E
Hemiptera	Nobarnus picarti	0.524	550	313	10	253	222	208	244	520	187	252	54	VS	F
Hemiptera	Notomacer araucariae	0.544	464	545	5	244	206	192	233	498	166	240	41	UM	F
Diptera	Pouebo symmetrica	0.697	775	613	15	235	199	185	226	662	240	232	42	VS	F
Diptera	Lapita boucheti	0.697	636	118	15	260	222	207	249	638	256	256	35	VS	F
Squamata	Simiscincus aurantiacus	1.402	688	773	30	237	199	185	227	755	305	234	34	UM	F
Coleoptera	Megatracheloides millei	1.402	605	60	5	255	219	206	245	702	250	253	32	UM	F
Diptera	Limonia ovalistigma	4.072	596	700	20	239	201	187	229	773	313	235	34	UM	F
Trichoptera	Xanthochorema johnwardi	5.218	405	224	15	254	217	203	244	650	270	250	34	UM	F,E
Squamata	Dierogekko baaba	0.341	112	57	5	261	231	218	252	674	157	259	55	UM	M
Squamata	Bavayia cyclura clade	0.034	110	55	5	261	229	216	250	672	157	259	55	UM	S
Diptera	Corindia amieuensis	0.341	197	42	5	257	225	212	248	621	184	257	47	VS	S
Diptera	Dasybasis danielae	0.341	347	462	15	246	208	194	236	817	332	242	35	UM	S
Diptera	Dasybasis tillierorum	0.341	172	1263	5	208	169	155	197	395	134	204	34	UM	S
Diptera	Dasyhelea neocaledoniensis	1.402	347	462	15	246	208	194	236	817	332	242	35	UM	S
Diptera	Dimorphelia stirpicola	1.402	450	57	5	260	223	208	249	550	210	256	34	C	S
Diptera	Dimorphelia tergata	3.863	810	868	30	235	203	189	226	950	242	234	52	UM	S
Collembola	Dinaphorura chazeau	0.341	557	387	15	246	208	194	235	750	310	242	34	UM	S
Collembola	Dinaphorura matileorum	0.043	451	147	5	259	221	207	249	681	273	255	35	UM	S
Collembola	Ectonura minima	0.043	388	773	30	237	199	185	227	755	305	234	34	UM	S
Diptera	Encyocrypta panie	3.863	477	1206	30	215	181	168	205	733	187	212	50	VS	S
Diptera	Forcipomyia pectinunguis	3.863	489	501	15	246	208	194	236	613	248	242	34	UM	S
Diptera	Lapita ponerihouen	4.072	789	402	15	248	217	204	239	773	215	247	49	VS	S
Diptera	Lapita ternata	0.043	540	226	20	256	225	212	247	545	130	254	57	VS	S,F
Diptera	Mycodrosophila legrandi	0.043	537	221	20	252	223	212	247	550	134	257	57	VS	S
Hemiptera	Nobarnus typicus	0.043	275	551	15	237	203	190	227	556	166	235	47	UM	S
Coleoptera	Scirtes ebenus	4.072	679	1075	15	219	180	166	208	801	316	215	34	VS	S,E
Lepidoptera	Sabatinca delobeli	5.218	880	522	10	241	205	191	230	613	209	238	43	VS	S

Microendemic species were observed in different regions of New Caledonia's mainland, and in Isle of Pines and Loyalty islands. In spite of this, their distribution is quite aggregate with either several species are reported to the same grid-cell (between 1-11), or sets of cells with microendemic species very close to each other. This makes a main spot with microendemics in the South, from the North of Yaté Lake to the region of Mt Mou, a second in the center, in the region of Saraméa and Farino-Table Unio, a third in Mt Aoupinié, and finally in the north one grid at the Panié-Mandgélia ridge and another in the northwest in Mt Kaala. The highest numbers of microendemic species per grid-cell were recorded in Mt Khogis, followed by the region of Farino-Table d'Unio and Panié (Fig.1A).

Due to the much higher number (386) and larger distribution range, the richness of non-microendemic species covers a much greater part of the territory (986 grid cells), and is more variable within New Caledonia. It is much higher in the central region of the south, increasing progressively from Col de Roussettes to Mt Koghis, where maximum values are observed. To the north, the highest values are on the mountains along the East coast, with a peak on Mt Panié (Fig. 1B). The comparison of the environmental and sampling variables between grid-cells containing microendemic species with grid cells containing the other species shows that, in average, cells with microendemic species were significantly more sampled, are in higher altitude, in sites where the slope is steeper, and submitted to milder climate. In addition, the great majority of microendemic species were restricted to forests, whereas other species were inferred to occur much more equally in other ecosystems. Concerning soils, the difference between these two sets of species is less contrasting. But microendemic tend to be more frequent on ultramafic, whereas the non-microendemic species are more frequent in volcano-sedimentary soils (Table 3).

The results of the classification of these variables with Random Uniform Forest are presented in Table 4 and in Figs. 2A, B. It shows that the number of collectors and the species richness are by far the most predictive features of the distribution of microendemic species. They are followed by Bio16 (precipitation of the wettest quarter), road density, slope, and Bio17 (precipitation of the driest quarter) (Fig. 2A). The same five top ranking variables are also the most important based on interactions with other variables but the scores shift slightly (Fig. 2B). This puts in evidence Bio16 as the environmental variable with greater interaction with all other variables.

