TEN YEARS of UDZUNGWA ECOLOGICAL MONITORING CENTRE

Report (2006-2016)

Science Museum MuSe

Report Prepared by Francesco Rovero and Claudia Barelli
(E-mail contact francesco.rovero@muse.it)
Layout editing: Osvaldo Negra
Printed by Grafiche Futura srl

Suggested citation: ROVERO F., BARELLI C. (2017). *Ten years of Udzungwa Ecological Monitoring Centre. Report (2006-2016).* MUSE – Museo delle Scienze, Trento, Italy.

Cover photos: R. Merler, F. Rovero

TEN YEARS of UDZUNGWA ECOLOGICAL MONITORING CENTRE

Report (2006-2016)

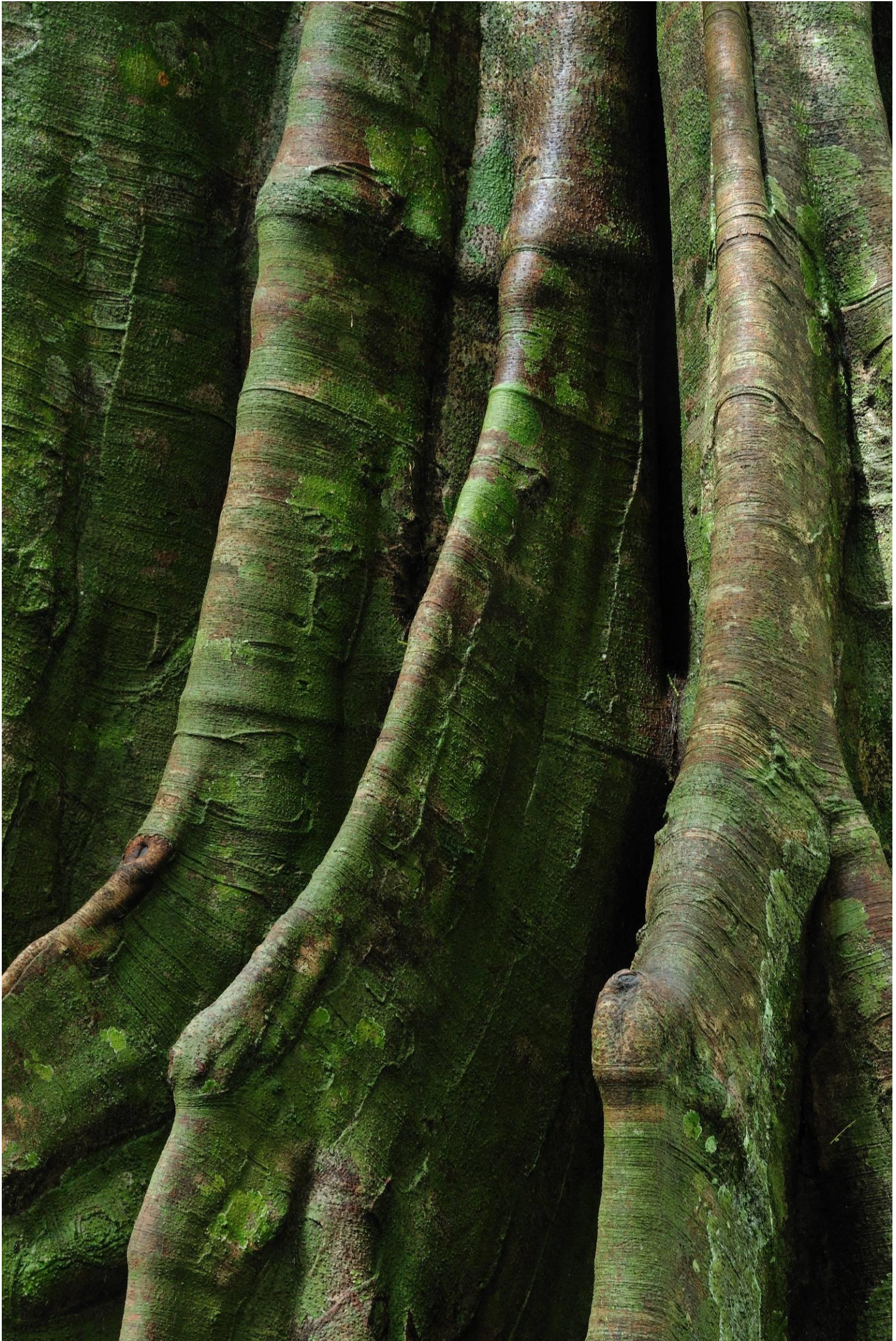
FOREWORD

With one-quarter of its surface set aside for conservation, Tanzania protects a variety of ecosystems with outstanding richness in biodiversity that are destinations of hundreds of thousands of people visiting each year. The 16 national parks under TANAPA (Tanzania National Park Authority) play a primary role in this scenario. Besides the world-famous Serengeti, Kilimanjaro and other parks, however, there are other unique parks that deserve as much attention, and Udzungwa Mountains National Park is among them. Not a 'conventional', savannah destination, Udzungwa hosts lush rainforests and is a heaven for hikers.

*Udzungwa is the only national park protecting a significant portion of the Eastern Arc Mountains, one of the single most outstanding biodiversity hotspots on the planet. Besides being home to endemic and flagship species such as the iconic Udzungwa red colobus (*Procolobus gordonorum*) and the Sanje mangabey (*Cercocebus sanjei*), the park—gazetted in 1992 and extending over nearly 2,000 km^2—protects a water-catchment basin of prime importance at the national level for hydroelectric and agricultural production. The park also provides water, a favourable climate and good soil fertility for roughly a million people living in its surroundings.*

Given this importance, the realization in 2006 of the Udzungwa Ecological Monitoring Centre (UEMC) has been particularly critical to ensure that adequate efforts and capacities are developed to assess and monitor the special but also vulnerable biological diversity of this park. It is therefore with great pleasure that on behalf of TANAPA I welcome this report that describes the many important accomplishment of UEMC during the past 10 years. These progresses set a valuable example within TANAPA of how ecological monitoring has a primary role for the effective protection of our parks' biodiversity. I thus also express sincere gratitude to MUSE - Science Museum (Trento, Italy) for supporting the establishment and management of the centre, and I hope in a continued and fruitful collaboration in the years to come.

Allan J.H. Kijazi
Director General, Tanzania National Parks



PREFACE

In their essence, modern natural science museums are places where the public explores the beauty and diversity of nature, and understands that caring for it has become everyone's responsibility. In a globalised planet, this mission of museums often extends beyond the involvement in their local natural and social settings. The long-term involvement of MUSE – Science Museum (Trento, Italy) in the Udzungwa Mountains of Tanzania well exemplifies this move, and aligns MUSE with the many important museums in the world that take active part in research and conservation of tropical forests, the world's richest but most threatened biome.

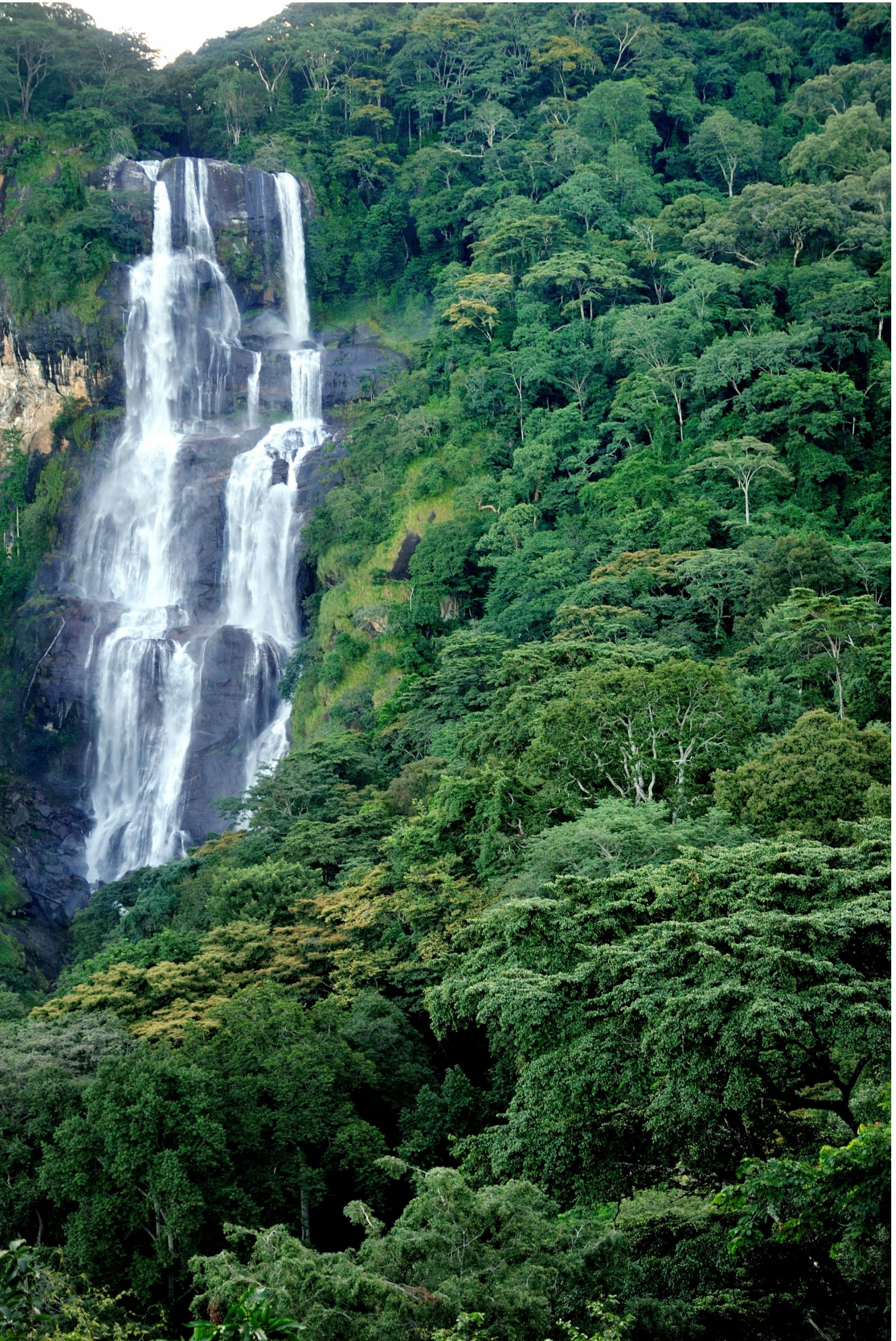
MUSE is the science museum of Trento, in northern Italy, which in 2013 moved from a historical building to a new structure designed by architect Renzo Piano, thus enlarging its scope from that of a local natural science museum to one of a world-class science museum. In the museum exhibits, the Udzungwa Mountains occupy a special place, as the visitors' itinerary includes a tropical greenhouse that reproduces a 'live' piece of Udzungwa rainforest. During the four years since MUSE opened its doors, an impressive 2.5 million visitors have had a chance to learn about this place and marvel at its beauty.

The featuring of Udzungwa within MUSE spawns from the museum's actual involvement in the area. Since the late 1990s, museum researchers visited the Udzungwa, driven by the curiosity for its outstanding and yet little known biodiversity. A few years later, this interest triggered a long-term programme that in 2006 established the Udzungwa Ecological Monitoring Centre with Tanzania National Parks. This field station enabled long-term research and facilitated the work of dozens of other researchers and institutions, hence contributing data and understanding of Udzungwa's biological diversity and the fragile balance of its vulnerable ecosystem. At the same time, UEMC activities blended research, monitoring, training and community education, hence effectively realizing the core museum's mission: using scientific tools to bridge biodiversity and the environmental awareness of the local community and institutions.

By summarizing the wealth of activities and achievements over a decade, this report is an important tool to document UEMC efforts and draw wider attention on one of Tanzania's prime biodiversity areas. We hope that UEMC will continue to play a role for years to come as an example of sustainable approaches to biodiversity monitoring and conservation. Towards this purpose we are especially proud to have contributed the establishment of the newly realized Visitor Information Centre at the park premises, an invaluable and innovative tool for boosting education and enriching the experience of community members and tourists.

