TWENTY-YEAR DEVELOPMENT OF ZOOLOGICAL AND BOTANICAL RESEARCH TOPICS IN THE UNIVERSITY OF ANTANANARIVO: IMPLICATION FOR FUTURE CHALLENGES OF BIODIVERSITY CONSERVATION

Hajanirina RAKOTOMANANA
Department of Zoology & Animal Biodiversity, Faculty of Science, University of Antananarivo, Madagascar
Aro Vonjy RAMAROSANDRATANA
Department of Plant Ecology and Biology, Faculty of Science, University of Antananarivo, Madagascar

ABSTRACT The Department of Zoology and Animal Biodiversity (DZAB) and the Department of Plant Ecology and Biology (DPEB), Faculty of Science, University of Antananarivo, Madagascar), have played a major role in the education of the national natural scientists since 1990. To assess their roles in fauna and flora conservation, the number of the graduated students per year, the number of research done by the two departments in Madagascar, the development of research topics, the type of ecosystem, and the type of jobs after the academic education were explored from 1995 to 2015. As results, those departments, through different partnerships and collaborations with overseas institutions (that include universities, associations and NGOs) have collected large quantity of biological data corresponding to 570 doctoral dissertations and master theses (276 from the field of zoology and 294 from the field of botany). 11 students defended theses on genetics, seven on Plant-Animal interactions and only one on Animal physiology, probably due to high cost of modern biological technologies or a bias in funding priorities. 95% of the studies were funded by international or national private agencies. The number of research undertaken by our students in both fields of zoology and botany has increased during the last decade. About 60% of the studies have been carried out in dense forest area in which research topics are less diversified than in other areas like coastal forest area, wetland, town/city, etc. Only 7% were carried out in marine, mangrove and coastal forest areas. Concerning the employment status of our graduates after the graduation, 125 among 210 graduates answered to the questionnaires and 64% of them are working with government or private agencies serving as consultants or permanent jobs on conservation. Thus, the two departments have played crucial roles in training a meritable generation of national natural scientists which are able to provide scientific expertise to support sustainable conservation. These departments can also be identified as a good networking system through fostering collaboration with the foreign institutions, and can be considered as data collectors. The biological data obtained by our students could be used and analyzed by stakeholders for biodiversity planning and monitoring process. The results from this study are expected to help the policy-makers and the users of information determine and set the conservation priorities in the future. To conclude, this study examines the different roles played by DZAB and DPEB in conserving Madagascar biodiversity, and presents their future challenges for improving the quality of education and research at the departments.

Key Words: Botany; Conservation; Department; Madagascar; Role; Zoology.

INTRODUCTION

The main threat to Madagascar's biodiversity is the loss of native forests (Harper et al., 2007). The slash and burn approach used by the island's farmers leads to uncontrolled bush fires which can be devastating in their own right for forests (Rakotomanana et al., 2013). In many areas the cleared land is abandoned after a few years and new areas of forests make way for agriculture (Scales, 2014a). On the coastline, mangrove forests are cleared for shrimp farms (Giri & Muhlhausen, 2008). The loss of these trees and other vegetation increases erosion and this can provoke a reduction of the quality of wetlands and their productivity as fisheries (Rasolofo & Ramilijaona, 2009). Selective logging of commercial valuable trees damages the structure of the forest, through opening the canopy and establishing new human settlement and roadways (Rakotomanana et al., 2013). However, habitat loss is not only threat. Hunting of protected species for food threatens many mammals, birds and reptiles in Madagascar (Garcia & Goodman, 2003; Jenkins et al., 2011). It is mainly carried out for subsistence purposes, but in some areas there is a high commercial demand for some species (Barrett & Ratsimbazafy, 2009; Randrianandrianina et al., 2010; Jenkins et al., 2011). In fact, the removal of endemic animals and plants from the wild threatens species throughout Madagascar because legislation governing the harvest is rarely implemented or simply ignored (Rakotomanana et al., 2013). When the rewards for illegal exportation of highly valuable species for international trade, like the rosewood trees (*Dalbergia maritima*), the angonoka tortoise (*Astrochelys yniphora*) and the radiated tortoise (*A. radiata*), are high, it becomes increasingly more difficult to combat the threats (Innes, 2010; Castellano et al., 2013). Periodic political instability, with its substantial and negative impacts on conservation issues and corruption accentuated the challenges faced by conservationists in Madagascar.