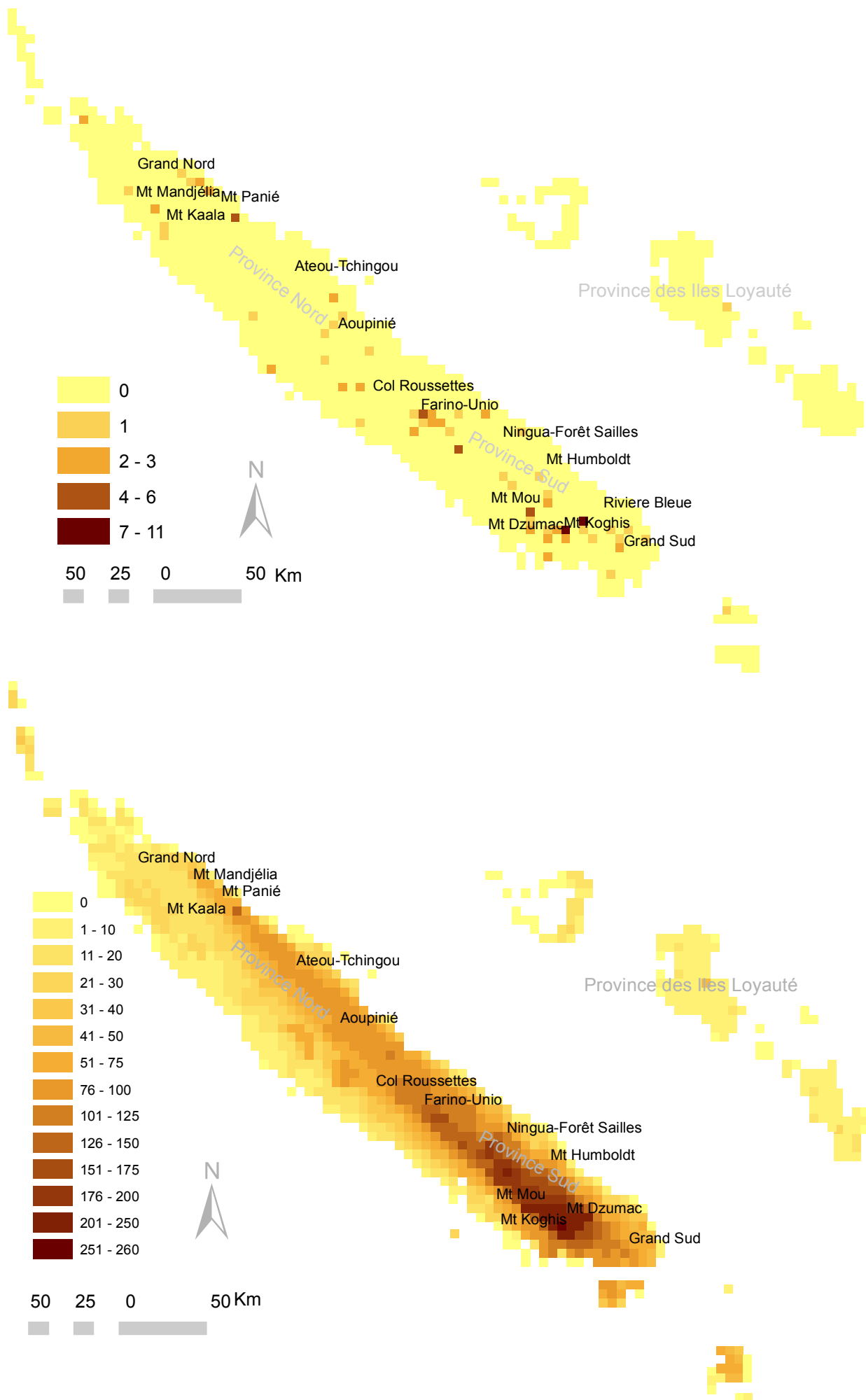


Figure 1. Distribution of the richness of microendemic (A) and non-microendemic species (B) in New Caledonia.

Table 3. Summary of the environmental and sampling values in the grid-cells containing microendemic and non-microendemic species. For the classes of soil and land use, we show the raw values and their respective percentage. UM: ultramafic, VS: volcano-sedimentary, C: calcareous; E: fresh and salt water, F: Forests, M: Mangroves, S: Savannas, H: Transformed areas, A: Bushy vegetation, V: Sparsely vegetated areas (see Material and Methods for detailed information of the categories included in each

C	Microendemic	Other Species	Test T
	Mean±SE Median	Mean±SE Median	
	3±0.3 1	52±1.6 32	
Nb_Collectors	51±2.2 48	25±0.3 20	t= 11.75 p<0.0001
RoadDensity (m/km ²)	599±16 569	588±5.7 489	t= 0.65 p= 0.51
Altitude (m)	459±17 415	325±4 259	t= 7.90 p<0.0001
Slope (%)	16±0.39 15	13±0.09 10	t= 8.53 p<0.0001
Bio1 (°C)	244±0.64 246	242±0.13 252	t= 2.19 p= 0.02
Bio5 (°C)	209±0.71 210	209±0.15 218	t= -0.45 p= 0.64
Bio6 (°C)	195±0.71 196	196±0.15 204	t= -1.06 p= 0.28
Bio12 (mm)	234±0.65 206	233±0.13 242	t= 1.66 p= 0.09
Bio16 (mm)	615±12 662	622±2.7 658	t= -0.58 p= 0.55
Bio17 (mm)	209±4.29 216	198±0.9 208	t= 2.52 p= 0.011
Bio3 (°C)	242±0.66 243	239±0.13 250	t= 2.42 p= 0.015
Bio15 (mm)	41±0.41 42	43±0.09 44	t= -3.04 p= 0.002
Soils			
UM	64 (55%)	70 (18%)	
VS	45 (39%)	178 (46%)	
C	7 (6%)	138 (36%)	
Land Use			
E	-	10(3%)	
F	97(84%)	146(38%)	
M	1 (1%)	19 (5%)	
S	18 (15%)	43 (11%)	
H	-	27 (7%)	
A	-	72(18%)	
V	-	69(17%)	

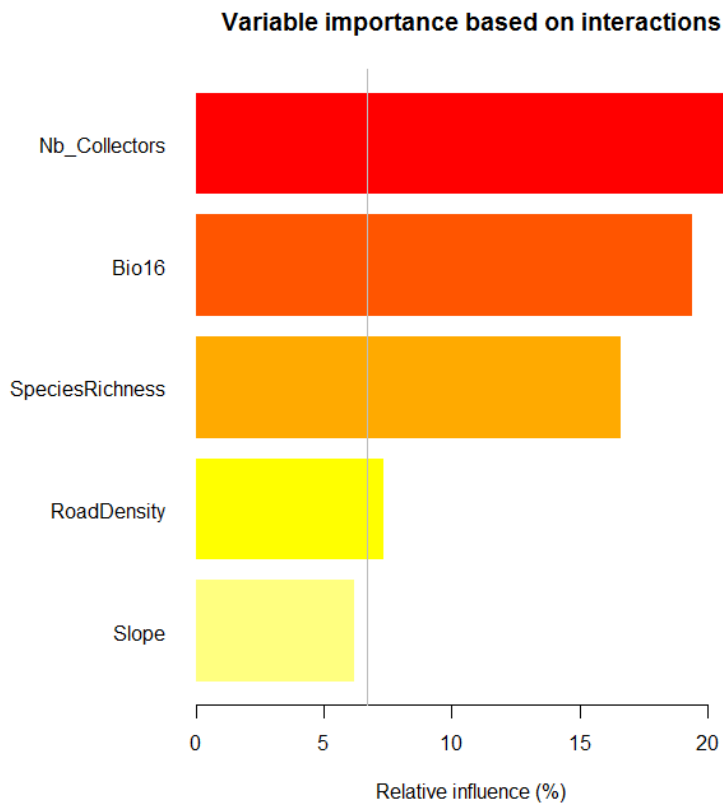
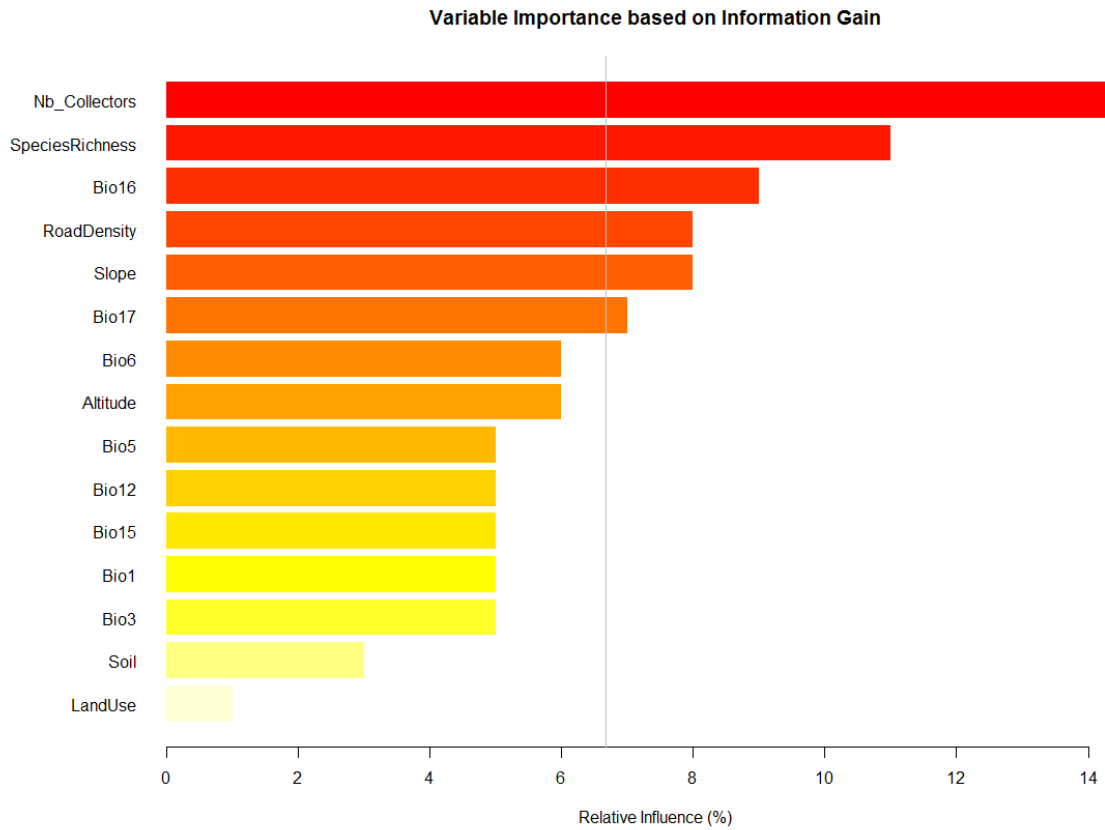


