Darwin Initiative: Final Report

To be completed with reference to the "Project Reporting Information Note": (https://www.darwininitiative.org.uk/resources-for-projects/information-notes-learning-notes-briefing-papers-and-reviews/).

It is expected that this report will be a **maximum** of 20 pages in length, excluding annexes.

Darwin Project Information

Project reference	26-018
Project title	**Promoting public health in a biodiverse agroforest landscape in Guinea-Bissau**
Country(ies)	Guinea-Bissau
Lead organisation	University of Exeter, UK
Partner institution(s)	Institute for Biodiversity and Protected Areas (IBAP); Associação Nacional para o Desenvolvimento Local e Urbano (NADEL), Guinea-Bissau; Robert Koch Institute (RKI), Germany; Centre for Research in Anthropology (CRIA), Portugal
Darwin grant value	£325,043.20
Start/end dates of project	01.07.2019 – 30.06.2022
Project leader's name	Dr Kimberley Jane Hockings
Project website/blog/social media	@KJHockings @hellen_wildlife
Report author(s) and date	PL Hockings and DRF Bersacola wrote the report with contributions from project partners. 19th July 2022

1 Project Summary

The ongoing outbreaks of Ebola and Covid-19 highlight one of the greatest challenges that we will face this century: the threat of infectious diseases. These can represent serious risks to public health, and conservation problems when animal reservoir species are endangered. Infectious diseases shared between humans and wildlife are predicted to increase due to habitat destruction, road building and hunting, especially as some wildlife shift their distributions to utilise human-impacted habitats. The risks in less economically developed countries are high as they often lack the systems to detect and respond to outbreaks.

Guinea-Bissau, West Africa, is among the poorest countries with 67% population living below $1.90 USD/day and many without access to healthcare. The alleviation of poverty in local communities can be achieved through direct approaches such as improving access to healthcare and One Health knowledge, and indirect approaches such as safeguarding traditional rights, cultural values, ecosystem services, or capacity building of local groups and institutions. Of considerable importance is developing strong working relationships and collaborations amongst local stakeholders, as well as national and international institutions.

Cantanhez National Park (NP) is 1067km^2 and is inhabited by approximately 28,000 people. It is the country's most biodiverse protected area, with numerous threatened species

such as the western chimpanzee (*Pan troglodytes verus*) and red colobus monkey (*Piliocolobus badius temminckii*) persisting within forest fragments surrounded by human settlements. In April 2018, we identified incidences of leprosy (*Mycobacterium leprae*) in Critically Endangered chimpanzees at Cantanhez NP; the first in wild great apes (Fig1a). Although leprosy is present in humans in Guinea-Bissau, data are lacking for human cases within Cantanhez NP. Our camera trap footage shows that other primates, which are commonly hunted for food and kept as pets, are also likely to be infected with leprosy (Fig1b). Such incidence of leprosy in several primate species of Cantanhez NP mean that people and wildlife are both at risk, either because of potential cross-infections or through retaliatory wildlife killings. This is compounded by a lack of knowledge about the disease and behaviours that might influence its spread.

This project's objectives were to: (1) evaluate the occurrence of leprosy in nonhuman primates and humans; (2) improve surveillance capacity for early- stage leprosy by the local health system; (3) work with NGOs, health practitioners and local communities to develop and trial a One Health awareness campaign; (4) make progress towards developing a multi-stakeholder preparedness and response plan for disease outbreaks and conservation conflicts over disease, and; (5) improve longer-term conservation capacity of key habitat and biodiversity.