Due to those threats, Madagascar is known as a global biodiversity hotspot, not simply because it has a high diversity of species and most of which are found nowhere else on Earth, but because a high proportion of its endemic fauna and flora is threatened with extinction (Myer et al., 2000). The ability of national institutions to conserve the island's biodiversity is intrinsically linked to their human capacity and it is here that the university plays a key role in both training natural scientists and fostering collaborations. Through collaboration with overseas institutions, Department of Zoology and Animal Biodiversity (DZAB) and Department of Plant Ecology and Biology (DPEB), Faculty of Science, University of Antananarivo, have trained a significant number of Malagasy natural scientists since 1990 (Goodman & Benstead, 2003). They have played an important role for education and scientific research in order to minimize the increasing loss of biodiversity. The origin of above departments' dates from the foundation of the Faculty of Science in 1961. At the time, they were known as laboratories of zoology and botany. They have become departments since the number of teacher-researchers (who fulfill at the same time both higher education and academic research at the university) and students were increasing. The research slowly has begun to develop into a more significant activity in those academic institu-

tions.

This article provides the first assessment of the role of academic institutions in conserving the unique flora and fauna of Madagascar. The objectives of this article are to emphasize the performance of the two academic institutions in conservations issues, to ensure that science is better used to support sustainable conservation and to answer the future image of Madagascar in the next decades.

METHODS

DZAB and DPEB are two key departments working on the biodiversity in Madagascar. Those departments have been part of scientific committee of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) since 2005 (DPEB is still in the scientific authority whereas DZAB was until 2012). We reviewed 570 master theses and doctoral dissertations (from 1995 to 2015) at those departments. The degrees offered by DZAB totaled 276 consisting of 241 Masters and 35 PhD and those offered by DPEB were 294 consisting of 255 Masters and 39 PhD during 20 years. Every three years through that 20 year-period, the development of research topics was examined in those theses and dissertations. From these, the geographical distribution of research topics, the proportion of topics in different ecosystems, the number of the graduated students per year, the type of research topics, the number of research done in different ecosystems, the type of study areas (ecosystem type) and the origin of research funding were explored. Following the map of FTM BD 500 (Malagasy National Geographic and Hydrographic Institute) classification, the ecosystems where the studies were carried out were categorized as: dense forest (including rain forest, dry forest and spiny forest), degraded forest, coastal forest, thicket, crop, mangrove, grassland, reforestation area, wetland, marine ecosystem, city and others. On the basis of the main data obtained in each thesis or dissertation, the research topics were classified as Animal conservation, Animal species inventory, Animal systematics, Epidemiology, Parasitology, Ethology, Animal Physiology and Genetics in DZAB, whereas Plant species inventory, Natural product, Plant breeding/Agriculture, Animal-Plant interactions, Plant Systematics/Palynology, Restoration/Environmental Impact Assessment (EIA)/Plant conservation, Ethnobotany in DPEB. For simplicity, research topic was then counted as one case per thesis or dissertation in the analysis. However, for each study, ecosystem types and different geographical distributions were counted. To analyze the diversity of research topics in the different habitats, we used Shannon–Wiener index (H') (Magurran, 1988). A chi-square test (X^2) was used to determine whether there is a significant difference or not between the number of studies and the topics and between the proportion of research topics and the type of ecosystem. For inquiring about the employment status after the graduation, we prepared questionnaire for 210 graduates whose emails are available. The questionnaire has only the following information; name of the graduate, his or her current job, and name of organization and length of time in current job. The employment status was categorized as; Conservation jobs (environmental officers at Government, private agencies,

big company and consultants), research jobs (teacher-researchers at the Higher education, researchers at center of research and institute), administration jobs (officers at private agencies that are not concerned with environmental conservation) and education job (teachers at the College level). Those who have not their job up to the present time were considered as unemployed.