Figure 2. Classification of 15 variables with Random Uniform Forest. A) Variable importance based on information gain; B) Variable importance based on interactions

The classification in Random Uniform Forest also provides a list of the most discriminant variables. This result attracts the attention to the land use and soil as the most discriminant variables (Table 4), despite their lowest predictive importance (Fig. 1A).

Table 4. Global variable importance based on information gain. The most predictive features are ordered by scores, as in Fig. 2 A; the most discriminant ones are given in the class frequency column.

	variables	score	class	class.frequency	percent	percent.importance
1	Nb_Collectors	164	1	0.28	100.00	15
2	SpeciesRichness	123	1	0.37	75.23	11
3	Bio16	95	1	0.34	58.18	9
4	RoadDensity	85	1	0.34	51.52	8
5	Slope	83	1	0.30	50.46	8
6	Bio17	74	1	0.35	44.87	7
7	Bio6	70	1	0.29	42.59	6
8	Altitude	68	1	0.34	41.25	6
9	Bio5	56	1	0.34	34.13	5
10	Bio12	55	1	0.37	33.40	5
11	Bio15	54	1	0.34	33.16	5
12	Bio1	53	1	0.37	32.35	5
13	Bio3	52	1	0.37	31.80	5
14	Soil	36	1	0.42	21.99	3
15	LandUse	15	1	0.56	9.33	1

Multiple Linear Regression model gives a mix of the results obtained with RUF (Table 5). It indicates a strong positive correlation of species richness and number of collectors with the other variables, and a small but significant correlation of Bio16, Bio17, Volcano-Sedimentary soil and forests (Table 5).

Table 5. Results of the Multiple Linear Regression Model. Signification codes: *** $p \leq 0.001$; * $p \leq 0.05$; . $p \leq 0.1$.

	Estimate	SE	t-value	p-value
(Intercept)	-6.2645315	18.7656155	-0.334	0.7392
Bio1	-0.9271050	0.6626338	-1.399	0.1647
Bio5	1.6065668	1.0596368	1.516	0.1324
Bio6	-1.1432342	0.9167051	-1.247	0.2151
Bio12	0.9404478	0.6497966	1.447	0.1507
Bio16	-0.0101598	0.0048050	-2.114	0.0368 *
Bio17	0.0276285	0.0118148	2.338	0.0212 *
Altitude	0.0047758	0.0025976	1.839	0.0688 .
Bio3	-0.4116066	0.4662435	-0.883	0.3793
Bio15	-0.0125559	0.0729570	-0.172	0.8637
SoilUM	-1.1876474	0.6461511	-1.838	0.0688 .
SoilVS	-1.5827033	0.6828488	-2.318	0.0224 *
SoilC	0.5751031	0.6514466	0.300	0.4234
LandUseM	0.3761983	1.7307664	0.217	0.8283
LandUseS	-0.3262901	0.4249889	-0.768	0.4443
LandUseF	1.2341940	1.5207554	0.115	0.0223 *
RoadDensity	-0.0009445	0.0007228	-1.307	0.1941
Slope	0.0194437	0.0270479	0.719	0.4738
SpeciesRichness	0.0018710	0.0030519	9.613	<2e-16 ***
Nb_Collectors	0.0348029	0.0036305	9.586	4.42e-16***

Residual standard error: 1.596 on 107 degrees of freedom Multiple R-squared: 0.8238, Adjusted R-squared: 0.7958 F-statistic: 29.43 on 17 and 107 DF, p-value: < 2.2e-16

Discussion and Conclusion

Until recently the importance of microendemism and rarity in New Caledonia's fauna was known by several separated studies on systematics and evolution of different groups (e.g., Murienne et al., 2005; 2008; Bauer et al., 2006; Espeland & Johanson, 2010, Nattier et al., 2013). The general appreciation about microendemism was then generated by putting together these different studies (e.g. Grandcolas et al., 2008; Pellens & Grandcolas, 2010) and lacked an evaluation taking in account the sampling effort in order to separate species that are really rare and/or microendemic from those that are poorly sampled. Our first study in this respect showed that 116 (out of 1149) species, although adequately sampled, had extremely narrow distribution ranges. This and the fact that these species belong to several different taxonomic groups confirmed the hypothesis of a biodiversity marked by an outstanding rate of microendemic species in New Caledonia (Caesar et al., 2017).

In the present study we showed that microendemic species are not particularly clustered geographically. They were recorded in different sites from north to south and in the east and west coast of New Caledonia's mainland, and in smaller isolated islands. Similarly, they are not restricted to a particular type of soil or ecosystems, even if they are much more frequent in forests and in ultramafic soils. So, these features have minor contribution in predicting their occurrence.

The role of sampling effort

The high importance of the number of collectors and road density in terms of information gain and of interactions with other variables shows that sampling effort plays an important role in the assessment of these organisms, complicating the characterization of the environmental features that govern their distribution.

The probability of finding more species, particularly of finding new species, is recognized to play an important role in the choice of sites to be sampled (Sheil, 1996, 2012; Angulo et al., 2009). Here we cannot discard the attraction that areas with important richness of the fauna and the flora to scientists, and its implications in finding the rare ones. Nevertheless, the strong importance of the density of roads suggests that not all sites that could attract the attention of scientists by their remarkable richness were equally sampled. In one analysis made with this same dataset we observed that most of the sampling records are very biased towards the nearest road (mean=787m, SE=15.3m,