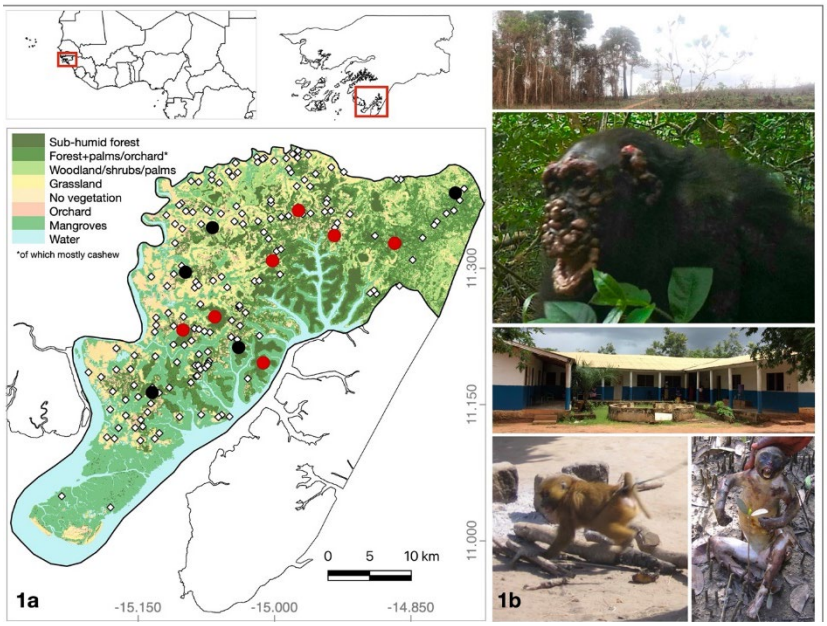

Fig 1a. Map of Cantanhez NP showing villages (white diamonds), and locations of known chimpanzee communities (black circles), including those with confirmed leprosy cases (red circles) before this project (N=3, south), and those with leprosy cases identified during this project (N=4, north, Output 2). **1b.** Partially burned forest corridor next to a road & agricultural field. An adult female chimpanzee with leprosy. The hospital in Iemberem has 3 nurses who provide care to patients from > 20 villages. Nonhuman primates, including baboons, are often hunted for meat and kept as pets.

2 Project Partnerships

[please note that Evidence for this report is listed in Annex 7]

Following the confirmation of leprosy in wild chimpanzees in Cantanhez NP, we discussed the situation with the Institute for Biodiversity and Protected Areas (**IBAP**), Guinea-Bissau, who are in charge of managing biodiversity and Protected Areas in Guinea-Bissau. Our discussions included ways to reduce the negative impacts of leprosy on endangered wildlife and the local human population. This collaborative project was consequently developed at the invitation of IBAP to respond to a potential health emergency resultant from the discovery of leprosy in chimpanzees and concern that it might result in conflicts with local people. Several representatives from partner Institutions and Organisations in Guinea-Bissau and Europe were involved in identifying and designing research, conservation, and development priorities. All partners were directly involved in planning and making decisions about project activities, with UoE coordinating the research, and monitoring and evaluation activities. Over the course of the project, staff from the lead organisation, University of Exeter (**UoE**), spent 52 weeks in Guinea-Bissau, resulting in a strong partnership between the Lead and Partner organisations, with significant progress made towards achieving the projects stated objectives (Sections 3.1, 3.2).

IBAP is our main host partner, and we have worked closely with Abílio Said (Coordinator Dep. Terrestrial Protected Areas and CBS focal point in Guinea-Bissau), Aissa Regalla (Coordinator Dep. Monitoring and Biodiversity Conservation), Queba Quecuta (Director of Cantanhez NP) to ensure the timely completion of activities implemented *in situ* by the IBAP DPOs (Maimuna Jaló and Américo Sanhá), eight DFOs and two local research consultants (RCs). IBAP provided essential logistical support in-country including transport to and within Cantanhez NP; advised on biodiversity survey protocols; facilitated meetings and workshops;

received funds to pay staff and complete project activities; and assisted and advised on day-to-day activities on the ground. Working directly with IBAP, the PL Kimberley Hockings and DRF Elena Bersacola produced the Biodiversity and Environmental Action Plan for Cantanhez NP in English and Portuguese (Evidence 1), the first of its kind for any terrestrial National Park in Guinea-Bissau (Section 3.1 Output 3). Aissa Regalla and PL Hockings co-represent Guinea-Bissau in the IUCN Western Chimpanzee Action Plan (WCAP) Implementation Committee and will both be attending a regional chimpanzee surveys and conservation planning meeting in Monrovia, Liberia, in September 2022. Maimuna Jaló (DPO) presented project findings at the IUCN Africa Protected Areas Congress (2022) in Kigali, Rwanda (Evidence 2). The PL has been collaborating with IBAP since 2008 and collaborations will continue after project completion.

We have worked with our Guinean partner NGO **NADEL** (Associação Nacional para o Desenvolvimento Local e Urbano), including Sidi Jaquite (NADEL Director and High Commission in Guinea-Bissau), Aristoteles Gomes (NADEL National Coordinator), Samba Tenem Camará (DPO, Y1/2) to adapt and develop a locally appropriate social science survey to determine local knowledge of infectious diseases in Cantanhez NP and gather background information on the health system and health services available. We worked with Sara Quade (DPO, Y3/4) to design/collect One Health data, developing a novel participatory approach to examining One Health knowledge in local people (Section 3.1 Output 1; Evidence 3). We worked with NADEL to employ 8 health agents (residents from villages across Cantanhez NP with training on 'basic health') to collect data on human resource use, interactions with wildlife, and behaviours that might impact disease transmission. NADEL facilitated collaborations with **Cumura** (the referral hospital for leprosy in Guinea-Bissau) including the lead person in Guinea-Bissau working on leprosy treatment in people, Dr Silvio Coelho (**Ministry of Health, Republic of Guinea-Bissau**; General Directorate of Prevention and Health Promotion; National Program for the Fight against Leprosy and Tuberculosis; Directorate of Service of Neglected Transmissible Diseases), a Guinean **WHO** consultant Mireille da Rosa Fernandes Pereira, and Arniel Silot (Amici di Raoul Follereau, **AIFO**, Italian NGO that specialises in combating leprosy with a base in Bissau). We worked with this team to run the leprosy training to health personnel across Cantanhez NP (Output 1) and co-drafted the One Health leprosy report in English and Portuguese which details strategies and actions, including a new collaborative communication chain to ensure information is shared on human and wildlife dimensions of leprosy in Guinea-Bissau, confirming that collaborations between the PL, DRF, NADEL, Cumura and AIFO are ongoing.