RESULTS

The two departments are composed of 41 permanent teacher-researchers (2 Assistant Professors, 28 Associate Professors and 11 Professors). Those teacher-researchers have different specialties on plants and animals. On average, 27.1 ± 13.6 students per year obtained their degree in those departments. Fig. 1 suggested that most of the studies were carried out in the dense forest both in the fields of zoology and botany. Some ecosystems such as degraded forest, mangrove, crop and reforestation area remained unexplored in the field of zoology whereas the marine ecosystem and wetland were not explored in the field of botany. Many of our graduate students had developed their theses on the following topics; 113 on Animal species inventory, 94 on Plant species inventory, 74 on Ethology, 60 on Plant physiology and 35 on Restoration/EIA/Plant conservation. Only very few students have presented theses on the following topics; 19 on Ethnobotany and 11 on Genetics, seven on Animal-Plant interactions, five on Epidemiology and only one on Animal physiology. The number of research and topics varied significantly with the years (from 1995–2015) both in the fields of zoology and botany (X^2 = 438.4, $P < 0.01$, ddl = 36; X^2 = 149.1, $P < 0.01$, ddl = 36 respectively) (Fig. 2). Some topics like Genetics, Epidemiology and Plant-Animal interactions started to appear and to be developed in the middle of 2001-2003. In Fig. 3, the data shows that the percentage of research done and the topics varied significantly with the type of ecosystem (from 1995–2015) both in the fields of zoology and botany (X^2 = 564.0, $P < 0.0001$, ddl = 36; X^2 = 904.0, $P < 0.0001$, ddl = 48, respectively). However, the research topics are less diversified in dense forest (H' = 1.4) than in coastal forest (H' = 1.5) and wetland (H'= 1.4) in the field of zoology whereas they are also less diversified in dense forest (H' = 1.5) than in others (H' = 1.9) and town/city (H' = 1.7) in the field of botany. 90% of those studies were funded by international NGOs (Institute for the Conservation of Tropical Environments, The Missouri Botanical Garden, Kyoto University, Michigan University, The Peregrine Fund, Word Wide Fund for Nature, Wildlife Conservation Society, Deutsches Primatenzentrum, etc.) and the two departments have developed 89 protocols of collaboration (31 from the DZAB and 58 from the DPEB) with overseas institutions during 20 years.

The map (Fig. 4) shows the distribution of research done by the two departments in the different parts of the island during the two decades. Some regional points have the different-sized circles with the same color because research site locations were very close to each other. Many of the circles (small, medium and big-sized circles) are generally grouped in central eastern side (corresponding to Andasibe-Mantadia, Analamazaotra, Maromizaha dense rainforests, the corridor