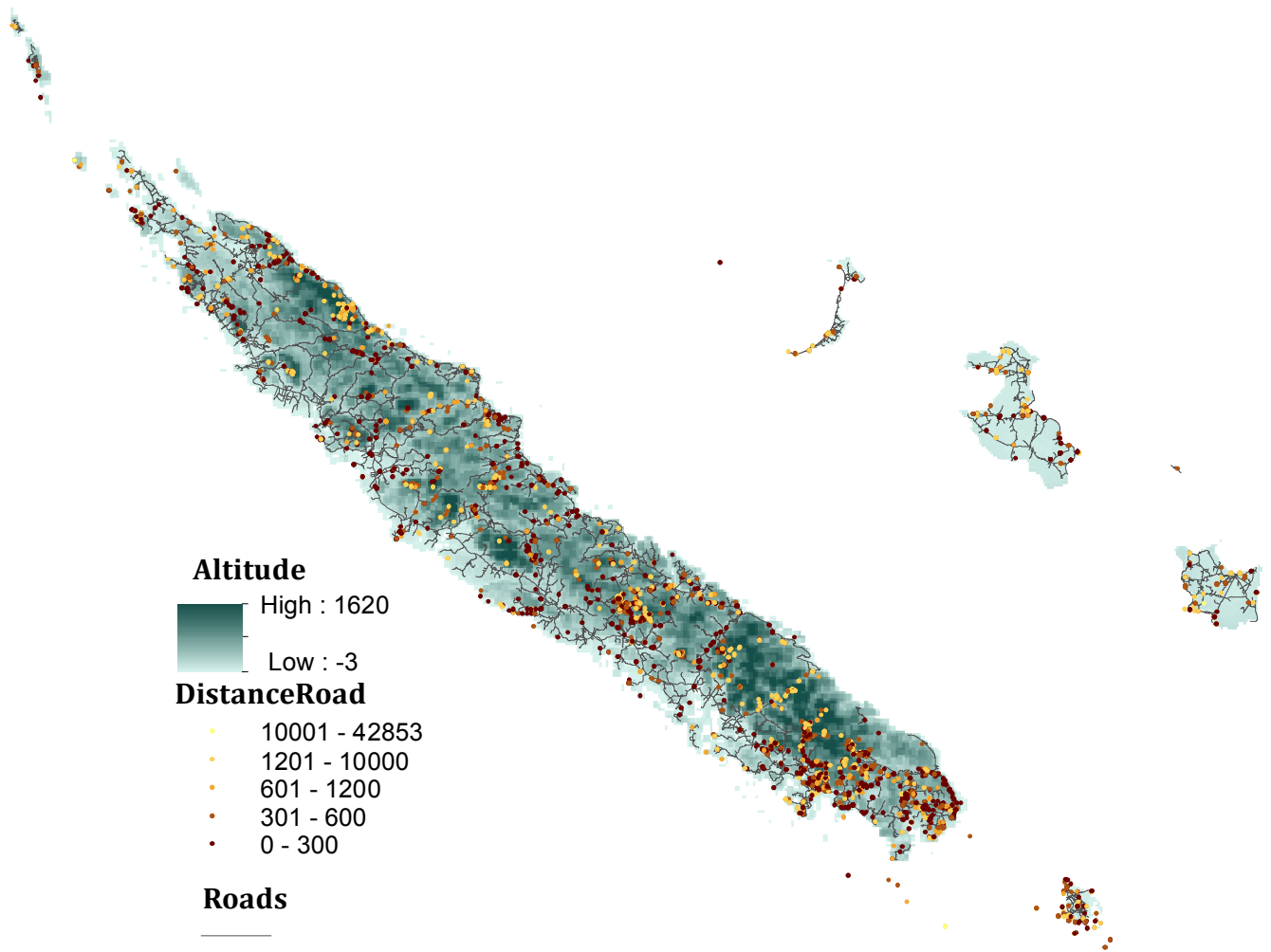


Figure 3. Distribution of sampling points of all species in this dataset with Roads and Altitude.

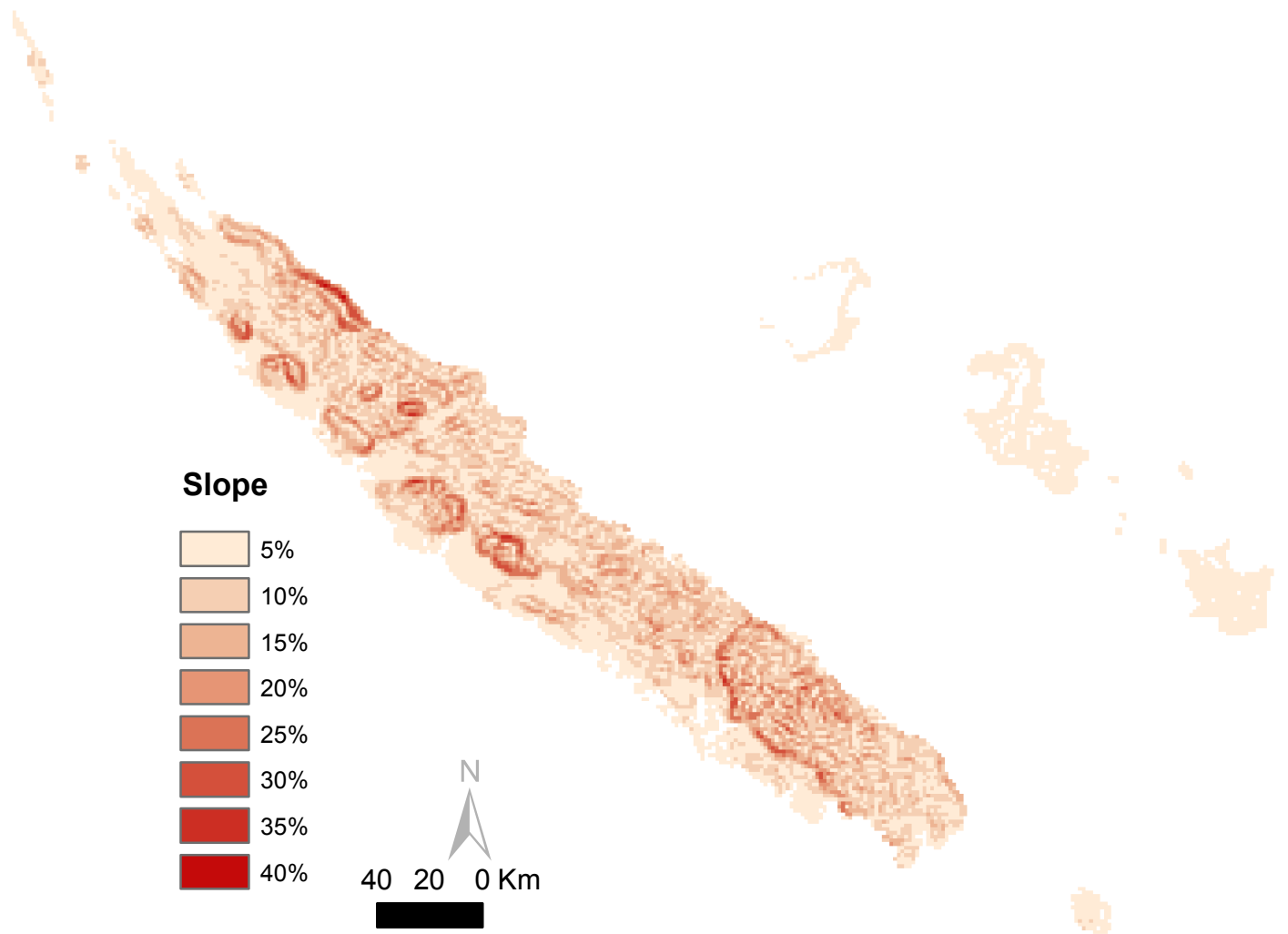


Figure 4. Distribution of the slope in New Caledonia.

Median=282m), and the existence of major sampling gaps in regions not served by this infrastructure (Fig. 3). This makes that entire regions still covered by “primary” humid forests, as in the Southeast coast, from Mts Dzumac to Riviere Bleue, the Center of New Caledonia along the Haute Tchamba, and the major part of Mt Panié-Mandgélia ridge system are still poorly sampled (Caesar, Grandcolas & Pellens in preparation). Roadside effect has been reported to play an important role in the assessment of species distribution (Kadmon et al., 2004; Ramp et al., 2006; Pautasso et al., 2007; Yang et al., 2014), but so far in much broader spatial scale. The intricate relief and steep slopes separating each mountain are quite likely to be a major reason for this sampling bias.