Michele Lanzinger
Director, MUSE – Museo delle Scienze

CONTENTS



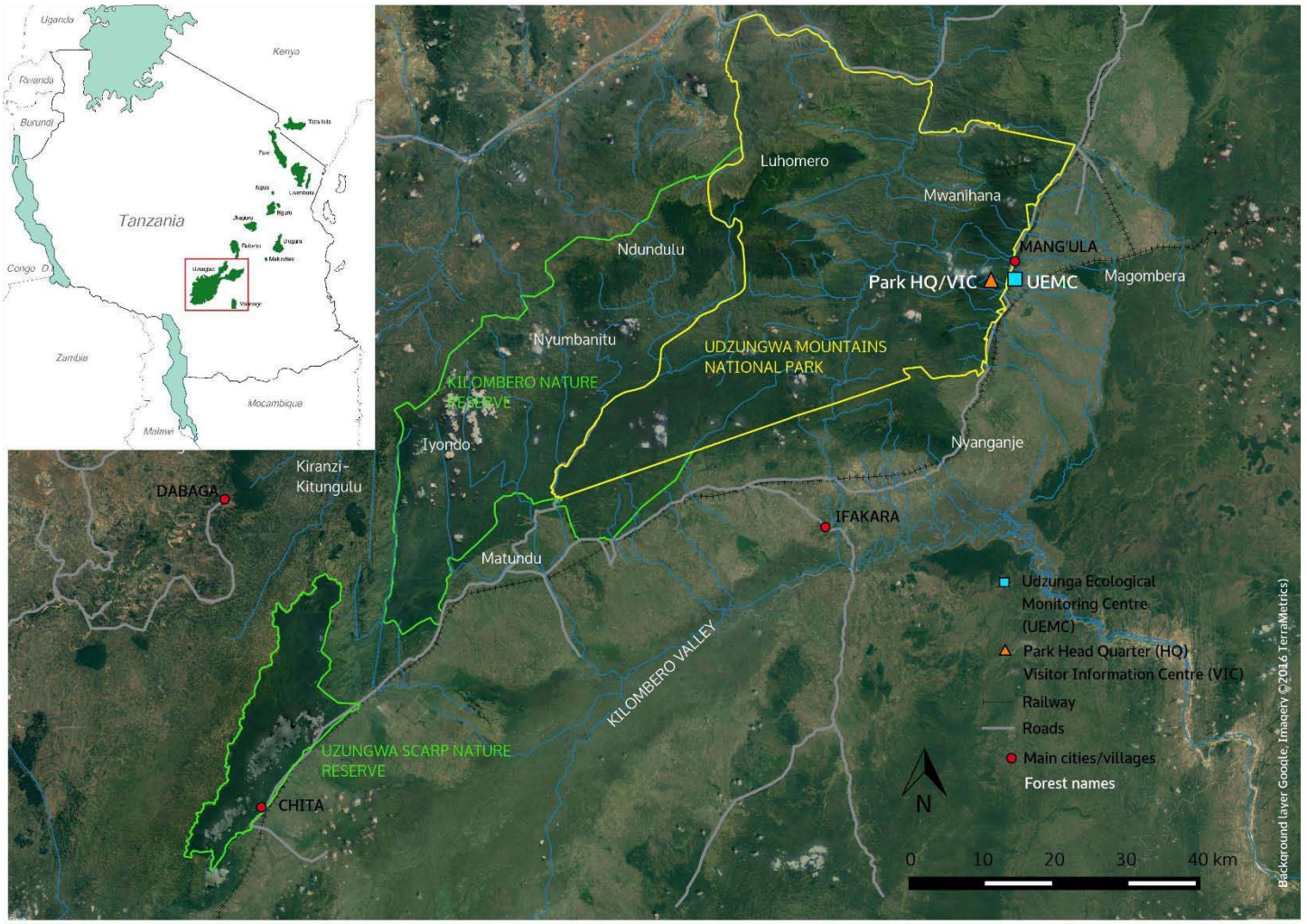
BACKGROUND

The Udzungwa Ecological Monitoring Centre (UEMC) is a field station of the Udzungwa Mountains National Park (UMNP), Tanzania, established by Italy's MUSE – Science Museum in 2006 in partnership with Tanzanian National Parks (TANAPA). Beyond providing accommodation and research facilities to local and visiting scientists and students, UEMC aims to provide technical advisory to the National Park and more generally to facilitate research, conservation planning and community outreach programmes in the area. Among the strategic activities, UEMC contributes to the implementation of biodiversity monitoring programmes, the organization of training courses for rangers, park ecologists and university students, the promotion of school education programmes for scholars, as well as networking with other biological field stations in the tropics.

Located in south-central Tanzania, the Udzungwa Mountains (hereafter also called 'Udzungwas') occupy an area of approximately 19,000 km^2, comprising the largest remaining forests blocks in the Eastern Arc Mountains, a renowned region ranging from southern Kenya to Tanzania within the *Eastern Afromontane Biodiversity Hotspot.*

Covering an altitudinal gradient of 300 m in the Kilombero valley to 2,576 m at Luhomero peak, the Udzungwas include tropical lowland and montane rainforest, as well as miombo woodland, dense dry forest, and grassland. This region holds outstanding levels of biological diversity and endemism comprising **more than 400 bird species, over 120 mammals and 2,500 species of plants.**

The Udzungwa Mountains are a mosaic of forest blocks interspersed with drier and settled or farmed areas, with most of the natural habitat protected under different reserve categories. The Udzungwa Mountains National Park protects 1990 km^2 in the north-eastern portion of the range, while Kilkombero and Udzungwa Scarp Nature Reserves protect other important chunks of natural habitat.



Owing to a combination of natural (i.e., geology, climate) and human-induced factors (i.e., subsistence and commercial logging, pole cutting agriculture, bushfires), the habitats in Udzungwas are highly fragmented, making a mosaic of intact and modified closed-canopy forests interspersed with drier habitats, settlements and agricultural areas. In particular, the conversion of surrounding lands in the Kilombero valley into intensive agriculture for sugar cane and rice, and the associated infrastructural and human population increases, pose the highest threats to biodiversity in the Udzungwa landscape.

By the early 2000s, the outstanding biological value of the Udzungwas had triggered considerable international research attention.

This matched the mission of TANAPA for the conservation of the outstanding natural heritage in the country, and its mandate of realizing an ecological monitoring centre in each park to effectively monitor biodiversity.

Concomitantly, MUSE - Science Museum (a world-class museum of natural science in Italy) had just started a research programme within the Udzungwa Mountains National Park. MUSE merged the needs for facilitating the increased research presence in the area and realizing an ecological monitoring centre by proposing the establishment of a field station. In 2006, MUSE entered into agreement with TANAPA. This agreement was instrumental to fund and establish the core buildings first and the hostel subsequently. The funding came mainly from Trento's province administration (Trento Autonomous Province), with co-funding from the US-based Margot Marsh Biodiversity Fund. MUSE has run and coordinated UEMC for the first 10 years in partnership with TANAPA.

This report describes ten years of UEMC activities towards achieving UEMC mission and it ends by outlining the perspectives.

The Udzungwa red colobus (*Procolobus gordonorum*) is one of the iconic species in this area that holds outstanding levels of biological diversity and endemism comprising more than 400 bird species, over 120 mammals and 2,500 species of plants.

MISSION

The mission of UEMC is to increase the understanding of the biological importance of the Udzungwa Mountains by promoting and facilitating research and monitoring of biological diversity. UEMC aimed to make use of the long-term data collected within this area for developing more effective conservation management and community education plans for the preservation of the Udzungwa Mountains National Park, as well as the adjacent Forest and Nature Reserves.

UEMC aims to make use of the long-term data collected on biodiversity to develop more effective conservation management and community education plans for the preservation of the Udzungwas.


Museo delle scienze
MUSE
HIFADHI ZA TAIFA
TANZANIA
NATIONAL PARKS
NATURAL
HISTORY MUSEUM
OF DENMARK
UNIVERSITY OF
COPENHAGEN
UEMC OFFICE, SEMINAR ROOM AND
RESEARCHERS HOUSE'S
UEMC HOSTEL & DINING HALL.

MANAGEMENT & RESOURCES

UEMC was inaugurated on the 10th of November 2006 and it is located within TANAPA plot near the park headquarters in Mang'ula, in the Kilombero District of the Morogoro region.

The structure was donated by MUSE to TANAPA and it has been managed by MUSE for the 10 years following a formal agreement between the two institutions. MUSE-employed staff, including a coordinator, have attended the daily management routines, while a management committee - formed by representatives of both MUSE and the park - has ensured smooth cooperation and decision making on any relevant administrative matters.

MUSE reported to TANAPA on quarterly basis on UEMC activities and finances, and technical reports describing key achievements have been produced yearly and made publicly available through UEMC website (www.udzungwacentre.org).

UEMC has been established by MUSE in 2006 and donated to TANAPA. Here, representatives of TANAPA and MUSE inaugurates the UEMC hostel building in 2010.

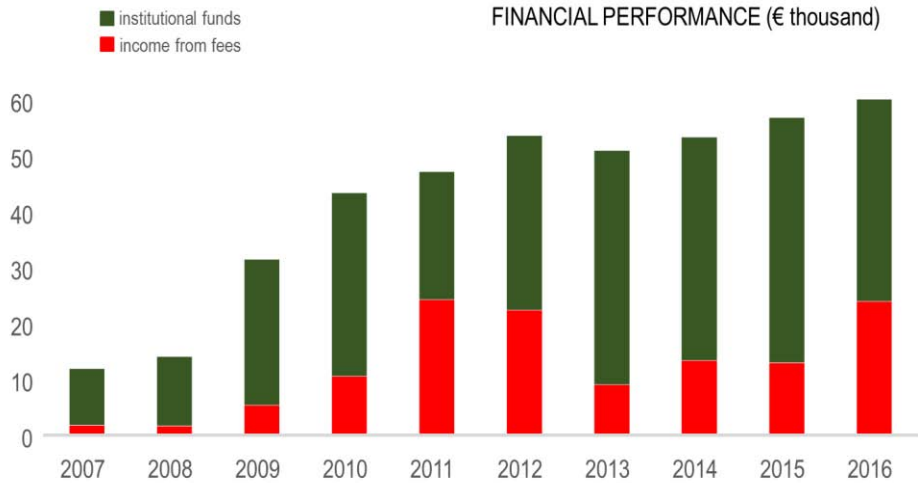
Since 2006, UEMC staff has increased the number of employees from 8 to 22 people, including 3 project coordinators, 10 project officers (which are mainly field technicians), 2 drivers, 1 gardener, 2 house attendants, 4 watchmen.

This section briefly illustrates the human and financial resources that ensured UEMC functioning. Since 2006, **UEMC staff has increased in number of employees from 8 to 22 people**. It was initially composed of one coordinator, one field assistant, one gardener, one housekeeper and four watchmen; as activities began to take off, more personnel came on board. These additions include a coordinator for logistic and environmental education, a school educational officer, more field assistants, gardeners, watchmen and drivers.

UEMC staff progressively gained experience and professionalism, and a number of technical staff enrolled into formal higher education with support from MUSE and its partners (see Activities & Achievements). Thus by 2016, UEMC with the long-term projects that are directly run by MUSE, particularly the TEAM Network project and Association Mazingira's community conservation project, employed 22 Tanzanians, including 3 project coordinators, 10 project officers (which are mainly field technicians), 2 drivers, 1 gardener, 2 house attendants, 4 watchmen.

UEMC has concomitantly grown in financial terms as a direct consequence of the increased volume of activities needing more personnel, vehicles and other assets. Such increase has been approximately 500%, from a **budget of around 12,000 € in 2007 to around 60,000 € in 2016**. While the institutional funds from MUSE have covered the bulk of funding in the first years, during the ten years of activity **UEMC was able to raise more than 30% of the total income from accommodation fees**, reaching its peak in 2011 when the income from fees exceeded the institutional funds.

However, UEMC never aimed to grow indefinitely: the underlying strategy has been to reach an affordable and manageable set of essential activities and then consolidate them over the next years, with critical attention at sustaining them over the long run.



Annual financial budget of UEMC in thousands of Euro during 2007-2016, divided by institutional funding, mainly from MUSE, and internal income, which overall represented 30% of the budget.

FACILITIES

The basic function of UEMC is to provide accommodation and facilities to visiting researchers, national students and international students staying in Udzungwa for training and research. Over the decade, UEMC diversified its offer. UEMC provides accommodation for short and long-term students and researchers, it also organizes summer schools and training courses, and it provides logistic support and lodging facilities for independently-organized courses and summer camps. In addition, UEMC facilitated research and conservation programmes led by external agencies.

In 2006, when UEMC was inaugurated, the facilities included four main buildings: an office with research facilities (Internet, computers, printers, maps and the like), a large (150 m^2) seminar room that can accommodate over 50 people, and three more buildings as researchers' houses. Each house has two self-contained double rooms, and shared kitchen corner and living room.

After a few years, it became obvious that more facilities were needed to accommodate more students and researchers. Thus, in February 2010, two more buildings were built: a large dormitory block with four rooms that can host up to 24 students, and a dining hall with annexed kitchen and stores. In addition, a store building was also built.

UEMC premises include three reseachers' houses, a seminar room for training and workshops, and a hostel/dining room for students that can accommodate up to 24 people.