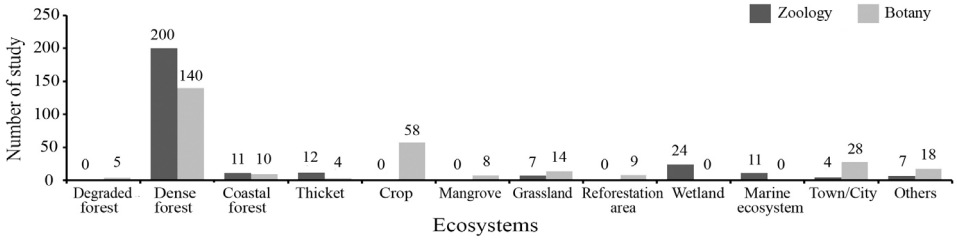

Fig. 1. The number of research undertaken in the different ecosystems

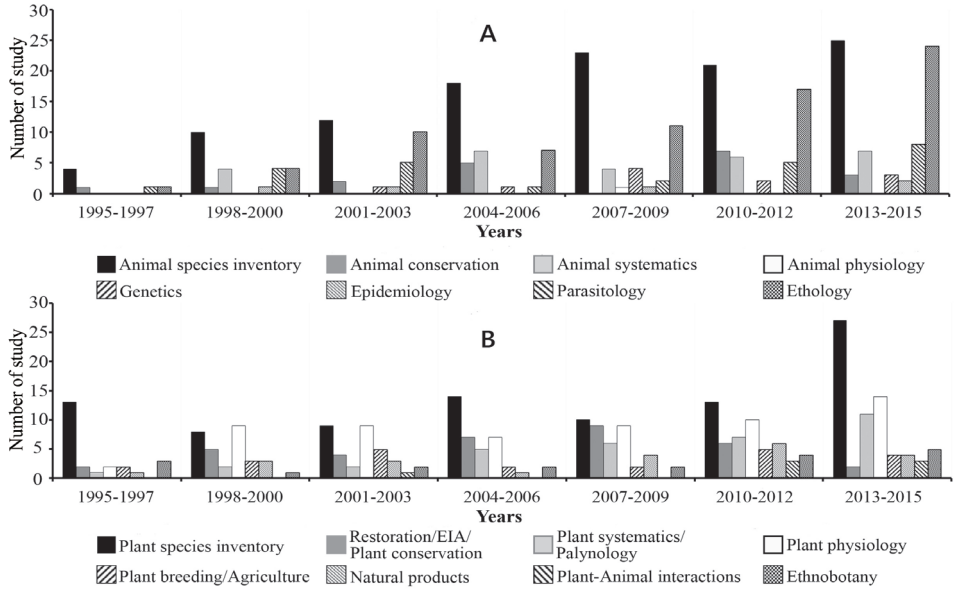

Fig. 2. The number of studies in each topic at DZAB (A) and DPEB (B) from 1995 to 2015

Zahamena-Ankeniheny, the Torotorofotsy Ramsar site), and scattered in northern side of the island. Very few studies were carried out in southern and western Madagascar. Big-sized circles in some parts of the island correspond to the famous protected areas which contain dense forests, harboring high densities of animals and plants, for example, tropical rainforests of Andasibe-Mantadia and Ranomafana in the east, tropical deciduous dry forest of Ankarafantsika in the northwest and tropical dry forest of Kirindy in the southwest of the island.

Nowadays, 60% of graduates who received a questionnaire by email responded. 64% of the respondents had a conservation job, 24% had a research job, 6% had an administration job, 5% had an education job and 1% was unemployed. Some of them have top ranking positions (decision-makers, head of international NGOs, scientific coordinators of different projects, top researchers, national park managers, etc.) at different governmental organizations, conservation NGO, the universities, etc.