The good news of these sampling biases is that the total richness of New Caledonia’s fauna is likely to be much higher than actually known. Future finer exploration of the fauna in the regions mentioned above might bring to light new microendemic species, or more information about the range of species now considered microendemic.

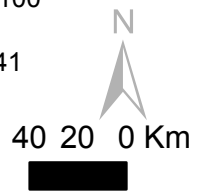
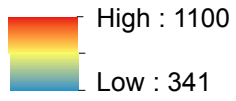
Environmental variables

Due the large area occupied by ultramafic soils and the high number of organisms that evolved in this environment and are able to deal with high levels of metals, the hypothesis that soils play an important role in the distribution of the New Caledonia’s fauna and flora permeates the literature (e.g. Pillon et al. 2010, Espeland et al., 2008 and Espeland and Johanson, 2010). In this study ultramafic soils harbor a slightly higher richness of microendemic species, but we found no evidences that soils, or specifically ultramafic soil, predict their distribution.

The environmental variables identified as important predictor of the presence of microendemic species were slope (Fig. 4) and the precipitation of the wettest and driest quarters (Fig. 5 a, b). The importance of slope (Fig. 4) was one expected result of our research. Our hypothesis is that slope not only creates difficulties of access to field workers, as mentioned above. We assume that it indicates habitat discontinuities, which favors the delimitation of the distribution of populations, and could promote speciation (Losos and Glor, 2003).

The high importance of the precipitation of the wettest and driest quarter (Fig. 5 a, b) in predicting the distribution of microendemic species is in accordance with some recent studies taking in consideration more refined interpolations of the regional climate (Hijmans et al., 2005). These studies show that precipitation seasonality are better

PpWettestQtr



PpDriestQtr

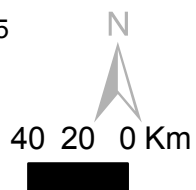
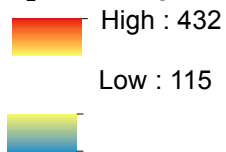


Figure 5. Distribution of the Precipitation of the Wettest (BIO16) and Driest Quarter (BIO17).

predictions of the distribution of the biota (e.g. Murienne et al., 2009; Kumar & Stohlgren, 2009 ; Nattier et al., 2012; Pouteau et al., 2015) than annual estimates of total rainfall or temperatures minimum, mean and maximum, that were at the core of the hypothesis of the distribution of the New Caledonia's biota two decades ago (Pintaud et al., 2001). Our results reinforce the importance of certain level of humidity along the dry season to provide conditions for the occurrence of microendemic species.

Based on it, we can infer that the areas poorly explored mentioned above might still contain an important number of unknown species for this region. But, rather than building roads and infrastructures to facilitate the access of scientists we recommend careful protection of these so far unattained forests.

References

- Angulo, E., Deves, A. L., Saint Jalmes, M., & Courchamp, F. (2009). Fatal attraction: rare species in the spotlight. *Proceedings of the Royal Society of London B: Biological Sciences*, 276(1660), 1331-1337.
- Bauer AM, Jackman T, Sadlier RA, Whitaker AH (2006) A Revision of the *Bavayia validiclavis* group (Squamata: Gekkota: Diplodactylidae), a Clade of New Caledonian Geckos Exhibiting Microendemism. *Proceedings of the California Academy of Sciences* 57: 503-547.
- Caesar M, Grandcolas P, & Pellens R (2017) Outstanding microendemism in New Caledonia: more than one out of ten animal species has a very restricted range of distribution. *Plos One* (accepted)
- Ciss S (2014) *RandomUniformForest: random Uniform Forests for Classification, Regression and Unsupervised Learning: an overview*. R package version 1.1.2, <http://CRAN.R-project.org/package=randomUniformForest>.
- Cutler DR, Edwards TC, Beard KH, Cutler A, Hess KT (2007) Random forests for classification in ecology. *Ecology* 88: 2783-2792.

- Espeland M, Johanson KA, & Hovmöller R (2008) Early Xanthochorema (Trichoptera, Insecta) radiations in New Caledonia originated on ultrabasic rocks. *Molecular Phylogenetics and Evolution* 48:904-917.
- Espeland M, Johanson KA (2010) The effect of environmental diversification on species diversification in New Caledonian caddisflies (Insecta: Trichoptera: Hydropsychidae). *Journal of Biogeography* 37: 879-890.
- Grandcolas P (2016) The origin of island biota: Several things in one. *Origins - Studies in Biological and Cultural Evolution* 4.
- Grandcolas P, Murienne J, Robillard T, Desutter-Grandcolas L, Jourdan H, et al. (2008) New Caledonia: a very old Darwinian island? *Philosophical Transactions of the Royal Society of London, B* 363: 3309-3317.
- Grandcolas P, Nattier R, Trewick S (2014) Relict species: a relict concept? *Trends in Ecology & Evolution* 29: 655-663.
- Hijmans RJ, Cameron SE, Parra JL, Jones PG, Jarvis A (2005) Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology* 25: 1965-1978.
- Kadmon R, Farber O, Danin A (2004) Effect of roadside bias on the accuracy of predictive maps produced by bioclimatic models. *Ecological Applications* 14: 401-413.
- Kier G, Kreft H, Lee TM, Jetz W, Ibisch PL, et al. (2009) A global assessment of endemism and species richness across island and mainland regions. *Proceedings of the National Academy of Science USA* 106: 9322-9327.
- Kumar S & Stohlgren TJ (2009) Maxent modeling for predicting suitable habitat for threatened and endangered tree *Canacomyrica monticola* in New Caledonia. *Journal of Ecology and Natural Environment* 1(4):094-098.
- Liu CR, Berry PM, Dawson TP, Pearson RG (2005) Selecting thresholds of occurrence in the prediction of species distributions. *Ecography* 28: 385-393.
- Losos JB & Glor RE (2003) Phylogenetic comparative methods and the geography of speciation. *Trends in Ecology and Evolution* 18(5):220-227.
- Murienne J, Guilbert E, & Grandcolas P (2009) Species' diversity in the New Caledonian endemic genera *Cephalidiosus* and *Nobarnus* (Insecta: Heteroptera: Tingidae), an approach using phylogeny and species' distribution modelling. *Biological Journal of the Linnean Society* 97:177-184.