ACTIVITIES & ACHIEVEMENTS

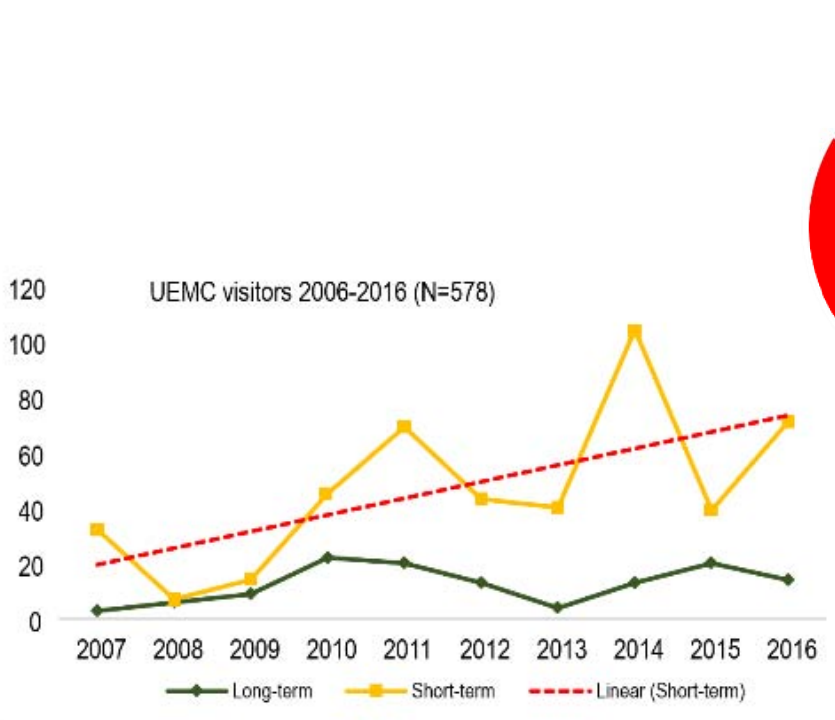
Main activities and related achievements are grouped as follows:

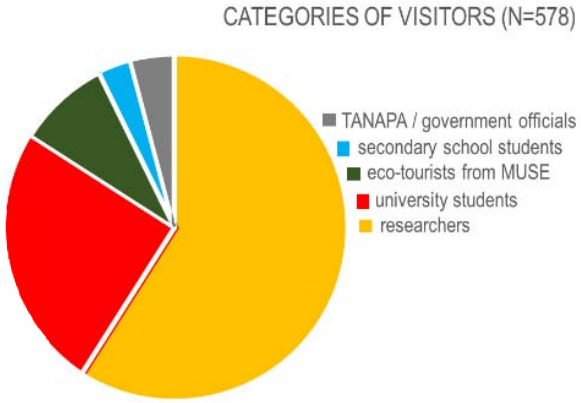
- Accommodating researchers and students
- Ecological monitoring
- Promoting and facilitating research and conservation programmes
- Technical advisory and training to TANAPA staff
- Provision of scholarships for higher education of local staff
- Environmental education and community-based conservation
- Networking among field stations, researchers and conservation agencies
- UEMC promotion and communication activities

ACCOMMODATING RESEARCHERS AND STUDENTS

Over the ten years of activity, UEMC hosted national and international researchers and students that lodged for short- to long-term periods. The **overall number of visitors reached over 1,200 people, including 23 Ph.D. and 7 Master students.** Most visitors (over 60%) came from abroad, indicating how UEMC has become a reference place for research, especially at international level. The total number reported here includes guests visiting on daily basis, representing approximately 50%.

Of all visitors, 10% included researchers and students that stayed at UEMC for one month or more, and 39% comprised researchers and students that lodged at UEMC for less than a month. Analyzing the number of visitors that lodged at UEMC by category reveals that **the vast majority was represented by researchers and students**, with a remaining share of other categories (eco-tourists, TANAPA and Government officials, secondary school students, and others).





The number of UEMC visitors by year (chart on the left) accommodated for short (less than 1 month) and long periods. The trend line shows that on average the number of short-term guests increased over the decade. The pie chart above reports the category of visitors lodged at UEMC, which were mainly (84%) researchers and students.

ECOLOGICAL MONITORING

Non-human primates

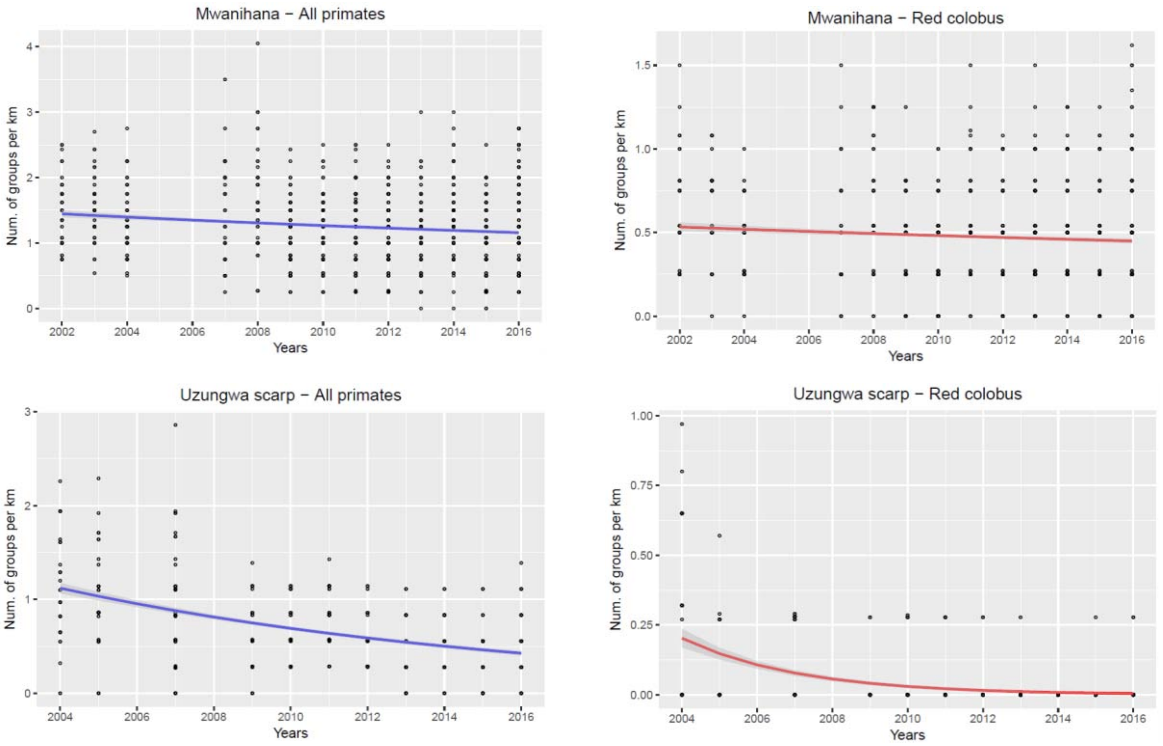
Primates are an iconic faunal group across the tropics: our closest relatives are among the most threatened animals on the planet, facing constant reduction across their range due to hunting and habitat loss. Yet, non-human primates are an essential component of tropical forest ecosystems. They are, therefore, a priority group for monitoring and conservation efforts. With 13 species, including range-restricted and endemic ones, **the Udzungwas are an outstanding hotspot in Africa for primate conservation**, and a recent assessment indicates that it is also **the top-ranking site in Tanzania for presence of globally rare, red-listed and range-restricted species and subspecies**. Thus, it is not surprising that a Primate Monitoring Programme has been in place for nearly two decades now, indeed representing the longest-term one, and yielding among the most important data-sets on any biological component of the Udzungwa forests.

Udzungwa is a global hotpost for primates. The Primate Monitoring Programme targets primarily the arboreal Udzungwa red colobus (top left), the Tanzania Sykes' monkey (top right) and the Angolan colobus (bottom right). The Sanje mangabey (bottom left) is primarily monitored by camera trapping.

The **Primate Monitoring Programme was set up in the late 1990s** by Thomas Struhsaker from Duke University as part of a broader primate research programme, co-led with Carolyn Ehardt and Thomas Butynski. The transect-based protocol for monitoring diurnal primates was placed in the east-facing Mwanihana forest, one of the largest blocks, easily accessible from the eastern edge of the National Park. Researchers identified four trails of 4 km in length as 'line transects', regularly maintained, that entered the forest from its edge leading west, and walked regularly by trained local technicians and students. Line transect counts are the most common method to monitor primate abundance: observers slowly walk the trail and record all sightings of primate social groups with their position along the trail (as indicated by tags placed on trees every 50 m), as well as the number of individuals and any other useful information. This includes the distance from transect to the animals seen, which can later allow researchers to estimate the density of groups or individuals. This is the 'actual' abundance in number of groups (or individuals) per unit area. Due to a relatively long phase of fine-tuning the programme, it was only from 2002 that data collection became standardized.
Moreover, from 2004, the programme was extended by Francesco Rovero of MUSE to another important forest, Uzungwa Scarp (now a Nature Reserve; USNR), 150 km to the southwest.

In 2006, UEMC took up this programme and continued the data collection in agreement with both the park's Ecology Department for Mwanihana forest and the Tanzania Forest Service for USNR. **By the end of 2016, an impressive sampling effort had been realized: 972 repetitions of the four transects in Mwanihana, and 401 of the three transects in USNR, which translates into over 5,200 km of transects surveyed overall.**

Among the diurnal primates occurring in Udzungwas, five species were regularly monitored, including the endangered and endemic Udzungwa red colobus monkey (*Procolobus gordonorum*), the Peters' Angola colobus (*Colobus angolensis*), the Tanzania Sykes' monkey (*Cercopithecus mitis monoides*), the endangered and endemic Sanje mangabey (*Cercocebus sanjei*) and the yellow baboon (*Papio cynocephalus*). However, the latter two species were not properly monitored, as they are mainly terrestrial and notably shy; therefore they are not easily sighted from transects. Sanje mangabey is Udzungwa's most iconic species, and fortunately it has been targeted by other research efforts, including monitoring through camera trapping (*see next session*).
It is not the purpose of this report to present the scientific results in great details, for which the reader is referred to annual technical reports available from UEMC website and the scientific literature. However, here the key results in terms of variation of population abundance in time, quantified as the number of primate groups counted per km of transect traversed, is summarizedd. This metric is called 'encounter rate' and is commonly considered a raw index of primate abundance. Thus, charts below show the actual data by year and the trend derived through regression analysis for all five primates, as well as for the Udzungwa red colobus.
These results clearly highlight a key contrast in population abundance dynamics between the two study forests: first, the relative abundance in terms of primate groups' encounter rate is generally lower in USNR than in the Park, with the only exception of the Sykes's monkey, an opportunistic species that seemingly thrives in disturbed habitat with regenerating vegetation. Second, and most alarmingly, **while the relative abundance for these species in Mwanihana appears stable, or perhaps only declining slightly, in USNR the trend is clearly negative, especially for the two colobines.** The dramatic crash in primate abundance shown in the last decade may anticipate potential local extinction.



Results of the Primate Monitoring Programme in two of the Udzungwa forests: Mwanihana included in the National Park (charts above) and Uzungwa Scarp Nature Reserve (charts below). Dots indicate the number of groups seen per km during each transect repetition. Results are shown for the three best sighted diurnal primates (Udzungwa red colobus, Peters' Angola colobus and Sykes' monkey – charts on the left) and for the Udzungwa red colobus only (charts on the right). Regression lines indicate the general trend, rather stable in the National Park and declining in USNR (data by F. Rovero and Udzungwa Ecological Monitoring Centre).

Importantly, statistical analyses have shown that such trends in encounter rate are 'real' despite the background noise from two potentially confounding factors: the involvement of different field technicians over the years and the sampling across different seasons. These factors may bias the results and return a false trend. However, these analyses showed that difference among years caused by seasonal conditions and different observers does not alter the general trend. This is important because it indicates that even a simple routine data collection can yield robust results provided that the protocol is standardized and observers are well trained.

In summary, these results not only show the importance of consistent and long-term ecological monitoring and how efficient a relatively simple protocol is at detecting trends, but they also call for urgent action, pointing to the imperative need for increasing protection of primate habitats, and hence reducing hunting pressure in Udzungwa Scarp.

Instances of illegal poaching and logging in the former Udzungwa Scarp Forest Reserve, now a Nature Reserve.

A leopard (*Panthera pardus*) "captured" by a camera trap in Matundu forest in the National Park. Camera trapping has been used extensively in Udzungwa to study and monitor the elusive fauna.

TEAM Network: standardized biodiversity monitoring in the global tropics

A second important monitoring programme at UEMC is carried out through its participation in a pantropical network of field stations since 2009. The stations coordinate the implementation of standardized monitoring protocols so that comparable data across the tropics can be available for local, regional and global studies. The Tropical Ecology, Assessment and Monitoring (TEAM) network has been set up by Conservation International, and more recently joined by other important agencies such as the Wildlife Conservation Society and the Smithsonian Institution. Currently, it includes 17 stations in the tropics across three continents. **As the first 'node' of this network in Africa, UEMC is proud to be part of this programme.**

By collecting and making an enormous amount of open access data available in near-real time, TEAM ultimately aims to become an Early Warning System for life on planet earth (see www.teamnetwork.org for more information).