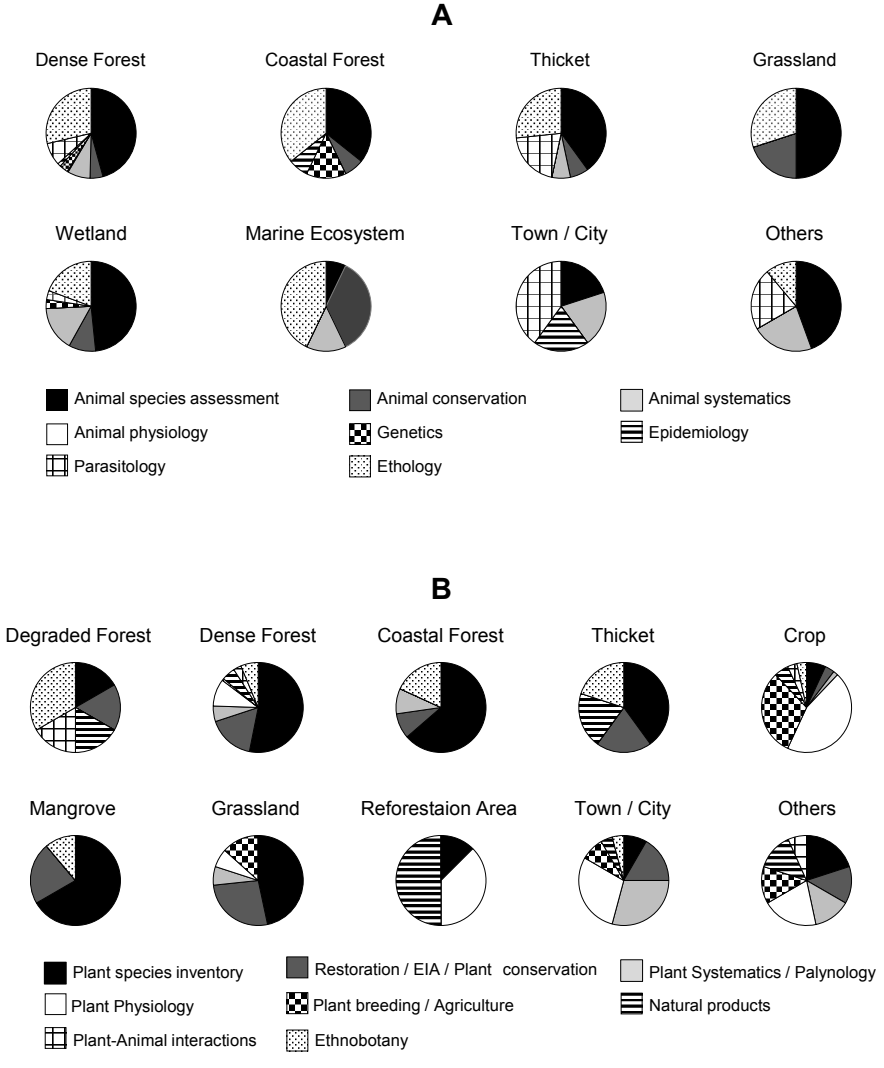

Fig. 3. The proportion of research topics per ecosystem in the fields of zoology (A) and botany (B)

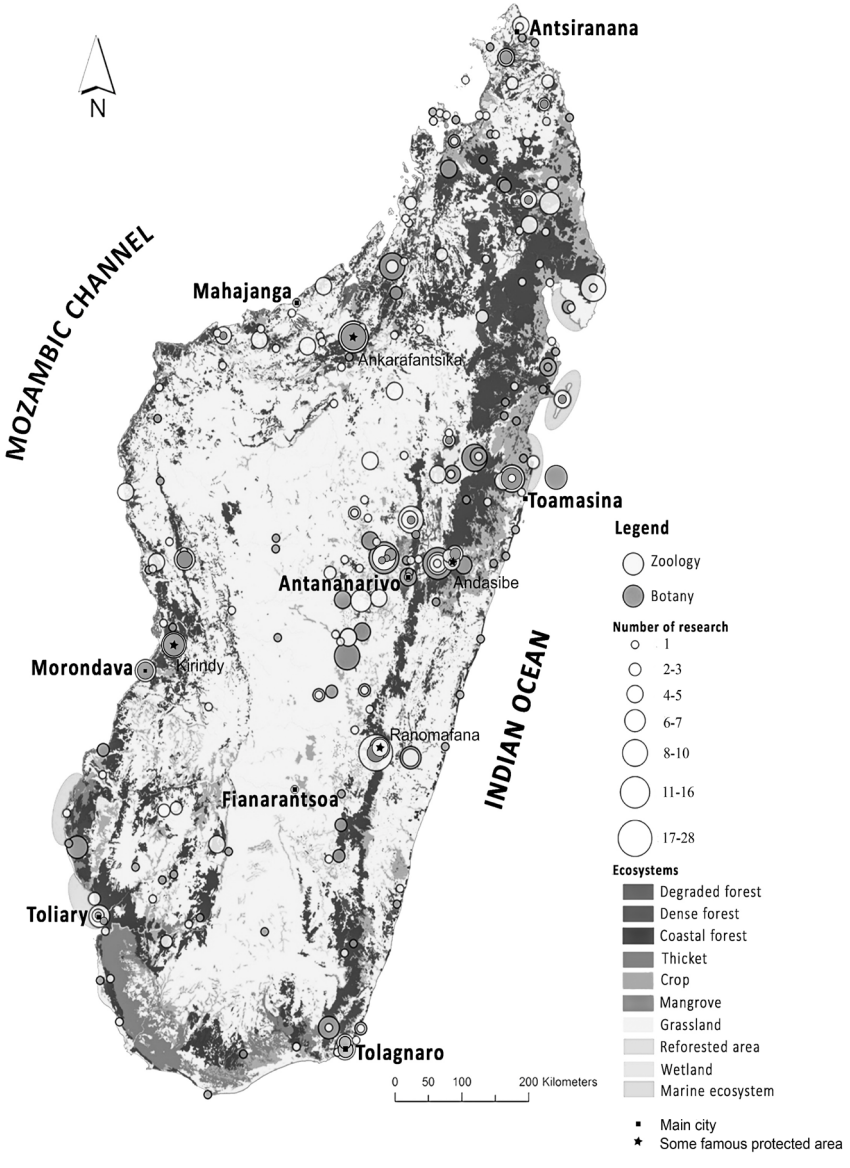

Fig. 4. The distribution map of research done in the fields of zoology and botany (the map was modified from vegetation map of FTM BD 500)