- Murienne J, Grandcolas P, Piulacs MD, Bellés X, D'Haese C, et al. (2005) Evolution on a shaky piece of Gondwana: is local endemism recent in New Caledonia? *Cladistics* 21: 2-7.
- Murienne J, Pellens R, Grandcolas P (2008) Short range endemism in the cockroach *Lauraesilpha* (Blattidae, Trypeticinae) in New Caledonia: distribution and new species. In: Grandcolas P, editor. *Zoologia Neocaledonica* 6, Systematics and Biodiversity in New Caledonia. Paris: *Mémoires du Muséum National d'Histoire Naturelle*. pp. 261-271.
- Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kent J (2000) Biodiversity hotspots for conservation priorities. *Nature* 403: 853-858.
- Nattier R, Grandcolas P, Elias M, Desutter-Grandcolas L, Jourdan H, et al. (2012) Secondary Sympatry Caused by Range Expansion Informs on the Dynamics of Microendemism in a Biodiversity Hotspot. *Plos One* 7.
- Nattier R, Grandcolas P, Pellens R, Jourdan H, Couloux A, et al. (2013) Climate and Soil Type Together Explain the Distribution of Microendemic Species in a Biodiversity Hotspot. *Plos One* 8.
- Oliveira S, Oehler F, San-Miguel-Ayanz J, Camia A, Pereira JMC (2012) Modeling spatial patterns of fire occurrence in Mediterranean Europe using Multiple Regression and Random Forest. *Forest Ecology and Management* 275: 117-129.
- Pautasso M, McKinney ML (2007) The botanist effect revisited: Plant species richness, county area, and human population size in the United States. *Conservation Biology* 21: 1333-1340.
- Phillips S, Dudík M, Schapire RE (2004) A Maximum entropy approach to species distribution modeling. *Proceedings of the Twenty-First International Conference on Machine Learning*. Banff, Canada. pp. 655-662.
- Phillips SJ, Anderson RP, Schapire RE (2006) Maximum entropy modeling of species geographic distributions. *Ecological Modelling* 190: 231-259.
- Pillon Y, Munzinger J, Amir H, & Lebrun M (2010) Ultramafic soils and species sorting in the flora of New Caledonia. *Journal of Ecology* 98:1108-1116.
- Pintaud JC, Jaffré T (2001) Patterns of diversity and endemism in palms on ultramafic rocks in New Caledonia. *South African Journal of Science* 97: 548-550.
- Pouteau R, Trueba S, Feild TS, Isnard S (2015) New Caledonia: a Pleistocene refugium for rain forest lineages of relict angiosperms. *Journal of Biogeography* 42: 2062-2077.

- R Core Team (2014) R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.
- Rabinowitz D (1981) Seven forms of rarity. In: Synge H, editor. *The Biological Aspects of Rare Plant Conservation*: John Wiley & Sons Ltd. pp. 205-217.
- Ramp D, Wilson VK, Croft DB (2006) Assessing the impacts of roads in peri-urban reserves: Road-based fatalities and road usage by wildlife in the Royal National Park, New South Wales, Australia. *Biological Conservation* 129: 348-359.
- Richardson JE, Weitz FM, Fay MF, Cronk QCB, Linder HP, et al. (2001) Rapid and recent origin of species richness in the Cape flora of South Africa. *Nature* 412: 181-183.
- Sheil D (1996) Species richness, tropical forest dynamics and sampling: questioning cause and effect. *OIKOS* 76: 587-590.
- Ungricht S, Rasplus J-Y, Kjellberg F (2005) Extinction threat evaluation of endemic fig trees of New Caledonia: priority assessment for taxonomy and conservation with herbarium collections. *Biodiversity and Conservation* 14: 205-232.
- Vences M, Wollenberg KC, Vieites DR, Lees DC (2009) Madagascar as a model region of species diversification. *Trends in Ecology & Evolution* 24: 456-465.
- Wulff AS, Hollingsworth PM, Ahrends A, Jaffre T, Veillon JM, et al. (2013) Conservation Priorities in a Biodiversity Hotspot: Analysis of Narrow Endemic Plant Species in New Caledonia. *Plos One* 8.
- Yang WJ, Ma KP, Kreft H (2014) Environmental and socio-economic factors shaping the geography of floristic collections in China. *Global Ecology and Biogeography* 23: 1284-1292.
- Zimmermann NE, Yoccoz NG, Edwards TC, Meier ES, Thuiller W, et al. (2009) Climatic extremes improve predictions of spatial patterns of tree species. *Proceedings of the National Academy of Sciences of the United States of America* 106: 19723-19728.

**E) Chapitre V -
Discussion et Conclusion de la Thèse**

Discussion et Conclusion de la Thèse

Les trois grands ensembles de travaux menés au cours de cette thèse m'auront permis de mesurer la dynamique, la qualité et la signification des données systématiques pour la compréhension de l'origine et du maintien de la biodiversité.

Dans une première partie, je me suis focalisé sur l'étude de la biodiversité d'une vaste région, le Moyen Orient, dans laquelle se trouve mon pays, la Syrie. Pour travailler à cette échelle, j'ai restreint le nombre de groupes d'organismes sur lesquels j'ai porté un regard. Je me suis ainsi focalisé sur l'ordre des Dictyoptères, un groupe d'Insectes diversement connu, comprenant Blattes, Termites et Mantes (Caesar et al., 2015). Ce travail m'a permis de montrer la cinétique de l'acquisition des connaissances taxonomiques sur une vaste région de cette taille. Le nombre d'espèces décrites varie au cours du temps de manière très claire et dépend manifestement de l'activité de petits nombre de spécialistes dont l'époque et le rythme de travail diffère selon les cas. Le résultat de cette étude est aussi de montrer que les inventaires sont très loin d'être complets, même en terme de simples descriptions et de listes d'espèces, sans même aller jusqu'à l'étude des répartitions précises de chaque espèce. Un constat alarmant est aussi que tous ces résultats sont assez anciens et qu'aucun travail récent d'ampleur ne marque cette région, montrant qu'il n'y a plus ou quasiment plus de taxonomistes actifs sur ces faunes, confirmant par là des tendances mondiales (May, 1990; Wheeler et al., 2004). Evidemment, ce groupe d'organismes n'est pas très grand (75 espèces dénombrées sur la région pour l'instant, pour plus de 9000 Dictyoptères au niveau mondial) mais cela montre précisément qu'un constat plus large au niveau de la totalité de la biodiversité sera constitué de l'addition de bilans sur de très nombreux groupes de ce type et sera donc vraisemblablement à la fois insuffisant et passablement hétéroclite. Une autre perspective qui apparaît déjà est que les données disponibles rendent aussi compte des faunes qui ont existé depuis deux siècles et qui sont susceptibles d'avoir changé de manière importante suite aux modifications du milieu, notamment sous l'influence de l'Homme.

Dans une deuxième partie, j'ai abordé la faune de Nouvelle-Calédonie. La nature de cet archipel est complètement à l'opposé de ma première zone d'étude. Sa surface terrestre est petite (environ 18000 km², environ deux fois la Corse) et naturellement délimitée par l'océan. Mais sa richesse et son endémisme sont extrêmes, ce qui en fait un hotspot de biodiversité lorsque l'on considère en outre les énormes pressions locales que l'Homme exerce sur l'environnement (Myers et al., 2000, Pellens & Grandcolas, 2010). De plus, l'archipel est un modèle d'étude extraordinaire en biologie de l'évolution : il s'agit de la plus vieille île océanique du monde, dont l'ancienneté et l'isolement a permis des diversifications et adaptations locales exceptionnelles (Grandcolas et al., 2008; Pellens et al., 2016; Grandcolas, 2017 ; Nattier et al., 2017). Dans ce cas, compte-tenu de la taille restreinte de l'aire géographique, j'ai élargi le cadre de mon étude à l'ensemble de la biodiversité animale terrestre. Le but de la démarche était de caractériser les répartitions des organismes et les facteurs environnementaux qui les déterminent, et ce pour une large gamme d'organismes. L'idée était de réaliser une avancée par rapport aux travaux antérieurs, consacrés chacun à un groupe d'organismes particuliers. Ceci requérait de faire la part des différences d'efforts d'échantillonnage et de ne pas confondre espèces rares parce que sous-échantillonnées et rares parce que réellement micro-endémiques (Rabinowitz, 1981; Pyke & Ehrlich, 2010).