Our partner, the Centro em Rede de Investigação em Antropologia (**CRIA**), including Amélia Frazão-Moreira and Hannah Parathian, have worked with NADEL and UoE to develop social science methods to evaluate medical and traditional knowledge about leprosy and other disease (Section 3.1, Output 1). CRIA have been working alongside NADEL to ensure a culturally sensitive approach when collecting interview data and have advised on participatory approaches to ensure that women's opinions are included in the development of our project. They have provided theoretical context to increase our understanding around human health and behaviour (based on the One Health concept). CRIA worked alongside Sara Quade to develop the One Health trial campaign and Amélia Frazão-Moreira conducted interviews with traditional healers to understand traditional leprosy diagnosis and treatments (Evidence 3).

Our partner, the Robert Kock Institute (**RKI**), has worked with UoE and IBAP to advise on the design of great ape disease monitoring in Cantanhez NP. RKI have analysed primate faecal samples from across Cantanhez NP for the presence of *M. leprae* and assisted in phylogenomic analysis of leprosy strains (Evidence 4). RKI have developed protocol and training instructions for sampling primate carcasses and have provided in-person training. RKI have hosted two Master's by Research students from the UoE to analyse chimpanzee and baboon faecal samples collected during this project for the presence of leprosy and to help determine transmission dynamics through dietary analysis and phylogenomics (Evidence 4).

While not formal project partners, local people (represented by Nalu chieftains, Women's Associations, Land Management Committee, Youth Associations, and elders) played a crucial role in supporting and advising on biodiversity conservation and healthcare matters in Cantanhez NP. IBAP, including Queba Quecuta, the Director of Cantanhez NP and the DPOs, have remained in consultation with local communities throughout the entire project. This includes informal discussions and management meetings, informing people of leprosy in wildlife, and distributing protective and cleaning equipment to reduce the spread of COVID-19.

3 Project Achievements

3.1 Outputs

Output 1 Leprosy Surveillance and One Health understanding: We made considerable advances in our understanding of local knowledge and perceptions of disease, facilitating leprosy surveillance across Cantanhez NP, and demonstrating changes in the understanding of the links between environmental, animal and human health in local people. To improve understanding of local knowledge/perceptions of disease and potential risk factors for wildlife-to-humans disease transmissions, we conducted interviews with local people (N=101 household participants across two separated questionnaires), traditional healers (N=5) and health workers (N=5) across 27 villages in Cantanhez NP (Evidence 11). Leprosy is known by local people, but knowledge of symptoms, causes and transmission is limited, particularly at its early stage (Fig 2A). There was a lack of knowledge by both traditional healers and health workers on how to treat leprosy and which health facilities to direct suspected leprosy patients, including no knowledge of the specialist leprosy hospital, Cumura. To inform the development of a One-Health strategy, we conducted a second round of interviews to understand perceptions and mitigation of risks of infectious disease transmission and barriers when accessing healthcare. Zoonotic disease transmission is an issue that people show little awareness of, although there is some knowledge of factors that might increase the risk of zoonotic disease transmission including the consumption of fruit that an infected animal has touched, the consumption of meat from a sick animal, and the use of shared water sources. Many people, but not all, perceive wildlife carcasses as possible disease risks. To avoid disease transmission, people suggest maintaining a distance and not touching the carcass. However, perceptions of what to do in the event of encountering a sick wild animal vary (Fig 2B). Most people said they would go to a hospital/or a health centre if they become ill, with some also visiting traditional healers. However, people experience difficulties (from a lack of finances, shortage of medication at the health centre/hospital, and a lack of transport) when trying to access medical help (Fig 2C). These interviews developed our understanding of local knowledge on leprosy transmission, diagnosis, and treatment at least three-fold from a low baseline (estimated at 5% from some previous literature) to at least 15%, ensuring our team could make more informed decisions when moving forward.