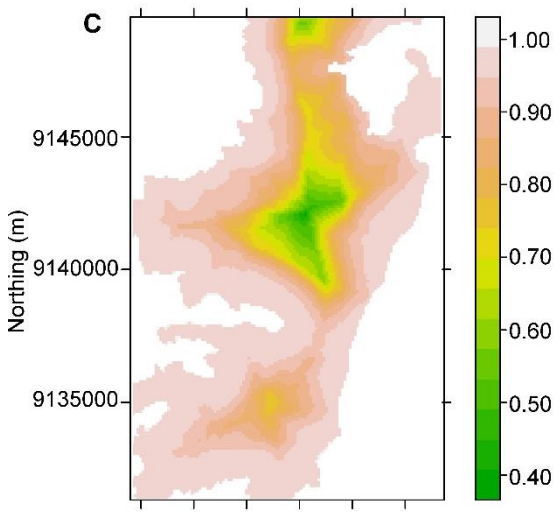
The standardized monitoring protocols target arboreal vegetation, climate and ground-dwelling mammals and birds. The focus here is placed on the latter protocol, which is implemented through the use of 'camera traps' (automatic cameras that take images of passing animals). These cameras are truly magical tools that have become the standard to detect and study elusive fauna around the globe over the last two decades. Monitoring through camera traps has progressively become a key method in the Udzungwas too, and it provides data that complements those on arboreal primates described above, as the targets are ground-dwelling animals. Thus, TEAM's 'terrestrial vertebrate' protocol consists of a grid of 60 locations in Mwanihana forest (one every 2 km^2) which have been sampled every year since 2009, with camera traps set for 30 days. Over the eight years, a remarkable dataset of approximately 150,000 camera trap images (on average 18,600 per year) has been accumulated, with around 30 species of mammals photographed. In addition to building a species inventory, such data allowed researchers to study population abundance and changes in both populations and the whole community over space and time. These statistically robust approaches use a metric – called *occupancy* – that estimates the probability of presence of each species across the forest. The figures below exemplifies the type of analyses that can be done based on this approach.

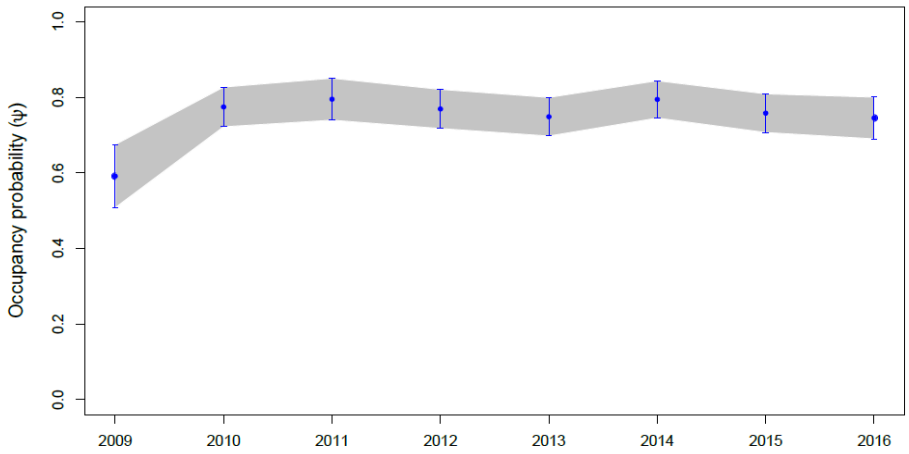
TEAM Network's field technician setting a camera trap in Udzungwa (top left), and images of wildlife detected: Lowe's servaline genet (top right), bush pig (bottom left) and hippopotamus (bottom right).

Starting with analyses on focal species, the data from any particular year can be modeled to estimate occupancy and assess how it changes across the target forest.

For example, we used data for the common forest antelope, Harvey's duiker (*Cephalophus harveyi*), also known as *funo* in Swahili, and found that its probability of presence increases with proximity to the edge of the forest, likely as a response to more optimal habitat towards the forest edges. Its map of predicted occupancy therefore indicates greater presence in the outer zones than in the interior forest. We could also estimate occupancy as an indicator of the abundance of the species, across years, resulting in profiles like the one provided for the Sanje mangabey.

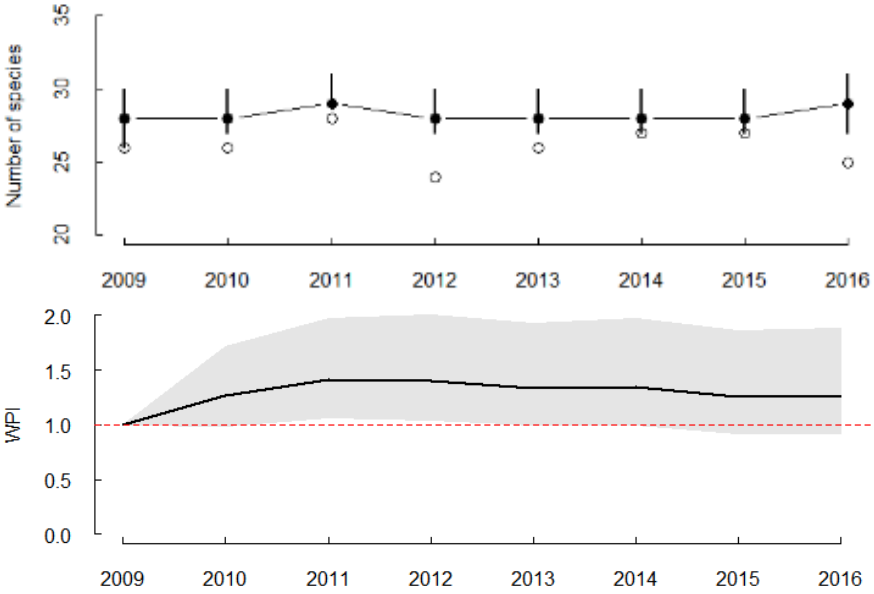
These 'dynamic occupancy models' allow researchers to assess factors that may have caused population changes and this example shows that the abundance of this endemic and endangered species appears to have been stable over the study period.





Examples of analyses in population abundance variation using data from camera traps. The map (above) shows the predicted 'occupancy' (probability of presence) of the forest antelope Harvey's duiker. Abundance estimates are represented with coloured scales from pale pink (high abundance) to dark green (low abundance), revealing higher abundance near forest edges (chart reproduced from *Rovero et al. 2014*, PLoS ONE). Temporal profile of estimated occupancy (graph below) for the endemic Sanje mangabey indicates relative stability of population abundance with time *(source: F. Rovero, unpublished data*).

Data derived from all species could also be relevant to infer temporal changes in the status of the entire mammal community, in terms of both species richness (see chart below) and population abundances. In particular, the **Wildlife Picture Index (WPI)** specifically quantifies such temporal changes of the community status. This index is sensitive to both species richness (a species that goes extinct or are new colonizers) and their abundance at each particular year. Below is an example of the WPI from 2009-2016 showing that the community of ground-dwelling mammals and birds has been relatively stable for both their species composition and abundance. As observed for the data on primates, this result confirms the adequate protection efforts ensured by the National Park over this period.



Temporal profiles of mammal community from occupancy analyses for the 8 years of camera trapping as part of the TEAM's network project. Results indicate overall that the community has not changed significantly in the number of species and abundances. The chart above shows the variation in estimated species richness (full dots and confidence interval bars) and observed species richness (open dots). The chart below profiles the Wildlife Picture Index (WPI), an index that signals changes in the number of species available and the abundance of such populations within the community (*source: TEAM Network and F. Rovero unpublished data*).

RESEARCH ARTICLE SUMMARY

FOREST ECOLOGY

Positive biodiversity-productivity relationship predominant in global forests

Jingjing Liang,* Thomas W. Crowther, Nicolas Picard, Susan Wiser, Mo Zhou, Giorgio Alberti, Ernst-Detlef Schulze, A. David McGuire, Fabio Bozzato, Hans Pretzsch, Sergio de-Miguel, Alain Paquette, Bruno Hérault, Michael Scherer-Lorenzen, Christopher B. Barrett, Henry B. Glick, Geerten M. Hengeveld, Gert-Jan Nabuurs, Sebastian Pfautsch, Helder Viana, Alexander C. Vibrans, Christian Ammer, Peter Schall, David Verbyla, Nadja Tchebakova, Markus Fischer, James V. Watson, Han Y. H. Chen, Xiangdong Lei, Mart-Jan Schelhaas, Huicui Lu, Damiano Gianelle, Elena I. Parfenova, Christian Salas, Eungul Lee, Boknam Lee, Hyun Seok Kim, Helge Bruelheide, David A. Coomes, Daniel Piotto, Terry Sunderland, Bernhard Schmid, Sylvie Gourlet-Fleury, Bonaventure Sonké, Rebecca Tavani, Jun Zhu, Susanne Brandl, Jordi Vayreda, Fumiaki Kitahara, Eric B. Searle, Victor J. Neldner, Michael R. Ngugi, Christopher Baraloto, Lorenzo Frizzera, Radomir Bałazy, Jacek Oleksyn, Tomasz Zawiła-Niedźwiecki, Olivier Bouriaud, Filippo Bussotti, Leena Finér, Bogdan Jaroszewicz, Tommaso Jucker, Fernando Valladares, Andrzej M. Jagodzinski, Pablo L. Peri, Christelle Gonmadje, William Marthy, Timothy O'Brien, Emanuel H. Martin, Andrew R. Marshall, Francesco Rovero, Robert Bitariho, Pascal A. Niklaus, Patricia Alvarez-Loayza, Nurdin Chamuya, Renato Valencia, Frédéric Mortier, Verginia Wortel, Nestor L. Engone-Obiang, Leandro V. Ferreira, David E. Odeke, Rodolfo M. Vasquez, Simon L. Lewis, Peter B. Reich

INTRODUCTION: The biodiversity-productivity relationship (BPR; the effect of biodiversity on ecosystem productivity) is foundational to our understanding of the global extinction crisis and its impacts on the functioning of natural ecosystems. The BPR has been a prominent research topic within ecology in recent decades, but it is only recently that we have begun to develop a global perspective.

RATIONALE: Forests are the most important global repositories of terrestrial biodiversity, but deforestation, forest degradation, climate change, and other factors are threatening approximately one half of tree species worldwide. Although there have been substantial efforts to strengthen the preservation and sustainable use of forest biodiversity throughout the globe, the consequences of this diversity loss pose a major uncertainty for ongoing international forest management and conservation efforts. The forest BPR represents a critical missing link for accurate valuation of global biodiversity and successful integration of biological conservation and socioeconomic development. Until now, there have been limited tree-based diversity experiments, and the forest BPR has only been explored within regional-scale observational studies. Thus, the strength and spatial variability of this relationship remains unexplored at a global scale.

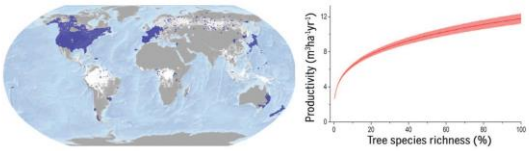
RESULTS: We explored the effect of tree species richness on tree volume productivity at the global scale using repeated forest inventories from 777,126 permanent sample plots in 44 countries containing more than 30 million trees from 8737 species spanning most of the global terrestrial biomes. Our findings reveal a consistent positive concave-down effect of biodiversity on forest productivity across the world, showing that a continued biodiversity loss would result in an accelerating decline in forest productivity worldwide.

ON OUR WEBSITE

Read the full article at http://dx.doi.org/10.1126/science.aaf8957

The BPR shows considerable geospatial variation across the world. The same percentage of biodiversity loss would lead to a greater relative (that is, percentage) productivity decline in the boreal forests of North America, Northeastern Europe, Central Siberia, East Asia, and scattered regions of South-central Africa and South-central Asia. In the Amazon, West and Southeastern Africa, Southern China, Myanmar, Nepal, and the Malay Archipelago, however, the same percentage of biodiversity loss would lead to greater absolute productivity decline.

CONCLUSION: Our findings highlight the negative effect of biodiversity loss on forest productivity and the potential benefits from the transition of monocultures to mixed-species stands in forestry practices. The BPR we discover across forest ecosystems worldwide corresponds well with recent theoretical advances, as well as with experimental and observational studies on forest and nonforest ecosystems. On the basis of this relationship, the ongoing species loss in forest ecosystems worldwide could substantially reduce forest productivity and thereby forest carbon absorption rate to compromise the global forest carbon sink. We further estimate that the economic value of biodiversity in maintaining commercial forest productivity alone is $166 billion to $490 billion per year. Although representing only a small percentage of the total value of biodiversity, this value is two to six times as much as it would cost to effectively implement conservation globally. These results highlight the necessity to reassess biodiversity valuation and the potential benefits of integrating and promoting biological conservation in forest resource management and forestry practices worldwide. ■



Global effect of tree species diversity on forest productivity. Ground-sourced data from 777,126 global forest biodiversity permanent sample plots (dark blue dots, left), which cover a substantial portion of the global forest extent (white), reveal a consistent positive and concave-down biodiversity-productivity relationship across forests worldwide (red line with pink bands representing 95% confidence interval, right).

The list of author affiliations is available in the full article online.
*Corresponding author. Email: albeca.liang@gmail.com
Cite this article as J. Liang et al., Science 354, aaf8957 (2016). DOI: 10.1126/science.aaf8957

Finally, the fundamental value of TEAM's programme is the availability of standardized data from several sites across the tropics, which has allowed for unprecedented regional and global-level analyses, to which the Udzungwas contributed.

For example, by 2017 the camera trapping protocol has accumulated over 3.4 million images from across the global tropics. This unique dataset is used by scientists for various assessments and comparisons on temporal changes, community size and composition, effects of climate changes and, by using the data from vegetation plots, relationships and interactions between terrestrial vertebrates and forest dynamics.

These efforts are not described here, but are available as publications in top-ranked and high impact journals. Due the paucity of standardized data from the tropics, all those type of studies could not be possibly performed before TEAM.