DISCUSSION

I. The roles of DZAB and DPEB

In this assessment, 571 theses were explored. In different ways, the two academic institutions play crucial roles in conservation of the Madagascar's megabiodiversity although their budget is very limited. Consequently, they have fostered collaborations with many international agencies for developing the education of their students and developed a good networking system. Accordingly, from the last two decades, the two academic institutions have produced meritable generations of Malagasy natural scientists which after their education are working as teacher-researchers, researchers, college teachers, environmental officers, etc. The results from the questionnaires show general career trends for biodiversity conservation although data might be biased due to lack of email address of all graduates and non-response (of 40% of the object graduates) survey. Nowadays, some of these professionals on conservation are occupying very important positions in the government organizations, international NGOs, etc. Then, they could be key people who are able to develop and direct sustainable conservation strategies. They provide scientific expertise to support the sustainable conservation and to restore the environment for local development through applied research, conservation dataset, education, planning and other services. But, we think that Madagascar still needs more professionals to combat the extensive degradation of its natural forests in the future. We believe that local solution has lasting impact, and has become a critical step toward minimizing the biodiversity loss in Madagascar. The important biological data obtained by our students could be used and analyzed by stakeholders and practitioners for insight that leads to better strategic decisions in the future.

It is important to note that many of the dissertations and theses have been published in the national and international journals. The results of this study suggest that national natural scientists have made remarkable progress in Animal and Plant species inventories, Plant physiology and Ethology. Much of the information was used and put into the recent national protected area planning process (Corson, 2014). On the other hand, in the field of Animal physiology, Epidemiology, Ethnobotany, Animal-Plant interactions, Genetics, a great deal is still remained to be studied, due probably to high cost of modern biological technologies or a bias in funding priorities. Another reason is that some of these topics might be much studied by specializing departments like the Department of Animal Physiology at the Faculty of Science and Department of Epidemiology at the Faculty of Medicine.

Madagascar's megabiodiversity has long attracted natural scientists from overseas in recent years although its loss does not seem to slow down (Butchart et al., 2010). Their arrival to Madagascar has increased considerably the number of studies conducted during the last decade in Madagascar. One of the reasons of the increase might be the declaration of the President Marc Ravalomanana to expand the surface of protected areas from 1.7 million to 6 million hectares at the World Parks Congress in Durban, South Africa, in 2003. Consequently, the

Madagascar Biodiversity Fund (the biggest endowment for the environment in Africa) was created in 2005. Through its funding, the foundation has supported significant number of research studies in the national park and reserve network, and the protocol of collaboration between our departments and foreign institutions has become more numerous.

This study shows the number of studies done by the graduate students at the two departments from 1995 to 2015. However, despite the great efforts made by the two departments, there is still a considerable gap in terms of knowledge of environmental change across the island (Fig. 4) because some of areas have been completely neglected or forgotten for example, mangrove and grassland areas (further mentioned by Scales, 2014b). Most of studies (60%) at our departments were carried out in dense forest in both fields of zoology and botany. The main reason is that there was a tendency to see Madagascar's dense forest to be the last fortress of the island's wild nature (Scales, 2014b) which suffered rapid degradation. Thus, these remaining wide forests were identified as National Conservation Priority (Ganzhorn et al., 2001), and numerous researches have been financially supported by international donors and conservation groups in those areas. From a conservation view, more attention has been paid and more efforts have tended to concentrate on protecting Madagascar's remaining forests since they are estimated to contain the majority of the island's endemic terrestrial animal and plant species (Goodman & Benstead, 2003). It is also essential to note that mainly the all year accessible areas equipped with big infrastructure for research (for example Ranomafana, Andasibe-Mantadia and Ankarafantsika national parks) have attracted more researchers. Those areas have long term research programs with various overseas institutions which have provided support and mentoring to Malagasy students (LCN, 2015; Wright et al., 2012; G. S. Ramangason, pers. com.). The map (Fig. 4) is expected to help conservation policy-makers (for example, The Ministry of Environment) and the users of scientific information (for example, The Madagascar National Park) determine and set the conservation priorities and vision.

We are convinced that science could be used to support conservation. Many international NGOs state that their conservation planning and decision making is based on sound science. Even when scientific data or publications on a subject are unavailable, managers, donors, governments often seek the opinion of scientists (Rakotomanana et al., 2013). Science can make an important contribution to conservation in Madagascar, and elsewhere, it is not in question. It is though perhaps considering whether scientific studies at the two departments are aligned to the needs of conservation. The scientific approach of evaluating hypotheses, statistical testing and transparent peer-reviewed publication of the results is used by conservation biologists.