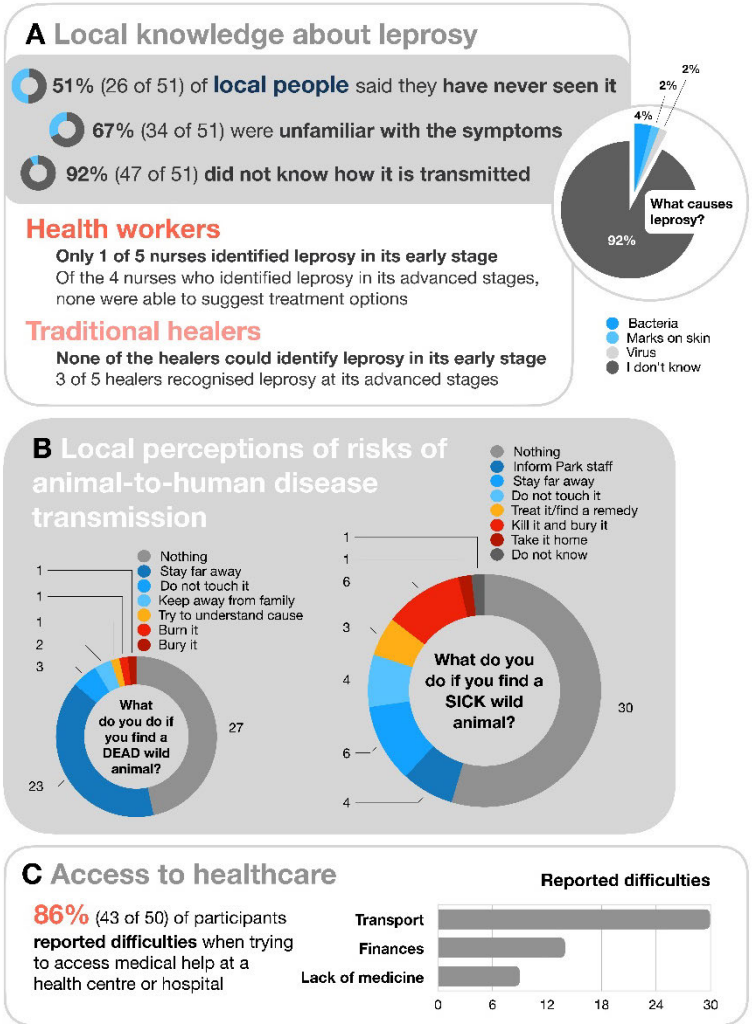

Figure 2. Summary of results from interviews conducted across 27 villages in Cantanhez NP, to (A) understand local knowledge of disease including leprosy (N=51 household participants, five health workers and five traditional healers from questionnaire 1); (B) local perceptions of disease transmission risks (N=50 household participants from questionnaire 2); and (C) reported problems to access health care in Cantanhez NP (N=50).

In collaboration with Cumura, we carried out leprosy training workshops with health workers. In May 2021 we collaborated with Cumura hospital to carry out training to nurses (N=10,3 from Cantanhez) in Catió (the capital of the Tombali Region, which includes Cantanhez NP). In May 2022 we carried out training to

identify leprosy in people, including leprosy at the early stages and multibacillary leprosy. Cumura staff trained a total of 46 people including 37 health workers including one nurse, 8 guards and one local collaborator from 28 villages across Cantanhez (Evidence 2). Please note that the number of health agents in May 2022 decreased from 50 due to several people changing jobs or moving to a different village/town outside Cantanhez NP (outside of the project's control). In May 2022 we identified 37 active health agents, two of whom could not attend the training. The health workers comprised one woman and 36 men, their age ranged from 22 to 48 years old, and comprised Balanta (N=23), Nalu (N=6), Fula (N=5), Mandingka (N=2), and Tanda (N=1) ethnicities. Most (73%) had at least five years of experience working as a health agent. 67.6% of health agents could not identify leprosy prior to the training via images of leprosy patients of various stages (Table 1). By the end of the training, nearly all participants were able to describe the symptoms and ways of human-to-human transmission and demonstrated a substantial increase in knowledge. Post-training, all health workers were able to say that treatment for leprosy is available and free of charge. Post-training, all health workers were aware of Cumura Hospital as the specialised centre for treating leprosy patients in Guinea-Bissau. All participants took the contact details of the Cumura training staff and agreed to contact them when identifying a suspected case. Cumura staff have arranged to return to Cantanhez NP in the dry season (January 2023) to conduct a door-to-door survey to identify new patients. Cumura have a protocol to not train 'curandeiros' (traditional healers) unless they have also received more formal medical training. This is to ensure that inappropriate action is not taken with sick patients. We followed Cumura's protocol and instead of training curandeiros, we conducted semi-structured interviews (N=5, 2 female, 3 male) to understand how they traditionally identify and treat with patients with leprosy and whether patients suspected to have leprosy are directed to a health centre/hospital. All curandeiros knew of leprosy and could accurately describe advanced physical symptoms (i.e. deformities), but only one proposed traditional ways to treat the disease. All curandeiros agreed to send patients to consult local health workers if they suspected leprosy in a patient.