PLOS | BIOLOGY

RESEARCH ARTICLE

Standardized Assessment of Biodiversity Trends in Tropical Forest Protected Areas: The End Is Not in Sight

Lydia Beaudrot[1☯*], Jorge A. Ahumada[1☯*], Timothy O'Brien[2], Patricia Alvarez-Loayza[3], Kelly Boekee[4], Ahimsa Campos-Arceiz[5], David Eichberg[6], Santiago Espinosa[7], Eric Fegraus[1], Christine Fletcher[8], Krisna Gajapersad[9], Chris Hallam[10], Johanna Hurtado[11], Patrick A. Jansen[4,12], Amit Kumar[13], Eileen Larney[14,15], Marcela Guimarães Moreira Lima[16], Colin Mahony[17], Emanuel H. Martin[18,19], Alex McWilliam[10], Badru Mugerwa[20,21,22], Mireille Ndoundou-Hockemba[23], Jean Claude Razafimahaimodison[14], Hugo Romero-Saltos[24], Francesco Rovero[18,25], Julia Salvador[26], Fernanda Santos[16], Douglas Sheil[27,28], Wilson R. Spironello[29], Michael R. Willig[30], Nurul L. Winarni[31], Alex Zvoleff[1], Sandy J. Andelman[1]

1 Moore Center for Science, Conservation International, Arlington, Virginia, United States of America, 2 Wildlife Conservation Society, Bronx, New York, United States of America, 3 Center for Tropical Conservation, Duke University, Durham, North Carolina, United States of America, 4 Department of Environmental Sciences, Wageningen University, Wageningen, The Netherlands, 5 School of Geography, Mindset Interdisciplinary Centre for Tropical Environmental Studies, University of Nottingham Malaysia Campus, Selangor, Malaysia, 6 HP Sustainability, HP Inc., Palo Alto, California, United States of America, 7 Escuela de Ciencias Biológicas, Pontificia Universidad Católica del Ecuador, Quito, Ecuador, 8 Forest Research Institute Malaysia, Kepong, Selangor, Malaysia, 9 Conservation International Suriname, Paramaribo, Suriname, 10 Wildlife Conservation Society—Lao PDR Program, Vientiane, Lao PDR, 11 Organization for Tropical Studies, La Selva Biological Station, Puerto Viejo de Sarapiquí, Costa Rica, 12 Center for Tropical Forest Science, Smithsonian Tropical Research Institute, Republic of Panama, 13 Enterprise Services, Hewlett Packard Enterprise, Palo Alto, California, United States of America, 14 Centre ValBio, Ranomafana, Madagascar, 15 Stony Brook University, Stony Brook, New York, United States of America, 16 Universidade Federal do Pará, Museu Paraense Emílio Goeldi, Belém, Pará, Brasil, 17 Hewlett Packard Enterprise Big Data, Palo Alto, California, United States of America, 18 Udzungwa Ecological Monitoring Centre, Udzungwa Mountains National Park, Tanzania, 19 Sokoine University of Agriculture, Morogoro, Tanzania, 20 Institute of Tropical Forest Conservation (ITFC), Mbarara University of Science and Technology (MUST), Mbarara, Uganda, 21 Department of Biology, Western University, London, Ontario, Canada, 22 Wildlife Conservation Research Unit (WildCRU), University of Oxford, Oxford, United Kingdom, 23 Wildlife Conservation Society—Congo Program, Brazzaville, Republic of Congo, 24 Department of Biology, Yachay Tech University, Urcuquí, Imbabura, Ecuador, 25 Tropical Biodiversity, MUSE—Museo delle Scienze, Trento, Italy, 26 Department of Wildlife Ecology and Conservation, University of Florida, Gainesville, Florida, United States of America, 27 Department of Ecology and Natural (INA) Resource Management, Norwegian University of Life Sciences (NMBU), Ås, Norway, 28 Center for International Forestry Research, Bogor, Indonesia, 29 National Institute for Amazonian Research (INPA), Manaus, Amazonas, Brazil, 30 Department of Ecology & Evolutionary Biology and Center for Environmental Sciences & Engineering, University of Connecticut, Storrs, Connecticut, United States of America, 31 Research Center for Climate Change, University of Indonesia, Depok, Indonesia

☯ These authors contributed equally to this work.
* beaudrot@umich.edu (LB); jahumada@conservation.org (JAA)

Abstract

Extinction rates in the Anthropocene are three orders of magnitude higher than background and disproportionately occur in the tropics, home of half the world's species. Despite global efforts to combat tropical species extinctions, lack of high-quality, objective information on

OPEN ACCESS

Citation: Beaudrot L, Ahumada JA, O'Brien T, Alvarez-Loayza P, Boekee K, Campos-Arceiz A, et al. (2016) Standardized Assessment of Biodiversity Trends in Tropical Forest Protected Areas: The End Is Not in Sight. PLoS Biol 14(1): e1002357. doi:10.1371/journal.pbio.1002357

Academic Editor: Andy P. Dobson, Princeton University, UNITED STATES

Received: September 2, 2015

Accepted: December 10, 2015

Published: January 19, 2016

Data Availability Statement: All TEAM data were provided by the Tropical Ecology Assessment and Monitoring (TEAM) Network, a collaboration between Conservation International, the Smithsonian Institute and the Wildlife Conservation Society. All raw data are available on the TEAM website www.teamnetwork.org. All relevant data are within the paper and its Supporting Information files.

Funding: This study was funded by the Gordon and Betty Moore Foundation, Northrop Grumman Foundation and other donors. Hewlett Packard Living Progress, in partnership with Conservation

LETTER

doi:10.1038/nature11318

Averting biodiversity collapse in tropical forest protected areas

A list of the authors and their affiliations appears at the end of the paper.

The rapid disruption of tropical forests probably imperils global biodiversity more than any other contemporary phenomenon[1–3]. With deforestation advancing quickly, protected areas are increasingly becoming final refuges for threatened species and natural ecosystem processes. However, many protected areas in the tropics are themselves vulnerable to human encroachment and other environmental stresses[4–9]. As pressures mount, it is vital to know whether existing reserves can sustain their biodiversity. A critical constraint in addressing this question has been that data describing a broad array of biodiversity groups have been unavailable for a sufficiently large and representative sample of reserves. Here we present a uniquely comprehensive data set on changes over the past 20 to 30 years in 31 functional groups of species and 21 potential drivers of environmental change, for 60 protected areas stratified across the world's major tropical regions. Our analysis reveals great variation in reserve 'health': about half of all reserves have been effective or performed passably, but the rest are experiencing an erosion of biodiversity that is often alarmingly widespread taxonomically and functionally. Habitat disruption, hunting and forest-product exploitation were the strongest predictors of declining reserve health. Crucially, environmental changes immediately outside reserves seemed nearly as important as those inside in determining their ecological fate, with changes inside reserves strongly mirroring those occurring around them. These findings suggest that tropical protected areas are often intimately linked ecologically to their surrounding habitats, and that a failure to stem broad-scale loss and degradation of such habitats could sharply increase the likelihood of serious biodiversity declines.

Tropical forests are the biologically richest ecosystems on Earth[1–3]. Growing concerns about the impacts of anthropogenic pressures on tropical biodiversity and natural ecosystem services have led to increases in the number and extent of protected areas across the tropics[10]. However, much remains unknown about the likelihood of biodiversity persisting in such protected areas. Remote-sensing technologies offer a bird's-eye view of tropical forests and provide many important insights[6,11–13], but are largely unable to discern crucial on-the-ground changes in forest biodiversity and ecological functioning[14].

To appraise both the ecological integrity and threats for tropical protected areas on a global scale, we conducted a systematic and uniquely comprehensive assessment of long-term changes within 60 protected areas stratified across the world's major tropical forest regions (Supplementary Fig. 1). To our knowledge, no other existing data set includes such a wide range of biodiversity and threat indicators for such a large and representative network of tropical reserves. Our study was motivated by three broad issues: whether tropical reserves will function as 'arks' for biodiversity and natural ecosystem processes; whether observed changes are mainly concordant or idiosyncratic among different protected areas; and what the principal predictors of reserve success or failure are, in terms of their intrinsic characteristics and drivers of change.

To conduct our study we amassed expert knowledge from 262 detailed interviews, focusing on veteran field biologists and environmental scientists who averaged nearly 2 decades of experience (mean ± s.d., 19.1 ± 9.6 years) at each protected area. Each interviewed researcher completed a detailed 10-page questionnaire, augmented by a telephone or face-to-face interview (see Supplementary Information). The questionnaires focused on longer-term (approximately 20–30-year) changes in the abundance of 31 animal and plant guilds (trophically or functionally similar groups of organisms), which collectively have diverse and fundamental roles in forest ecosystems (Table 1). We also recorded data on 21 potential drivers of environmental change both inside each reserve and within a 3-km-wide buffer zone immediately surrounding it (Table 1).

Our sample of protected areas spans 36 nations and represents a geographically stratified and broadly representative selection of sites across the African, American and Asia-Pacific tropics (Supplementary Fig. 1). The reserves ranged from 160 ha to 3.6 million ha in size, but most (85%) exceeded 10,000 ha in area (median = 99,350 ha; lower decile = 7,000 ha; upper decile = 750,000 ha). The protected areas fall under various International Union for Conservation of Nature (IUCN) reserve classifications. Using data from the World Database on Protected Areas (http://www.wdpa.org), we found no significant difference ($P = 0.13$) in the relative frequency of high-protection (IUCN Categories I–IV), multiple-use (Categories V–VI) and

Table 1 | The 31 animal and plant guilds, and the 21 environmental drivers assessed both inside and immediately outside each protected area.

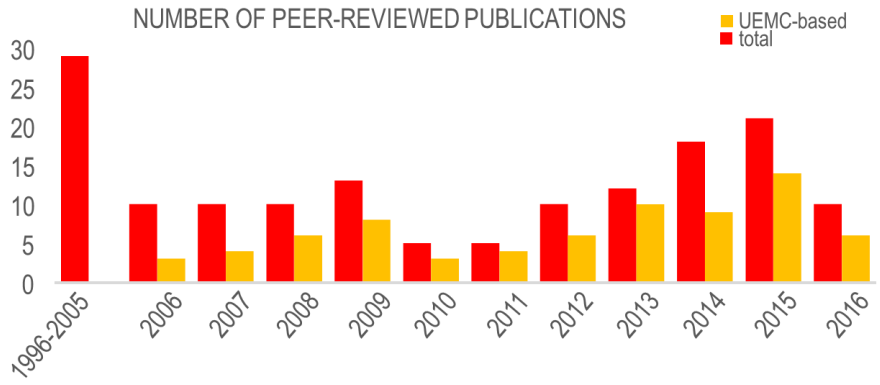
Guilds	Potential environmental drivers
Broadly forest-dependent guilds	
Apex predators	Changes in natural-forest cover
Large non-predatory species	Selective logging
Primates	Fires
Opportunistic omnivorous mammals	Hunting
Rodents	Harvests of non-timber forest products
Bats	Illegal mining
Understory insectivorous birds	Roads
Raptorial birds	Automobile traffic
Larger frugivorous birds	Exotic plantations
Larger game birds	Human population density
Lizards and larger reptiles	Livestock grazing
Venomous snakes	Air pollution
Non-venomous snakes	Water pollution
Terrestrial amphibians	Stream sedimentation
Stream-dwelling amphibians	Soil erosion
Freshwater fish	River & stream flows
Dung beetles	Ambient temperature
Army or driver ants	Annual rainfall
Aquatic invertebrates	Drought severity or intensity
Large-seeded old-growth trees	Flooding
Epiphytes	Windstorms
Other functional groups	
Ecological specialists	
Species requiring tree cavities	
Migratory species	
Disturbance-favouring guilds	
Lianas and vines	
Pioneer and generalist trees	
Exotic animal species	
Exotic plant species	
Disease-vectoring invertebrates	
Light-loving butterflies	
Human diseases	

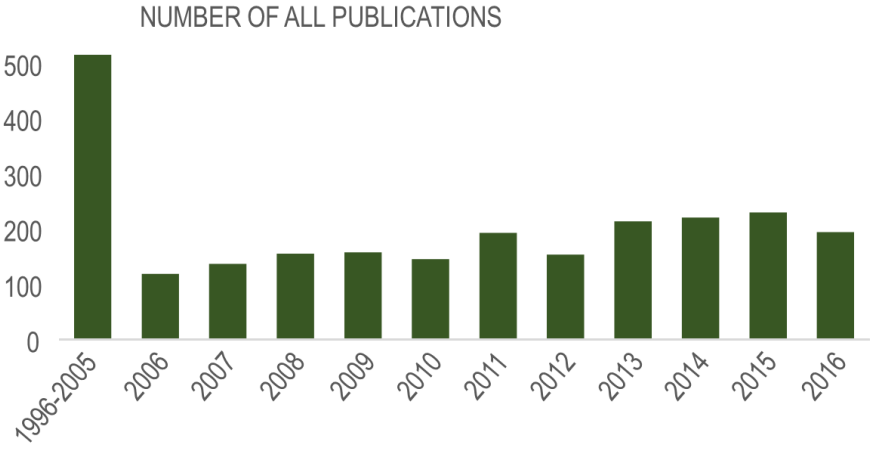
PROMOTING AND FACILITATING RESEARCH AND CONSERVATION PROGRAMMES

By facilitating individual researchers and agencies working in the area, UEMC has been instrumental to determine a sharp and relatively rapid expansion of the volume of research and conservation efforts in Udzungwas. Here, we summarize this impact and the range of research and conservation efforts achieved in the decade.