Dans ce cadre, j'ai eu la chance de bénéficier d'un important corpus de travaux de taxonomie - la série *Zoologia Neocaledonica* - publié par le Muséum national d'Histoire naturelle depuis 1988 (volume le plus récent en 2014). Ce corpus a donné lieu à un important travail de constitution et d'enrichissement de bases de données, incluant géolocalisation et ajouts de données de répartition pour plus d'un millier d'espèces. Mais il avait le grand avantage d'être déjà raisonnablement correct au plan nomenclatural, du fait qu'il était constitué d'articles de taxonomie écrits par des experts entre 1988 et 2014 et non pas de données brutes issues de collections, par exemple.

La stratégie d'analyse que j'ai choisi pour ce corpus de données a été ambitieuse : elle a privilégié plusieurs aspects qui nous paraissent importants et n'avaient pas toujours été pris en compte dans les rares travaux antérieurs du même type consacrés surtout aux plantes en Nouvelle-Calédonie (Ungricht et al., 2005; Wulff et al., 2013). Ces aspects étaient les suivants: contrôle des résultats par plusieurs estimations de l'effort

d'échantillonnage, contrôle des estimations d'aires de répartition par une modélisation bioclimatique s'ajoutant aux calculs classiques de polygones, prise en compte de facteurs de répartition différents (climat, sols, relief, structures anthropiques). L'analyse a ainsi été beaucoup plus puissante car elle n'a pas intégré des espèces insuffisamment échantillonnées et dont les répartitions seraient trop mal déterminées.

L'analyse a révélé tout d'abord que le micro-endémisme est bien une réalité en Nouvelle-Calédonie: ainsi plus d'une espèce sur dix s'est avérée présenter une aire inférieure à 5,2 km² (Caesar et al., 2017). Ces chiffres sont vraiment exceptionnels, même en regard de hotspots de biodiversité et laissent supposer qu'une bonne partie des espèces endémiques de la Grande Terre sont probablement d'origine récente au sein de clades relativement anciens (pour des cas similaires, voir Richardson et al., 2001 ou Vences et al., 2009). En effet, les analyses phylogénétiques et biogéographiques ont montré que les groupes d'organismes de Nouvelle-Calédonie sont assez anciens même s'ils sont issus de dispersions post-émersion de l'île il y a environ 37 millions d'années (Grandcolas et al., 2008; Nattier et al., 2011, 2017; Swenson et al., 2014). Mais les études phylogéographiques les plus détaillées (Nattier et al., 2012) ont montré que les espèces les plus micro-endémiques étaient aussi les plus récentes : en vieillissant, celles-ci augmentaient leur aires de répartition au point d'empiéter par sympatrie sur les aires de leur voisines. La comparaison entre des cas d'espèces détaillés réalisés par divers auteurs et notre analyse globale est donc particulièrement riche d'enseignements et permettra de déterminer clairement les questions à se poser dans de futures études. Ce résultat a également des conséquences pour la politique de conservation de la biodiversité dans la mesure où de multiples micro-endémiques devraient être considérées comme des membres de liste rouge (Bouchet et al., 1998; Pellens et al., 2010). Cette omniprésence des micro-endémiques plaide aussi pour une approche de la question avec la métrique de la diversité phylogénétique qui a l'avantage de ne pas compter les espèces comme équivalentes les unes aux autres (Pellens et al., 2016).

L'étude de l'effet collecteur et des biais d'échantillonnage a été aussi très intéressante. Elle a permis de caractériser les comportements des biologistes collecteurs en Nouvelle-Calédonie qui sont confrontés à un relief modéré mais très complexe et qui doivent se frayer un chemin vers des sommets déterminant de multiples vallées. L'analyse a aussi

révélé que la répartition des espèces non-endémiques était également souvent très restreinte sur la Grande Terre, ce qui nous a amené à penser que le contrôle environnemental des aires de répartition est sans doute assez puissant sur le territoire.

Cette conclusion m'amène à la troisième partie de la thèse, dans laquelle j'ai utilisé le même corpus de travaux de taxonomie - la série *Zoologia Neocaledonica* - validé et complété. Celui-ci ayant été trié dans la deuxième partie de la thèse pour sélectionner les espèces pour lesquelles l'effort d'échantillonnage est suffisant, il m'a été maintenant possible d'étudier les corrélats environnementaux de la répartition des espèces micro-endémiques en Nouvelle-Calédonie. Peu d'études ont pu préciser ceux-ci auparavant. Les travaux anciens sur la Nouvelle-Calédonie mentionnaient arbitrairement plusieurs causes au micro-endémisme avec l'effet du sol (métallifère, calcaire ou volcano-sédimentaire) du climat avec des zones particulièrement humides sur des plantes (e.g., Morat et al., 1986; Jaffré, 1993; Pintaud et al., 2001). Depuis ces synthèses, quelques travaux ont étudié l'aire bioclimatique d'espèces animales de Nouvelle-Calédonie avec notamment Kumr & Stohlgren (2009), Murienne et al., (2009), Nattier et al., (2013). L'étude de Nattier et al., (2013) est intéressante en particulier car elle met en évidence qu'une simple valeur de saisonnalité a la capacité de limiter des groupes entiers d'organismes à la moitié Sud du territoire; elle propose ainsi une hypothèse assez satisfaisante de déterminisme environnemental pour un type de répartition classique mais dont l'origine était jusqu'à présent incomprise sur le territoire. Wulff et al., (2013), Pouteau et al., (2015) et Pouteau & Birnbaum (2016) ont fait de même pour de larges échantillons de plantes. Leurs travaux sont donc très intéressants puisqu'ils concernent de grands groupes d'organismes mais ils ont par ailleurs l'inconvénient de se focaliser sur des groupes d'espèces considérées a priori comme endémiques ou relictées. Ils risquent de donner une image assez biaisée de la situation en ne séparant pas les différentes causes de rareté.

Notre analyse a permis de sélectionner un lot d'espèces animales validées comme étant micro-endémiques suite à un contrôle statistique sur la qualité de l'échantillonnage. Les calculs sur les corrélats environnementaux qui expliqueraient le mieux la répartition de ces espèces endémiques donnent un résultat intéressant : les paramètres climatiques qui montrent le caractère contraignant du climat sont les mois le plus sec et le plus

humide, respectivement. Cela signifie que les espèces de la Nouvelle-Calédonie sont contraintes par la persistance de l'humidité en Nouvelle-Calédonie tout au long de l'année, de manière comparable à ce qui avait trouvé pour le seul genre de criquet *Caledonula* par Nattier et al., (2013). Ce résultat est assez inattendu. Pour un observateur, une île comme la Nouvelle-Calédonie apparaît a priori peu contraignante de ce point de vue du fait du climat tropical humide du Pacifique. En réalité, du fait de la saisonnalité, des variations climatiques interannuelles et du relief, l'eau apparaît bien comme un élément contraignant pour la répartition des espèces endémiques. Ou alors peut-être est-ce aussi une trace de la différenciation ancienne des faunes (Nattier et al., 2017) contemporaine des premiers climats calédoniens extrêmement humides à la fin de l'Eocène (Reusch, 2011) Toujours est-il que ce résultat affine et généralise beaucoup celui mis en avant par des études antérieures qui se contentaient de citer les régions pluvieuses comme autant de zones propices à la richesse et à l'endémisme en ce qui concerne certains groupes.

De manière générale, l'ensemble de ces travaux a permis de mettre en avant des propriétés fondamentales des données de la systématique. Je vais les souligner tour à tour.

Tout d'abord, les données de la systématique représentent une connaissance indispensable sur la biodiversité. Sans elles, on ne pourra avoir aucune idée réelle de la magnitude de la diversité biologique dans telle ou telle zone. Il est extrêmement important que l'on comprenne qu'il n'est pas possible de se limiter aux espèces parapluies, aux espèces dites indicatrices, ou aux organismes-modèles mais qu'il faut vraiment intégrer la diversité taxonomique dans la prise en compte de la biodiversité.