Table 1 Results of the pre- and post-training questionnaire to health workers (N = 37).

Question	Answer	Pre-training %	Post-training %	% Increase
1. Do you know what this is? (Showing images of leprosy patients)	**Leprosy**	**24.3**	**100**	**311.5**
	Other / I don't know	67.6	0	
2. How do you explain this disease, what do you observe in the patient?	**At least one leprosy symptom mentioned**	**5.4**	**70.3**	**1201.9**
	Description of the image	40.5	18.9	
	Wrong symptoms	48.6	10.8	
	I don't know	5.4		
3. How does the patient feel?	**Loss of sensitivity and other symptoms stated**	**0**	**16.2**	**3103.7**
	Loss of sensitivity in the area affected	**2.7**	**70.3**	
	Wrong symptoms (e.g., pain in the area)	83.8	10.8	
	I don't know	13.5	2.7	
4. How is this disease transmitted?	**Contact, saliva and/or cough mentioned**	**16.2**	**94.6**	**484**
	Wrong answer	32.4	5.4	
	I don't know	45.9	0	

Using this knowledge, we carried out the One Health trial campaign in November-December 2021, locally known as the "**Djumbai Saúde Única**" (*One Health get-together)* (Evidence 3). We

implemented the One Health trial campaign in eight villages in central Cantanhez NP. We carried out nine *djumbai* sessions from 13 November to 5 December 2021. We involved a total of 142 participants, including 73 women and 69 men, with groups ranging from six to nine individuals (Fig 3a). Each *djumbai* session included a group of women and a group of men. Each group was asked by a facilitator to build a One Health network (Figure 3b). Of the 142 participants, 123 participants were interviewed pre-One health trial campaign, 127 were interviewed right after participating in the trial campaign and 125 were interviewed two to two-and-a-half months post-campaign (Annex 7, Table S1). Some participants were not available to be interviewed and in Lautchande, only post-campaign interviewed were carried out, hence the different number of respondents for each interview periods.

Figure 3. (a) The two groups building the One Health networks in Cadique Mbitna. (b) The elements of a One Health network built with djumbai groups: humans (centre), wild animals (left), domesticated animals (top), water (right) and forest/mangroves (bottom).

The questions that saw a higher increase in knowledge (Annex 7, Table S1) were related to human-to-wild animal disease transmission (129% increase in correct answer two months post-trial campaign), disease transmission from wild to domesticated animals (53.6% increase), disease transmission from domesticated animals to wild animals (48.2% increase) and from human to domesticated animal (45% increase) (Annex 7, Table S2; Evidence 3).

Building on the needs identified during discussions with local communities and utilising the infrastructure/networks developed in this Darwin project (Cantanhez Youth Association **AJEC**, NADEL, IBAP, CRIA), we raised funds via a crowdfunding campaign to purchase PPE (for Cantanhez NP guards, guides, healthcare workers at the outset of the COVID-19 pandemic) and solar panels, battery, lights, and a secure metal framework for the main hospital in Iemberem (Figs 1b,4). The Iemberem hospital previously lacked any lights, and nurses used their mobile phones at night to assist patients, including for childbirth. We held meetings with the community to ensure community responsibility for the equipment.

Figure 4. Solar panels installed at the hospital in Iemberem during this project.

Output 2 Improved wildlife management capacity: The project has established the first health and abundance systematic monitoring programme for key terrestrial biodiversity in Guinea-Bissau, improving knowledge of biodiversity and developed the first Biodiversity and Environmental Action Plan for Cantanhez NP that has been agreed by partner IBAP (Evidence 1). We increased wildlife monitoring capacity through establishing 64 transect routes and 48 camera trap sampling points across Cantanhez NP. Our multi-partner team carried out monthly

distance sampling along line transects using Cybertracker (transect repetitions, N=720, total effort=810km), recording chimpanzee nests, direct encounters with wildlife, and animal and human signs. We checked camera traps monthly (total N of camera trap days=21,400) and DPOs processed camera trap footage for animal presence and signs of leprosy. We initiated an animal carcass swabbing protocol (Evidence 5). The project has provided IBAP with the full capacity to monitor terrestrial biodiversity in Cantanhez NP through training and the implementation of the Biodiversity and Health Monitoring Programme, as well as training on how to analyse survey data by the DRF. In total, 29 people were trained in biodiversity survey data collection. All Cantanhez park staff (eight guards, one director and one vice-director), two local research consultants (RCs), two DPOs (young Guinean researchers) as well as five IBAP technicians and directors of National Parks, and representatives of the Environment Ministry, the National Directorate for Forest and Fauna, and the National Guard were fully trained in distance sampling using line transect surveys and camera trap surveys by UoE DRF. Six collaborators, as well as the two RCs were trained in faecal sampling and grid-based camera trap monitoring (leprosy intensive monitoring). DPOs, IBAP technicians and directors and government representatives were also trained by the DRF in data analysis (Excel, DISTANCE, QGIS). Reports were written up and shared by DPOs every six months. Six training manuals produced and shared with IBAP (GPS, camera trap, DISTANCE, QGIS and Maxent manuals) and the full methodology (Evidence 5).