Research outputs

The studies conducted by the researchers hosted at UEMC spanned a vast range of topics, from taxonomic assessments of flora and fauna (including invertebrates and vertebrates) to investigations of the ecology at population, species, community and ecosystem levels. In addition, a number of studies were primarily aimed at addressing conservation issues, for example studies on wildlife connectivity and human disturbance across a range of forests.





The number of scientific publications yielded from research conducted in Udzungwas. The chart above is based on a count of peer-reviewed papers in international, scientific journals (Source: ISI – Web of Science) and shows the share (averaging 59% in the decade) of papers from studies that were facilitated by UEMC. The chart below is a more general count of all publications and reports of all sorts as found by the Google Scholar engine (see text for more details).

A simple way to quantify the outcome of such efforts is to score the number of publications that have appeared in the scientific literature over the decade using dedicated search engines (Web of Science) to select publications where 'Udzungwa' appears in the title or the abstract. This score has been integrated by other publications which are mainly from TEAM's Network work and are of global scope, as described above. As these publications include the Udzungwas among several other sites, they are not automatically found by the search engines. Given the time gap between data collection and publication (which can span years, especially for taxonomic research), it is predictable that a number of publications will come out in following years. For these reasons, what is presented here is barely a minimum count of peer-reviewed publications.

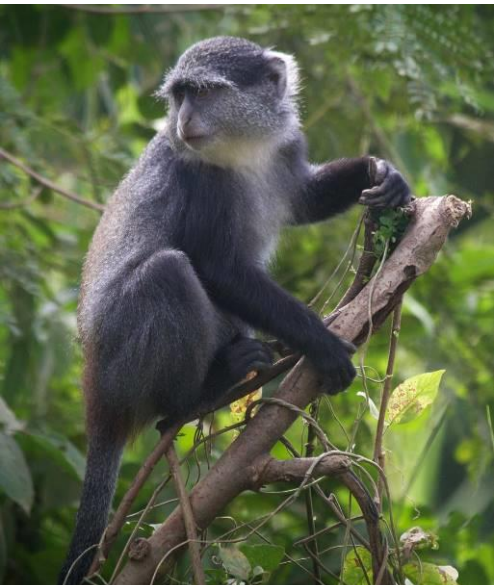
This count scores **124 papers published over the decade from research in the Udzungwas, with 59% that originate from studies that were facilitated by UEMC**, usually through accommodating researchers and/or providing logistic facilitation. A looser score of research outcome, in terms of publications, is provided by the Google Scholar engine that includes not only peer-reviewed papers but also the so-called 'grey' literature (unpublished report or other non-peer reviewed publications). These are papers where the word 'Udzungwa' appears anywhere in the text, and is therefore a maximum count, as it could include papers where Udzungwa is not the focal study area.

This metric yielded 514 records in the decade 1995-2005 and as many as 1,912 in the 2006-2016 decade, witnessing a remarkable, **general increase in the amount of research featuring the Udzungwas**.

Overview of research conducted

A complete summary of research conducted in the area is beyond the aim of this session, which only highlights the main themes and study subjects with emphasis on projects that were facilitated by UEMC. **Research on primates has had a strong focus in the decade**, with a number of research projects on the two endemic monkeys, Udzungwa red colobus and Sanje mangabey, and these projects concentrate on their socio-ecology and physiology, abundance estimation and drivers of distribution and abundance. Studies initially developed from earlier work by senior scientists from various institutions around the world (Tom Butynski, Carolyn Ehardt and Tom Struhsaker among others), and continued by other researchers (Claudia Barelli, Trevor Jones, Andy Marshall, Francesco Rovero, Nelson Ting among others). Many of these studies were conducted by the majority of Ph.D. students that made UEMC as their base (Alessandro Araldi, Nathalie Cavada, David Fernandez, Grainne McCabe, Kuruthumu Ally Mwamende, Ruth Steel, among others). As a result, we know much more than a decade ago about the ecology and conservation status of these flagship species across their narrow range.

The Tanzania Sykes' monkey (left) and the Udzungwa red colobus are among the primates targeted by monitoring and research programmes.



Research in Udzungwa has revealed dozens of species new to science, including the grey-faced sengi, or elephant-shrew (*Rhynchcyon udzungwensis*), described in 2008 as a unique new member of an ancient group of mammals that share a common ancestor with elephants.

Besides the primates, **mammals in general have also attracted significant and increasing research attention**, especially as scientists began to use camera trapping in the early 2000s. If general inventories with camera traps revealed the incredible diversity of the "hidden" fauna of the Udzungwa forests, including the discovery in 2005 of a new species of *sengi*, or elephant-shrew (*Rhynchocyon udzungwensis*) more systematic and focal use of this tool provided a wealth of ecological data on distribution, habitat preferences, population vulnerability and trends.

For example, detailed research on leopard's (*Panthera pardus*) landscape ecology, based on both camera trapping and genetics across the National Park and adjacent areas, has been carried out by the Natural History Museum of Denmark in collaboration with MUSE. Similarly, the use of molecular ecology methods also progressively increased, often integrated with other methods as for the leopard project, or a focal work on forest antelope (duikers and other species) conducted by Andy Bowkett.

A special place in the mammalian fauna of the Udzungwas is occupied by a unique population of savannah elephants (*Loxodonta africana*), that roam across the landscape from the dry habitats to the steepest rainforest. Elephants have become a focal study subject in the mid-2000s thanks to work by Trevor Jones and colleagues that progressively developed into a consolidated research and conservation programme.

A special place in the mammalian fauna of the Udzungwas is occupied by a unique population of savannah elephants (*Loxodonta africana*), that roam across the landscape from dry habitats to the steepest rainforest.

Members of the diversified group of forest antelope in Udzungwa: suni (left), bush duiker (centre) and the Tanzania-endemic Abbott's duiker (right).

Contrary to mammals, research on **birds**, which had been focal in previous years especially by the Natural History Museum of Denmark, has surprisingly received little attention in the decade, with little focal work being conducted apart from inventories and opportunistic work mainly done by researchers focusing on other topics.

Instead, **amphibians and reptiles** have been studied increasingly, especially by MUSE (with Michele Menegon) and partners, **revealing dozens of species new to science**.

Besides general inventories and biogeographical studies, a number of species-specific ecological studies on narrow-range endemics have also been conducted.

Resuming work that dates back to the 1970s and 1980s by Nikolaj Sharff and colleagues, the Natural History Museum of Denmark of the University of Copenhagen has recently established a systematic programme to assess invertebrate diversity and ecology in the area.

Along with mammals, amphibians, reptiles and birds have also been the subject of inventories that led to the description of dozens of new and narrow-range species, especially for the former two classes.

Relatively **less botanical than faunal research was conducted in the target decade**. Quentin Luke from the National Museums of Kenya conducted a thorough inventory of plant diversity over several years until the mid-2000s. The University of York, through Andy Marshall and colleagues, established 1-ha vegetation plots for studying dynamics and carbon storage of trees as part of the broader *Valuing the Arc* project. Some of this work was also conducted in collaboration with the TEAM Network project that monitored each year six of the 1-ha plots established in Mwanihana forest.

Additional studies on forest regeneration and responses to disturbance were also conducted in Magombera forest in the Kilombero valley.

Despite faunal research has been relatively more addressed than botanical research, the Udzungwa Mountains hold outstanding botanical diversity, including African violets *Saintpaulia* spp. (right).

A number of studies has established plots to assess and monitor the arboreal vegetation.

While wildlife research has been clearly predominant, there have been a number of **socio-ecological studies** too. Among these, Martin Nielsen from the University of Copenhagen conducted extensive socio-ecological research on the effectiveness of community-based conservation at maintaining wildlife in some of the forests outside the National Park. Julia Latham from the University of York conducted a Ph.D. study on the impact of forest protection on firewood demands by communities, and implications for REDD (Reducing Emissions from Deforestation and forest Degradation). Pennsylvania University, with Larry Gorenflo and colleagues, established a long-term training and research programme focusing on the link between people's livelihoods and land uses in villages adjacent to the park. Earlier work on socio-ecology was conducted by WWF-Tanzania programme in the context of assessments funded by the Critical Ecosystem Partnership Fund which were largely completed before UEMC establishment.

A common thread across all these research projects has been the close **collaboration with Tanzanian researchers and field assistants, and Tanzanian institutions**.

In some cases this led to independent research projects by Tanzanian researchers. For example, Emanuel Martin (now lecturer at the College of African Wildlife Management, Mweka, Tanzania) completed his Ph.D. on mammal ecology at Sokoine University of Agriculture-SUA (Morogoro, Tanzania) while coordinating a TEAM project. Kuruthumu Ally Mwamende has been enrolled as a research assistant for a number of projects before initiating her independent M.Sc. and Ph.D. project on primates. Similarly, wardens from the National Park, such as Ponjoli Joram and Joel Masuki, have conducted their research for higher degrees in connection with UEMC-based researchers. These projects add to research projects independently conducted by Tanzanian researchers, for example Devotha Kilave (SUA) and Edger Liheruka (Norwegian University of Life Sciences), that conducted research on water management and livelihoods.

Overall, these examples witness how research projects at UEMC were conducive to fostering research by Tanzanian scientists and institutions.

A common thread across all research projects conducted in the decade has been the close collaboration with Tanzanian researchers and institutions, including training and capacity building initiatives.

A large portion of research facilitated by UEMC has been of conservation relevance, and led to conservation outcomes. These included the initiation of community education and community conservation programmes.

In In this context, it is remarkable how UEMC contributed to shaping the professional capacities of its senior staff over the years, which is witnessed by the successful positioning of them in academia.

Indeed the first three coordinators of UEMC are currently all permanently employed by important Universities such as SUA (Amani Kitegile and Philipo Jacob) and the College of African Wildlife Management (Emanuel Martin).

Conservation outcomes of research and focal conservation projects

A large portion of research facilitated by UEMC fell within the realms of applied ecology and biodiversity science, and as such it carried conservation relevance, with some studies that were primarily aimed at addressing conservation issues. For example, by revealing the dramatic decline of primates in Udzungwa Scarp, the Primate Monitoring Programme has been instrumental to lobbying for increasing protection of this important forest. In conjunction with various other efforts, including herpetological inventories that revealed the extraordinary biodiversity of this forest, this eventually resulted in the **upgrading by the Government of the protection status of this forest from Forest Reserve to Nature Reserve**.

At the time of writing this report, the Tanzania Forest Service has allocated more staff to this Reserve and gathered funds for the necessary infrastructure and equipment. A collaboration between MUSE and the Whitley Wildlife Conservation Fund, with local facilitation from the Southern Tanzania Elephant Program, has initiated a project to build the capacity of Tanzania Forest Service's staff and support law enforcement by rangers and community scouts. This project represents an emblematic example of how applied research and long-term monitoring can trigger conservation action. Interestingly, moreover, these efforts on direct forest protection are complemented by a community-conservation project led by the Tanzania Forest Conservation Group, targeting all villages surrounding the Nature Reserve.

Indeed comparable initiatives of applied research leading to community-conservation efforts are in place in other areas, for example in villages the east of the park with work by MUSE and Association Mazingira (details below), and by Southern Tanzania Elephant Program, or around Magombera forest with work by Flamingo Land (UK).

UEMC conducted several training workshops dedicated to rangers and park ecologists. Overall, 40 rangers and 46 ecologists and assistant ecologists participated in training on various topics, from use of GPS and GIS to methods for standardizing ecological monitoring.

As conservation issues became to be identified at the landscape level, a number of focal conservation assessments have also been conducted. Among these stands up for importance the studies on connectivity which in a highly fragmented landscape such as Udzungwa are of critical importance. This work addressed both connectivity among Udzungwa forests, for example through the identification and assessment of the so-called "Mngeta corridor" linking Udzungwa Scarp and Kilombero Nature Reserves. And the connectivity among the Udzungwas and adjacent landscapes (Mikumi/Ruaha to the North and Northwest and Selous to the east) which is fundamental for "landscape species", notably the elephants.
Some success has already being achieved, such as the on-going gazettment of the "Mnegta corridor" as a new Forest Reserve by the Tanzania Government, and the inclusion of the proposed "Mwanihana-Magombera corridor" as case study of priority in the Government-led process of making regulations and establishing wildlife corridors across the country.

TECHNICAL ADVISORY AND TRAINING TO TANAPA STAFF

As the ecological monitoring centre of UMNP, UEMC worked closely with the park's Ecology Department through sharing data from relevant monitoring efforts, such as the Primate Monitoring Programme, assisting with planning and implementing park-driven monitoring efforts, providing routine advisory on technical issues pertinent to ecological monitoring and training UMNP staff. Important monitoring efforts by the park which were contributed by UEMC include a study on the use of dung beetles as indicators of human disturbance in the park through firewood collection. The study was conducted in 2008 in collaboration with Bruno Nyundo from the University of Dar es Salaam, who had established a baseline study with WWF-Tanzania already in 2005.
In line with results from the baseline, the study found that dung beetles' species diversity was impoverished in areas of the forest more intensively utilized by humans, suggesting a possible negative impact of firewood collection on biodiversity. This practice had been allowed by the park, whereby local villagers entered the lower portion of the forest once or twice a week to collect dead wood. Firewood collection was then completely banned as of July 2010.