Ensuite, ces données sont acquises à la suite d'efforts lourds et longs, avec une taxonomie qui évolue tout au long de ces efforts. En conséquence, les données de la systématique permettent des suivis de la biodiversité (très longues séries temporelles) sur des sujets qui se révèlent être intéressants a posteriori mais il faut faire attention aux noms et à leur signification qui peut varier avec le temps.

Peut-être l'aspect le plus remarquable de ces données est qu'elles ne sont pas acquises via un ou deux protocoles clairs et par le même chercheur ou groupe de chercheurs.

Elles sont par nature hétérogènes et leur utilisation globale comme dans le cas de la présente étude sur la Nouvelle-Calédonie demande toute une série de contrôles pour s'assurer de la qualité des données, de leur validation et de ce qu'elles représentent en termes d'effort d'échantillonnage.

Il n'en reste pas moins que ces contraintes d'utilisation sont peu de choses en regard de l'intérêt de ces données, qui représentent une quantité d'information exceptionnelle.

Enfin, les conclusions tirées d'approches globales comme celles que j'ai menées permettent non seulement de proposer des conclusions assez générales au plan biologique mais elles permettent aussi de présenter un état des lieux de la biodiversité qui est pertinent pour les gestionnaires des milieux naturels et pour la conservation de la biodiversité.

L'ensemble de ces caractéristiques et de ce potentiel des données de la systématique pour la biodiversité est particulièrement important pour le futur. Non seulement on peut réaliser des bilans rétrospectifs et caractériser des tendances mais en plus on possède ainsi un bilan qui permettra d'orienter potentiellement les politiques de conservation, de gestion, ou de valorisation de la biodiversité.

Références

- Bouchet P, Jaffré T, & Veillon J M (1998) Threatened plants of New Caledonia: Is the system of protected areas adequate? *Biodiversity and Conservation* 7, 109-135.
- Caesar M, Roy R, Legendre F, Grandcolas P, & Pellens R (2015) Catalogue of Dictyoptera from Syria and neighbouring countries (Lebanon, Turkey, Iraq and Jordan). *Zootaxa* 3948(1): 71-92.
- Grandcolas P (2017) Ten false ideas about New Caledonia biogeography. *Cladistics*, sous presse.
- Grandcolas P, Murienne J, Robillard T, Desutter-Grandcolas L, Jourdan H, Guilbert E, & Deharveng L (2008) New Caledonia: a very old Darwinian island? *Philosophical Transactions of the Royal Society of London, B* 363, 3309-3317.
- Jaffré T (1993) The Relationship between Ecological Diversity and Floristic Diversity in New Caledonia. *Biodiversity Letters* 1, 82-87.
- Kumar S, & Stohlgren TJ (2009) Maxent modeling for predicting suitable habitat for threatened and endangered tree *Canacomyrica monticola* in New Caledonia. *Journal of Ecology and Natural Environment* 1, 94-98.
- May RM (1990) Taxonomy as destiny. *Nature* 347, 129-130.
- Morat P, Veilloz JM, and MacKee HS (1986) Floristic relationships of New Caledonian rainforest phanerogams. *Telopea* 2, 631-679.
- Murienne J, Guilbert E, & Grandcolas P (2009) Species diversity in the New Caledonian endemic genera *Cephalidiosus* and *Nobarnus* (Insecta: Heteroptera: Tingidae), an approach using phylogeny and species distribution modeling. *Biological Journal of the Linnean Society* 97, 177-184.
- Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, & Kent J (2000) Biodiversity hotspots for conservation priorities. *Nature* 403, 853-858.
- Nattier R, Robillard T, Desutter-Grandcolas L, Couloux A, & Grandcolas P (2011) Older than New Caledonia emergence? A molecular phylogenetic study of the eneopterine crickets (Orthoptera: Grylloidea). *Journal of Biogeography* 38, 2195-2209.
- Nattier R, Grandcolas P, Elias M, Desutter-Grandcolas L, Jourdan H, Couloux A, & Robillard T (2012) Secondary sympatry caused by range expansion informs on the dynamics of microendemism in a biodiversity hotspot. *Plos ONE* 7, e48047.
- Nattier R, Grandcolas P, Jourdan H, Couloux A, Pellens R, et al. (2013) Climate and soil type together explain the distribution of microendemic species in a biodiversity hotspot. *PLoS ONE* 8: e80811.

- Nattier R, Pellens R, Robillard T, Jourdan H, Legendre F, Caesar M, Nel A, & Grandcolas P (2017) Updating the phylogenetic dating of New Caledonian biodiversity with a meta-analysis of the available evidence. *Scientific Reports*, sous presse.
- Pellens R, & Grandcolas P (2010) Conservation and management of the biodiversity in a hotspot characterized by short range endemism and rarity: the challenge of New Caledonia. In *Biodiversity Hotspots* (Rescigno, V. and Maletta, S., eds), pp. 139-151, Nova Publishers.
- Pellens R, Arhends A, Hollingsworth P, & Grandcolas P (2016) Assessing Hotspots of Evolutionary History with Data from Multiple Phylogenies: An Analysis of Endemic Clades from New Caledonia. In *Biodiversity Conservation and Phylogenetic Systematics: preserving our evolutionary heritage in an extinction crisis* (Pellens, R. and Grandcolas, P., eds), pp. 237-262, Springer Open.
- Pouteau R, & Birnbaum P (2016) Island biodiversity hotspots are getting hotter: vulnerability of tree species to climate change in New Caledonia. *Biological Conservation* 201, 111-119.
- Pouteau R, Trueba S, Feild TS, & Isnard S (2015) New Caledonia: a Pleistocene refugium for rain forest lineages of relict angiosperms. *Journal of Biogeography* 42, 2062-2077.
- Pyke GH, & Ehrlich PR (2010) Biological collections and ecological / environmental research: a review, some observations and a look to the future. *Biological Reviews* 85, 247-266.
- Rabinowitz D (1981) Seven forms of rarity. In: Synge H. (ed) *The Biological Aspects of Rare Plant Conservation*. John Wiley, New York, pp. 205-217.
- Reusch DN (2011) New Caledonian carbon sinks at the onset of Antarctic glaciation. *Geology* 39:807-810.
- Richardson JE, Weitz FM, Fay MF, Cronk QCB, Linder HP, et al. (2001) Rapid and recent origin of species richness in the Cape flora of South Africa. *Nature* 412: 181-183.
- Swenson U, Nylinder S, & Munzinger J (2014) Sapotaceae biogeography supports New Caledonia being an old Darwinian island. *Journal of Biogeography* 41, 797-809.
- Ungricht S, Rasplus, JY, & Kjellberg F (2005) Extinction threat evaluation of endemic fig trees of New Caledonia: Priority assessment for taxonomy and conservation with herbarium collections. *Biodiversity and Conservation* 14, 205-232.
- Vences M, Wollenberg KC, Vieites DR, & Lees DC (2009) Madagascar as a model region of species diversification. *Trends in Ecology & Evolution* 24, 456-465.
- Wheeler QD, Raven PH, & Wilson EO (2004) Taxonomy: Impediment or Expedient? *Science* 303, 285.

Wulff AS, Hollingsworth PM, Ahrends A, Jaffré T, Veillon JM, L'Huillier L, & Fogliani B (2013) Conservation Priorities in a Biodiversity Hotspot: Analysis of Narrow Endemic Plant Species in New Caledonia. *Plos ONE* 8, e73371.