Figure 5. Disease progression of leprosy in chimpanzees at Cantanhez NP. An adult female chimpanzee Rita over the course of 5 years (a-d).

IBAP and UoE produced a faunal inventory for the entire Cantanhez NP that includes records of medium- to large-bodied mammals, and provides information on their habitat use, behaviour, ecology, conservation status, and tracks/signs (Evidence 6). Biomonitoring surveys consisted of 810km of transect survey effort and 21,400 camera trap monitoring days across 12 protected forest blocks (115km^2) and surrounding agro-forest mosaics (435km^2). Data from this project were used to generate Bayesian distribution models for six primate species, habitat suitability Maxent models for three primate species, and presence maps of eight ungulates and three rare taxa (African forest elephant, African golden cat and ground pangolin) (Evidence 1). As of May 2022, ths project has confirmed that six chimpanzee communities across Cantanhez NP, including at least eight individuals, have advanced stage (multibacillary) leprosy with deformities (Figure 5) (Evidence 4). Genetic analysis of the leprosy strain present in Cantanhez NP suggests that the probable transmission from humans to chimpanzees was not recent and that another animal or environmental reservoir may be present (Evidence 4). Our team recently confirmed the occurrence of leprosy in Guinea baboons (*Papio papio*), and camera traps suggest that at least three groups are affected across Cantanhez NP (Evidence 10). Results from chimpanzee and baboon faecal samples analyses will be included in one PhD (Marina Ramon) and two MRes dissertations and further collaborative publications, including one in preparation on phylogenetic

Figure 6. (a) Collection of biological samples and disposal of a chimpanzee carcass by DRF Bersacola and IBAP team. (b) Laboratory analysis of samples by UoE MRes student at RKI.

variations in *M. leprae* strains across species and individuals (Fig 6). The RKI provided expert training to UoE (PhD Ramon and DRF) in carcass swabbing and disposal of carcass and PPE. An IBAP team comprising three persons were selected by IBAP and UoE and trained by UoE. So far, the team has collected biological samples from three dead animals encountered in the forest, including a chimpanzee (hair and bones), a green monkey (*Chlorocebus sabaeus*) and a Campbell's monkey (*Cercopithecus campbelli*) (six swabs) (Figure 6). A data collection and management protocol was produced in English and Creole (Evidence 1,5). Using data generated we evaluated and fine-tuned methods and sampling locations employed during the project and incorporated best practises into the first biodiversity monitoring programme protocol for terrestrial wildlife in Guinea-Bissau. This information was incorporated in the Biodiversity and Environmental Action Plan for Cantanhez NP (Evidence 1,5). Approaches and protocols used in Cantanhez NP are now incorporated into the long-term management of Cantanhez NP and IBAP have proposed applying these protocols for other NPs across Guinea-Bissau.

Output 3 One Health Environmental Action Plan: There was a consensus between partners to change the name of the "One Health Environmental Management Plan" to "Biodiversity and Environmental Action Plan for Cantanhez National Park, Guinea-Bissau" to encompass (1) One Health in its broadest terms including the impacts of habitat and climate change, (2) to ensure the conservation of threatened wildlife in response to inter-related threats was explicit, and (3) to produce one clear Action Plan to facilitate implementation rather than multiple plans with slightly different foci. The project has produced the first Biodiversity and Environment Action Plan with a strong emphasis on multi-stakeholder engagement and One Health to facilitate human-wildlife coexistence in Cantanhez NP (Evidence 1). Coexistence is considered a dynamic state in which humans and wildlife co-adjust to sharing landscapes, sometimes resulting in conflict over space, resources, and disease, albeit with costs remaining tolerable to both. This Action Plan provides information on mammal diversity and distribution (generated from Section 3.1 Output 2) which is viewed alongside human behaviour and distribution (Section 3,1 Output 1) including participatory mapping data from health agents, anthropogenic threats to fauna including those known to impact disease transmission and emergence such as habitat change, illegal hunting/trade, infrastructural development, and climate change. Using this information and our in-depth knowledge of the socio-ecological context including local ecological knowledge, priority conservation strategies, actions and indicators are proposed which explicitly consider local people's needs and explicit strategy to strengthen stakeholder coordination and decision-making capacity. From this, key wildlife habitat including corridors, areas of high human-wildlife interaction and potential disease transmission have been identified (Evidence 1,7).