A second important effort has been the establishment of a network of routes or 'transects' of 4 to 6 km in length at five different remote ranger posts across the park in 2008. Rangers monitored large mammals through counting direct sightings of animals, dungs, tracks and other signs.
Because of their extensive presence on the ground and familiarity with the area, rangers have an excellent potential for regular ecological data collection.
Unfortunately however, they are also intensively dedicated to law enforcement, making their chances to be involve in ecological monitoring discontinuous. It was therefore realized that technical inputs from experienced and dedicated field technicians was necessary and eventually a team of two technicians resumed data collection in collaboration with rangers.
While the programme overall ran discontinuously, mainly due to shortage of funding and staff availability, it remains a valuable example of how parks can conduct monitoring with potentially limited resources, by allocating a small number of rangers and field technicians that use simple routine for collecting data.

UEMC advisory to UMNP included training on the toolkit for ecological monitoring, with a long-term view of contributing to enhance and standardize efforts to monitor biodiversity in forest parks across the country.

In this regard, the above mentioned ranger-based monitoring, along with the Primate Monitoring Programme and the camera trapping monitoring by TEAM, have been instrumental to showcase protocols. These training activities progressively scaled up in the course of the decade. Thus, initial training involved rangers of UMNP and were mainly dedicated to the use of GPS and use of resulting data by the park ecologist for making reports and maps with routes of field monitoring work. Training sessions were organized through formal workshops at UEMC but also conducted in conjunction with field data collection, for example during the above mentioned ranger-based monitoring. A minimum of 40 rangers have benefitted from this type of training over the years, along with the senior staff and assistants in the Ecology Department of UMNP that were on duty at the time training was conducted. Notably, in 2009, Anglia Ruskin University (UK) with Nicholas MacWilliam led one of these workshop on the use of GPS and GIS.

In line with this effort, higher-level training was dedicated to park ecologists and assistant ecologists scaling up from the Udzungwa to other National Parks. Thus, 26 ecologists from TANAPA parks across the country altogether attended the international summer schools on GIS and field tools for assessing biodiversity run during 2011-2016 (see below for details in this school).

Lastly, UEMC organized two main training workshops that were dedicated to TANAPA staff (reports available in UEMC website): the first in 2013 on standardized methods for monitoring primates and terrestrial mammals with emphasis on transect methods, and the second in 2016 on the use of camera trapping for monitoring mammals.

These workshops were attended by 20 people, representing most of the ecologists and park ecologists of all National Parks in the country.

UEMC organized two training workshops that were dedicated to TANAPA staff (reports available in UEMC website): the first in 2013 on standardized methods for monitoring primates and terrestrial mammals with emphasis on transect methods (photo), and the second in 2016 on the use of camera trapping for monitoring mammals.

UEMC hosted a number of international field-based higher education trainings, including five editions of the summer school organized by MUSE with the University of Trento (Italy) and University of Copenhagen (Denmark) entitled “Tropical rainforest biodiversity: field and GIS tools for assessing, monitoring and mapping”.

PROVISION OF SCHOLARSHIPS FOR HIGHER EDUCATION OF LOCAL STAFF

While UEMC did not have a dedicated budget for providing scholarships, whenever possible financial support to both UEMC and TANAPA staff was given to enroll into higher education courses. Thus, UEMC met the tuition fees for two TANAPA employees (Richard Kishe: Diploma in Wildlife Management at the College of African Wildlife Management, Mweka (2010/12); Joel Masuki: M.Sc. in Natural Resource Management at the University of Dar es Salaam (2015/17)).

Support was also provided to UEMC staff either through covering all or part of the tuition fees, or through liaising with other supporting agencies. Thus, Scola Mwasenga and Aggrey Uisso obtained their Certificate degree ; Arafat Mtui and Steven Shinyambala their B.Sc. degree (College of African Wildlife Management, Mweka and Institute of Rural Development and Planning, Dodoma, respectively).

In addition Emanuel Martin, former coordinator of TEAM project, obtained his Ph.D. degree at the Sokoine University of Agriculture through a grant from Conservation International’s TEAM programme.

SUMMER SCHOOLS & STUDY ABROAD PROGRAMMES

The 2009 inauguration of the hostel block annexed to UEMC opened the way to host and organize training programmes for students. A major one has been the international summer school organized by MUSE in partnership with the University of Trento (Italy) and, for the later editions, the University of Copenhagen - Natural History Museum of Denmark. Starting in July 2011, the international summer school entitled “Tropical rainforest biodiversity: field and GIS tools for assessing, monitoring and mapping” reached its fifth edition in 2016. Through a combination of field trips in the rainforest, and lessons and exercises on a PC, the summer school aimed to provide field and GIS experience for assessing forest biodiversity, especially rainforest mammals, integrating state-of-the-art field techniques to assess key indicator species with GIS tools to map and model species distribution.

During the five editions held, 70 international students enrolled in Masters programmes from a range of countries participated, joined by staff from TANAPA (see above) and a number of students from Tanzanian Universities and conservation agencies.

Through a combination of field trips and class lessons and exercises, the summer school aimed to provide field and GIS tools for assessing forest biodiversity.

Based on student feedback solicited by questionnaire at each editions, the school was a success, and students especially enjoyed the mix of field trips with lessons in classes and exercises on a PC using the data collected.

While this summer school was directly organized by MUSE and its partners in alliance with TANAPA, UEMC offered the option of arranging independent courses and summer camps at any institution, by providing logistic support and lodging facilities.
Thus, every year since 2010, Penn State University has organized an integrated research-education abroad programme for a class of B.Sc. students in the general field of landscape planning and park-community interactions.
Co-directed by Larry Gorenflo (Department of Landscape Architecture) and Carter Hunt (Department of Recreation, Park, and Tourism Management), the Tanzania Parks and People Programme focuses on community design and ecotourism in selected communities close to the park. The project aims to help local people meet resource demands without adversely affecting Udzungwa Mountains National Park or other reserves in the area. Moreover, a single-edition of a primate conservation course has also been organized by “Tree Field Studies” and led by Grainne McCabe. Last, the University of Copenhagen, in collaboration with MUSE, has organized a summer school for 2017 on the model of the previous five editions but specifically dedicated to a B.Sc. course at that University. The school was also opened to students of Tanzanian Universities that attended at no cost.

ENVIRONMENTAL EDUCATION & COMMUNITY-BASED CONSERVATION

Environmental education activities conducted by UEMC begun at its establishment, as by then MUSE had been piloting them for a few years through community conservation initiatives around the Uzungwa Scarp area. Being a science museum and working extensively with schools back in Italy, this programme also fell among the primary objectives of MUSE's work in Tanzania. Environmental education initially involved only four primary schools closer to UEMC. The programme included lectures on forest and park protection, wildlife conservation, tree nurseries preparation and the importance of tree planting. Over 1,000 pupils were involved with nearly 70 lectures in the first year. In addition, guided walks both in the National Park and in the nearby rubber plantation, as well as 'cinema nights' and music performances on the relevance of conservation were progressively added to the programme, involving a greater number of students and family members.

From 2010, these activities were taken on by the Italian non-profit "Association *Mazingira*" (see below) that collaborated with MUSE to boost environmental education by UEMC. Thus, by 2012 the programme had expanded to 13 primary and five secondary schools for a total of 31 classes involved and nearly 2,500 students attending the initiatives every year. The themes embraced new relevant topics such as environmental-friendly sources of energy, agro-forestry and soil conservation, biodiversity and eco-tourism. In addition to traditional lessons, workshops on energy-saving technologies and regular visits to the park were also introduced. Between 2011 and 2013, four teacher-training courses targeting a total of 110 teachers and ward education officers were organized. Additional initiatives were successfully organized by UEMC in collaboration with the park and other local partners. One example for all is the celebration of the "World Environmental Day".

Mazingira Association with MUSE has established an integrated programme to help local communities establish tree nurseries, conduct tree planting and agro-forestry, and adopt energy efficient technologies to decrease the consumption of firewood from the forest. Here and in next page, community members are testing the production of biomass pellets and efficient stoves as an alternative to firewood.

Association *Mazingira* ("environment" in Swahili) was founded in 2010 by researchers working at MUSE to facilitate and improve sustainable development of local communities in developing countries through addressing environmental issues.

Besides environmental education, *Mazingira* established in Udzungwa an integrated programme to help local communities establish tree nurseries, conduct tree planting and agro-forestry, and adopt energy efficient technologies to decrease the consumption of firewood from the forest.

More recently, *Mazingira* has begun to explore the potential of eco-tourism in the area by organizing visits to Udzungwa by eco-tourists from Italy and by promoting locally-managed activities such as beekeeping, animal husbandry, tourism hospitality and hand-craft works.

In this context, *Mazingira* has a leading role in the establishment of the Visitor Information Centre due to open in 2017 (see below).

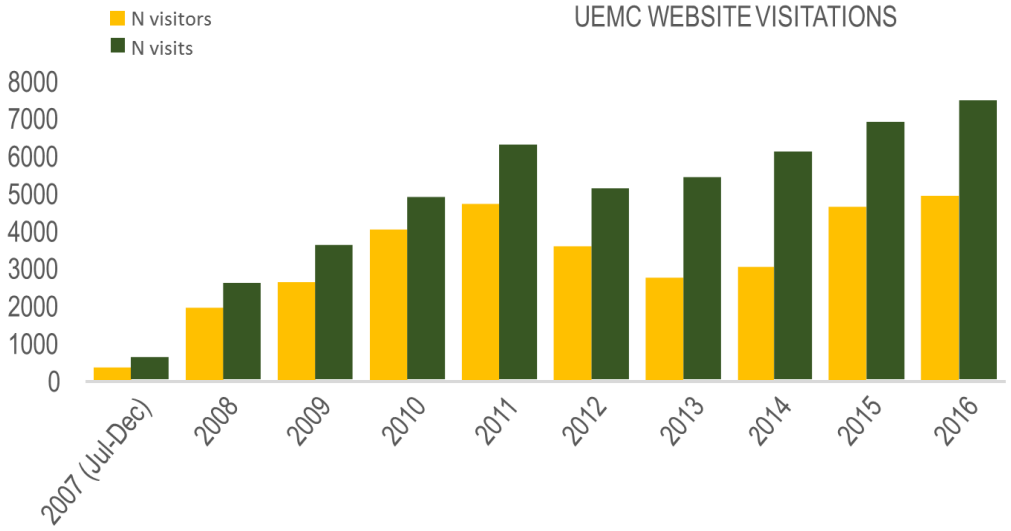
UEMC has piloted an environmental education programme then boosted by *Mazingira* Association: the programme operates in 13 primary and 5 secondary schools for a total of 31 classes and nearly 2,500 students involved every year.

NETWORKING AMONG FIELD STATIONS, RESEARCHERS AND CONSERVATION AGENCIES

Through its primary role of facilitating research, UEMC has also helped to boost networking among field stations in the tropics, and among individual researchers and agencies. UEMC participation in the TEAM Network has particularly helped linking UEMC efforts to similar field stations across the tropics. A key event in this context is the TEAM Network meeting that UEMC hosted in 2010, with representatives from TEAM sites across the tropics that visited UEMC and the forests. In addition, a number of important institutions have used UEMC as their entry point to the Udzungwas not only for conducting research by individual affiliates, but also for coordinated research and training programmes that, in turn, established new partnerships with local and international agencies. Examples include the training and research programme on land use planning and socio-economy of local communities that the Pennsylvania State University has been implementing continuously since 2010, or the research programme by the University of Copenhagen that built on research interests of individual scientists to become one of the major stakeholders in the current UEMC management.