II. Challenges of the two departments in the next decades

The two departments have three main challenges: (1) improvement of student education, (2) improvement of research needed by Madagascar conservation and (3) communication of the scientific results.

Since student education is one of the most important ways which can have an enormous impact to global conservation, the preparation and elaboration of most up-to-date local university programs in environmental sciences become a major challenge for the university teacher-researchers. Then, we have a fundamental obligation to develop our professional ability and competence, and then to familiarize our students with the basic concepts and necessary background for the study of conservation. The introduction of an up-to-date and a broad knowledge of ecology and conservation studies in our programs are needed because most of the members at our departments are too specialized in their field, and our departments in particular, have not had access to broad interdisciplinary training. The training of teacher-researchers is thus required in order to support the autonomous development of scientific staff of the local university (also mentioned in Bendix et al., 2013). Moreover, for an effective management and conservation of tropical forests, we believe that the university would become a leading institution capable of providing effective professional training, technical assistance and professional advices to the Government and local community. In relation to drastic population increase and the pressure from biodiversity loss, the two departments should have potential to increase the capacity to receive more students in the near future and develop capacity building strategy for supporting the academic training. The latter effort was already organized with international organizations like Tropical Biology Association (TBA), Institute for Conservation of Tropical Environment (ICTE), Association of Tropical Biology and Conservation (ATBC), etc. We think that capacity building should be effectively based and sustained for the benefit of the local community.

The second challenge in the future is for the overseas institutions and our institutions to make an improved contribution to the research needed by Madagascar. It is time now for the departments to have a strategic look at the type of research that is needed for country conservation. At the 10th meeting of the Conference of the Parties to the Convention on Biological Diversity in Nagoya, Japan, 2010, some of the targets that were agreed concerned ecosystem services, improving benefits from biodiversity, avoiding extinction and improving the sustainable use of natural resources. As an example, it might be useful to focus research on the ecological role of primates as seed dispersers (Dew & Wright, 1998; Ganzhorn et al., 1999; Sato, 2013; Martinez & Razafindratsima, 2014), their value to ecotourism (Maille & Mendelsohn, 1993) and drivers of illegal bushmeat hunting (Jenkins et al., 2011). An ideal world would see research projects on all of these, but there has been a bias towards the latter in Madagascar. The overseas scientists' research projects typically include an important contribution to training Malagasy students, but in many cases probably do not contribute directly to conservation (for example the Animal physiology, Natural products). Indeed, a recent collaborative publication by a number of natural scientist activities in Madagascar concluded that more research should be orientated towards answering conservation-relevant questions (Irwin et al., 2010).

The third challenge facing the two departments concerns the communication of the scientific results from different investigations. Like overseas natural scientists, national natural scientists are expected to publish their research findings in the

most influential journals. Those publications could enhance the university's international visibility and its global competitiveness (see Chou et al., 2013). However, a high profile publication in a high impact scientific journal about conservation, that might be genuinely useful in Madagascar, will have minimal impact unless greater effort is made to communicate the results to the potential beneficiaries (Rakotomanana et al., 2013). Scientists should identify the potential target audience, whether they are personnel from a protected area, or indigenous groups or government decision-makers, and explain the results of their research. This paper would like to emphasize the vital role played by the two departments through their trained manpower in educating local community. As we know, national natural scientists can communicate more smoothly with local community than overseas natural scientists can and thus, they would be able to transfer the knowledge from basic science to application. Public environmental education and training could be easily undertaken in order to foster and enhance education and awareness. It would be surprising if the feed-back during these meetings was in itself not helpful to the scientist to interpret the results differently or to design a new research project. Stakeholders in Madagascar need to welcome such initiatives, even if undertaken through translation, to maximize the benefit from research projects.

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——— Accepted *July 1, 2017*

Author's Names and Addresses: Hajanirina RAKOTOMANANA, *Department of Zoology & Animal Biodiversity, Faculty of Science, University of Antananarivo, MADAGASCAR.*
E-mail: rakotomh [at] yahoo.com
Aro Vonjy RAMAROSANDRATANA, *Department of Plant Ecology and Biology, Faculty of Science, University of Antananarivo, MADAGASCAR.*
E-mail: arovonjy [at] yahoo.fr