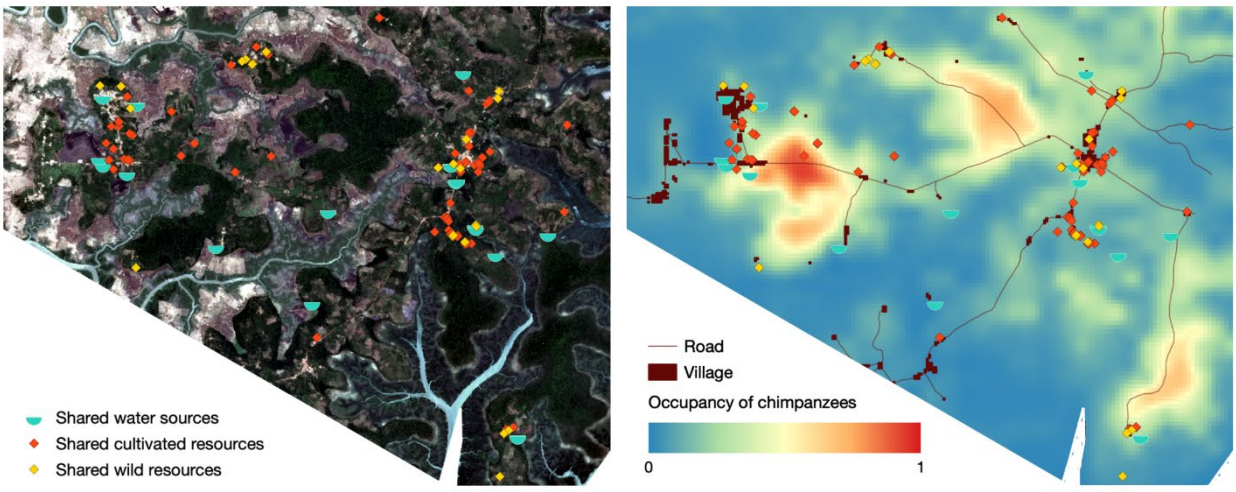

Figure 7. Human-chimpanzee interaction maps. A. Map showing shared resource use by humans and chimpanzees across 10 villages in central Cantanhez. B. map showing chimpanzee occupancy and shared resource use.

In Y2 and Y3, Queba Quecuta (Director of Cantanhez NP, IBAP) shared information about leprosy in primates with all Régulos, village committees and chiefs in settlements in proximity to infected primate groups and answered questions on transmission and treatment in people. To ensure local community involvement in the development of the Action Plan, we have held three meetings with the Cantanhez management committee, chaired by Queba Quecuta, which

included discussion of project findings and coexistence issues/solutions (including wildlife crop damage, wildlife attacks and leprosy in wildlife). The meetings were held on 24th-25th August 2021 (4 women, 46 men – more men because there are no female Régulos, and no female leaders/chiefs); 14-15th Oct 2021 (5 women, 19 men– Régulos, chiefs plus 2 representatives from each village, one of which should be female and the other male – women often can't attend due to household responsibilities; 15-17 Feb 2022 (5 women, 19 men as above). To ensure the opinions of women were included in decision-making, the DRF, Sara Quade (DPO) and Maimuna Jaló (DPO) held separate discussion groups in November 2022 with women, including the Cantanhez Women's Associations, across three villages (n=35; Cadique Nalu n= 9, Iemberem n=18, and Madina n=8). The Biodiversity and Environmental Action Plan has been written up and agreed by IBAP including discussions with the management committees at Cantanhez NP (Evidence 1,8).

Output 4 Multi-stakeholder One Health Leprosy response plan: We achieved our goal to increase long-term readiness to respond to zoonotic threats and disease-related conflicts through the collaboration of stakeholder organisations instrumental in human and wildlife health and the production of a One Health Leprosy Action Plan. Key organisations in the fight against leprosy were identified (Cumura, AIFO, WHO) and project partners (UoE, NADEL, IBAP, CRIA) engaged regularly through online and in-person meetings, and emails, with key contacts, including leprosy expert Dr Silvio Coelho from Cumura hospital (also holds critical positions in the Ministry of Health, Guinea-Bissau; General Directorate of Prevention and Health Promotion; National Program for the Fight against Leprosy and Tuberculosis; Directorate of Service of Neglected Transmissible Diseases), and Arniel Silot (Amici di Raoul Follereau, AIFO) (Section 3.1, Output 1; Evidence 9). This collaboration supported multi-stakeholder knowledge of leprosy occurrence in humans and wildlife, including case mapping of known human cases across Guinea-Bissau (using 2015-2020 data from Cumura) and project data on wildlife (Section 3.1, Output 2) and people's knowledge of One Health (Section 3.1, Output 1). These data were included in the One Health Leprosy response plan for Guinea-Bissau (Fig 8; Evidence 10). The first multi-stakeholder leprosy One Health response plan for Guinea-Bissau was co-written by Dr Silvio Coelho and UoE partners providing an up-to-date and comprehensive information on leprosy in humans and wildlife in Guinea-Bissau and proposes One Health strategies to ensure continued coordination, communication and collaboration amongst conservation and health stakeholders (Evidence 10).