UEMC PROMOTION AND COMMUNICATION ACTIVITIES

A variety of modalities was used to promote UEMC and generally to disseminate knowledge on the Udzungwas among the general public.
In July 2007, the website (www.udzungwacentre.org) was activated as the virtual "door" to use the field station, learn about its activities and more generally get a wealth of information on the area. Information housed here includes checklists to past and on-going research with a page where reports and other relevant publications can be downloaded. The site has been regularly updated, with major renovations in 2010 and 2017.
The number of visits increased steadily, from approximately 2,500 in 2008 to 7,500 in 2016 (see chart of visitation numbers)



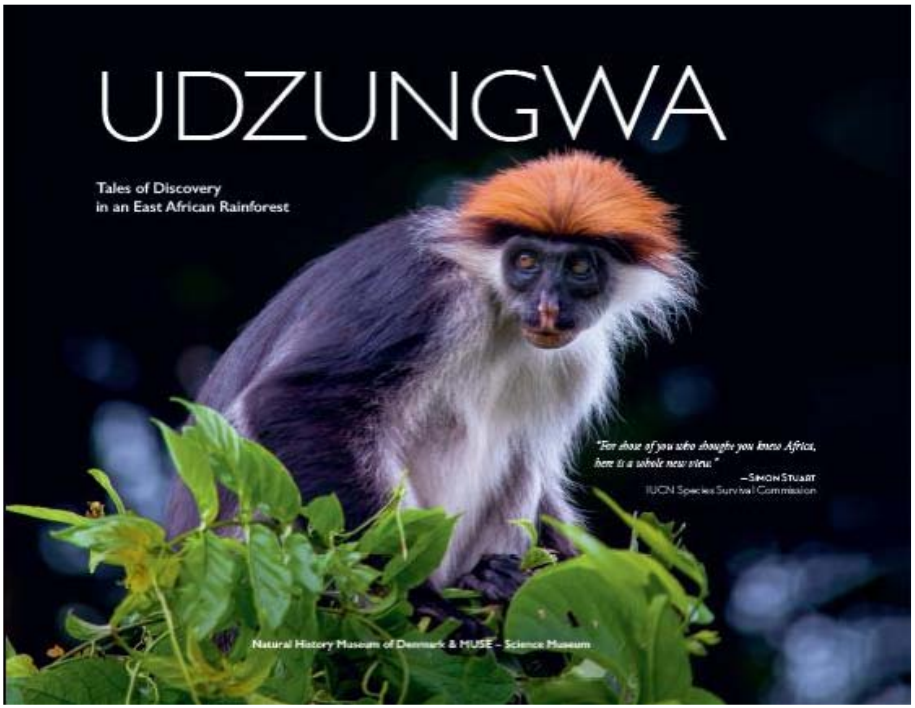
The number of UEMC website visitations expressed as number of different visitors and number of visits (source: http://www.udzungwacentre.org/stats/)

MUSE, the science museum in Trento, opened in 2013 with a ceremony attended by more than 30,000 people. Here, TANAPA's Director General Mr. Allan Kijazi inaugurating the greenhouse together with Renzo Piano, the world-famous architect that designed the new museum. MUSE exhibits include a live Udzungwa rainforest that attracts thousands of visitors each year.

In addition to the website, UEMC developed brochures distributed to partners locally and internationally, as well as video clips and a documentary (*"In the Udzungwa's shadow",* Italy 2014, produced by MGreporter and viewable at: http://www.cultureunplugged.com/documentary/watch-online/play/54725/-In-the-shadow-of-the-Udzungwa-).

Promotion of UEMC has also been made by MUSE scientists and partners through workshops, scientific and general public conferences, as well as at training courses. In 2013, with the opening of MUSE - a leading European museum with 12,000m^2 of exhibitions featuring local and global nature - the Udzungwa Mountains were given a prominent space in the museum exhibitions: a 600m^2 greenhouse reproducing the Udzungwa rainforest. This represents a geographically-focused approach to highlight global conservation themes to the public, and how rainforests are emblematic of the current environmental crisis. By the summer of 2017, MUSE has been visited by more than 2.5 million people since its opening, and we believe this too helped a great deal promoting the Udzungwas and UEMC to Italians and Europeans visiting the museum. The opening itself, attended by more than 30,000 people, has been an important promotion moment, with TANAPA's Director General Mr. Allan Kijazi inaugurating the greenhouse together with Renzo Piano, the world-famous architect that designed the new museum.

An important work to spread knowledge on Udzungwa is the book entitled *"UDZUNGWA: Tales of Discovery in an East African Rainforest"* that the Natural History Museum of Denmark and MUSE jointly published in 2015 (edited by Nikolaj Sharff, Francesco Rovero, Flemming Pagh Jensen and Steffen Brøgger-Jensen). Beautifully illustrated, the book was contributed by most of the senior biologists that worked in Udzungwa over the last decades, collating stories of discoveries, and providing an overview on the natural history, biogeography, biological importance and conservation needs of the area.



An important tool to spread knowledge on Udzungwa is the book entitled "UDZUNGWA: Tales of Discovery in an East African Rainforest" that the Natural History Museum of Denmark and MUSE jointly published in 2015 (edited by Nikolaj Sharff, Francesco Rovero, Flemming Pagh Jensen and Steffen Brøgger-Jensen).

PERSPECTIVES

A NEW MANAGEMENT PHASE (2017-2021)

Towards the last period of current management, MUSE and TANAPA began discussing plans in view of a progressive handing over to TANAPA of UEMC management. This led to the current new agreement, covering 2017-2021, which introduced two major changes: the first is that TANAPA now manages UEMC in closer collaboration with MUSE in terms of the core functioning, such as accommodating researchers; the second is that the Natural History Museum of Denmark entered into the partnership by joining MUSE to provide continued funding and involvement in the area with biodiversity research projects.
Hence, the alliance MUSE-NHMD has established a fund that includes both a direct contribution to TANAPA for the key functioning of UEMC, and support to running core scientific projects.

Besides management procedures, the new phase aims to

- ❖ consolidate the long-term biodiversity inventorying and ecological monitoring with priority to the Primate Monitoring Programme, the TEAM Network programme and the invertebrate assessment and monitoring towards a timely and efficient use of data by the park for management decisions
- ❖ continue providing technical training to TANAPA staff and other professionals from protected areas and conservation agencies for the use of standardized monitoring tools
- ❖ consolidate the facilitation by UEMC of community education and community-based conservation initiatives. This latter objective includes the development of eco-tourism activities that can be beneficial to both the park and local communities.

BOOSTING FIELD-BASED, HIGHER EDUCATION TRAINING COURSES

Along with the continuation of the long-term ecological monitoring and technical advisory to park staff, UEMC aims to continue and boost the hosting and facilitation of field-based training of students, such as summer schools and studying abroad visits. Through the international network built over the years, UEMC has now greater potential and attraction by Universities and other international programmes. Indeed, the decade of experience in conducting and facilitating biodiversity projects provides a wealth of options for making the Udzungwas a fascinating “laboratory” of tropical forests where students can apply first-hand the diversified range of tools used to study biodiversity.

A NEW VISITOR INFORMATION CENTRE AND RELATED COMMUNITY INITIATIVES

According to TANAPA’s vision, each park should have a visitor centre as a small museum and interpretation centre to introduce visitors to the park and provide a wealth of information for the visit.
A visitor information centre is especially critical for the Udzungwa Mountains National Park given the peculiarities of the forest habitat and the complexity of the broader ecosystem, with its huge levels of biodiversity most of which is secretive and hence difficult to sight. Thus, the realization of a Visitor Information Centre (VIC) at the National Park entrance was one of the objectives of the second management phase of UEMC.

Planning began in 2013 with the visit of TANAPA's Director General to MUSE and the international cooperation office of Trento's Autonomous Province who had already provided the bulk of funding for UEMC establishment.
Funding from Trento Province was secured in 2015, through an alliance of institutions led by the non-profit Association *Nadir* based in Trento, together with MUSE and Association *Mazingira* as partners.
The Natural History Museum of Denmark later joined the partnership and provided funding for most of the exhibits.

At the time of writing this report the Udzungwa VIC is up and its inauguration is scheduled for the end of 2017/early 2018. The structure is made of two modular block buildings, one being a museum and interpretation centre, and one a seminar/video projection room. The structure was designed by the Italian architect Flavio Ridolfi and is made of eco-friendly construction materials. These include bricks made of pressed soil and sand with little use of cement.
Before the project commenced, all partners agreed with TANAPA that the VIC would not just serve the tourists visiting the park, but also the local communities and especially the students of primary and secondary schools.
Hence, we envision the visitor centre as a special "tool" for boosting greater involvement by the park and adjacent communities to get further involved into environmental education and to boost eco-tourism.

AND MORE TO COME… WITH SOME WORDS OF CONCLUSION

There are other important plans for developing UEMC in the current management phase. One of these, by primary initiative of the Natural History Museum of Denmark, is the construction of an additional building to be used as a laboratory for all research that needs screening, preparation, identification and storing of samples collected in the field, for example for the invertebrate assessment programme by NHMD or studies of population genetics. We believe such structure would address a significant gap in the current facilities and hence make UEMC attractive to a broader range of research projects.

Besides this additional infrastructural development, we ultimately hope UEMC will continue to serve for its primary and fundamental functions it was realized for: host researchers, facilitate research in the Udzungwas, support the capacity of the park and the other reserves in the area by monitoring their exceptional biological treasure, and use this knowledge to fine tune management. In a context of ever increasing anthropogenic pressure on the forests, with rapidly escalating conflicts in land use between conservation and intensive agriculture at their surroundings, we must not overlook the importance of monitoring and protecting them. For it is precisely the very existence of these forests that provides the natural assets (water, hydropower, soil fertility, rainfall, etc.) on which thousands of people's livelihoods depend on.

ACKNOWLEDGEMENTS

We would like to thank Tanzania National Parks for the constructive partnership and especially the Director General, Mr. Allan Kijazi, the Manager for Ecological Monitoring, Mr. Inyasi Lejora, and all Chief Park Wardens and Wardens for Ecology that were stationed at Udzungwa Mountains National Park since UEMC was established.
We also thank the following Tanzanian Institutions for allowing research activities in the area: Tanzania Wildlife Research Institute (TAWIRI), Tanzania Commission for Science and Technology (COSTECH) and Tanzania Forest Service (TFS).

UEMC would not have been a success without the dedicated and responsible efforts of its staff. We thank Amani Kitegile, Philipo Jacob, Emanuel Martin and Arafat Mtui for their hard work as project coordinators at UEMC. With them, we thank all the staff that served over the years, with special thanks to Leonard Ngungulu, Shabani Ponda, Nickson Nyenda, Ruben Mwakisoma, Aloyce Mwakisoma, Richard Laizzer, Mwajuto Matola, Steven Shinyambala, Aggrey Uisso, Mokoro Kitenana.
For the committed work in community conservation, we thank Silvia Ricci from MUSE and all staff from *Mazingira* Association, particularly the project coordinator Pima Nyenga.

We thank all researchers, students and others that stayed at UEMC.
A particular thank goes to long-term researchers and colleagues that in various ways have been supporting the establishment or functioning of UEMC, including Andy Bowkett, Marco Ciolli, Baraka de Graaf, Larry Gorenflo, Trevor Jones, Andy Marshall, Michele Menegon, Nikolaj Sharff, Tom Struhsaker.
A special thank to Trevor Jones of the Southern Tanzania Elephant Program for collaborating on a range of projects, Larry Gorenflo of Pennsylvania State University for his constant support, and Nikolaj Sharff of the Natural History Museum of Denmark for helping to develop the institutional collaboration in place for the current UEMC management.
Several colleagues at MUSE have been helping over the years, and special thanks go to the Director, Michele Lanzinger, and to Michele Menegon and Paolo Pedrini. Osvaldo Negra (MUSE) is thanked for graphic layout of the report and Nicole Murray (University of Illinois, USA) for language editing.
Moreover, we express sincere gratitude to the following colleagues who kindly made available their photographs for reproduction in this report: Jon Fjeldså, Rasmus Gren Havmøller, Christine Gupfinger, Trevor Jones, Michele Menegon, Raffaele Merler, Silvia Ricci, Francesco Rovero, Nikolaj Sharff.

We also thank the following collaborating institutions:

Animal Behaviour Research Unit (Tanzania) - Anglia Ruskin University (UK)
Association *Mazingira* (Italy)
Conservation International - Tropical Ecology Assessment and Monitoring (USA)
Department of Zoology and Wildlife Conservation, University of Dar es Salaam (Tanzania)
Natural History Museum of Denmark, University of Copenhagen (Denmark)
Paignton Zoo (UK)
Pennsylvania State University (USA)
Sokoine University of Agriculture (Tanzania)
Southern Tanzania Elephant Program (Tanzania)
Tanzania Forest Conservation Group (Tanzania)

Udzungwa Forest Project - Flamingo Land and University of York (UK)
University of Exeter (UK)
University of Trento (Italy)
Whitley Wildlife Conservation Trust (UK)
Wildlife Conservation Society (Tanzania Program)
World Wildlife Fund (Tanzania)
For financial support, we thank the following institutions:

Funding for UEMC building
Provincia Autonoma di Trento – Servizio Attività Internazionali (Italy)
MUSE – Museo delle Scienze (Italy)
Margot Marsh Biodiversity Fund (USA)

Funding for UEMC general running
Provincia Autonoma di Trento – Servizio Attività Internazionali (Italy)
MUSE – Museo delle Scienze (Italy)
Conservation International – TEAM Network (USA)

With an additional thank to Pennsylvania State University (USA), the Natural History Museum of Denmark (Denmark), and all researchers and institutions that contributed through lodging fees.

Funding for running UEMC-based research and monitoring by MUSE
Provincia Autonoma di Trento – Servizio Attività Internazionali (Italy)
MUSE – Museo delle Scienze (Italy)
Conservation International – TEAM Network (USA)
Critical Ecosystem Partnership Fund (USA)
Rufford Small Grants Foundation (UK)
National Geographic Society (USA)
Mohamed bin Zayed Species Conservation Fund (United Arab Emirates)
Whitley Wildlife Conservation Trust (UK)
Fondazione Foresta Futura (Italy)

PROVINCIA AUTONOMA DI TRENTO

Museo delle Scienze MUSE

CONSERVATION INTERNATIONAL

TEAM NETWORK

MARGOT MARSH BIODIVERSITY FOUNDATION

CRITICAL ECOSYSTEM PARTNERSHIP FUND

The Rufford Foundation

NATIONAL GEOGRAPHIC

صندوق محمد بن زايد للمحافظة على الكائنات الحية
The Mohamed bin Zayed SPECIES CONSERVATION FUND

WHITLEY WILDLIFE CONSERVATION TRUST