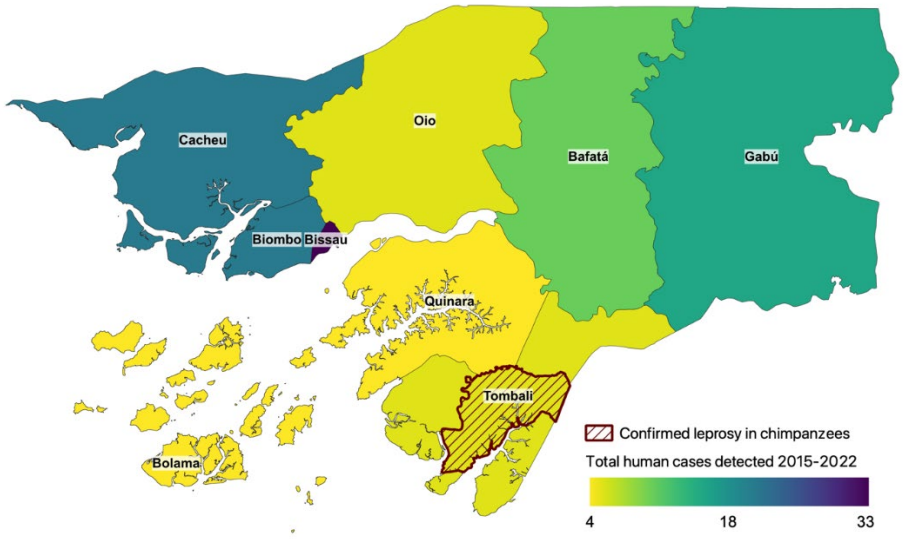

Figure 8. Total number of recorded cases of leprosy in humans by administrative Region (2015-2020 data from Cumura) and Cantanhez NP highlighted with confirmed cases in chimpanzees.

3.2 Outcome

Outcome statement: Improved knowledge and surveillance of leprosy in wildlife and humans, with enhanced capacity to manage human-wildlife interactions and support conservation and human health at Cantanhez NP.

Through an integrated program of participatory research, capacity building, and multi-stakeholder collaboration this project has achieved its intended outcome by equipping government agencies, local NGOs, and local communities with the skills and One Health knowledge to suppport biodiversity conservation and human health and ultimately facilitate human-wildlife coexistence in Cantanhez NP. This was acheived via the production of the first Biodiversity and Environment Action Plan for Cantanhez NP that faciltates multi-stakeholder engagement and integrates tailored One Health strategies (Section 3.1 Output 3; Evidence 1) and a One Health Leprosy Plan that was co-written by experts in human and willdife health to facilitate long-term coordination, communication and collaboration amongst conservation and health stakeholders (Section 3.1 Output 4; Evidence 10). Disease surveillance necessitates the identification of paucibacillary and multibacillary symptoms in people which requires health workers to be trained by leprosy experts which was achieved in Cantanhez NP (Section 3.1, Output 1) with strategy outlined in the One Health Leprosy Plan. Participatory data collection, meetings, workshops, and focus groups delivered with partners have also ensured that local communities played a key role in the development of these plans (Section 3.1 Outputs 1-4; Evidence 2,3,7,8). An evidence-based and participatory One Health campaign strategy developed with UoE, CRIA, IBAP, and NADEL (including two Guinean DPOs), was developed for Cantanhez NP and achieved enhanced female representation, with increased One Health knowledge compared to pre-project baselines and knowledge retention (Section 3.1 Output 1; Evidence 3).

From a baseline of zero, the project has provided IBAP with the full (100%) capacity to monitor and analyse data on biodiversity health in Cantanhez NP through the implementation of the Biodiversity and Health Monitoring Programme, including tailored training, with all relevant IBAP staff members as well as other Government authorities. All Cantanhez NP staff (eight guards, one director and one vice-director), two local researchers, two DPOs (young Guinean researchers) as well as five IBAP technicians and directors of National Parks, and representatives of the Environment Ministry, the National Directorate for Forest and Fauna, and the National Guard were fully trained in distance sampling for line transect surveys and camera trap surveys by UoE DRF. DPOs, IBAP technicians and directors and government representatives were also trained by the DRF in data analysis (Excel, DISTANCE, QGIS). Partner RKI trained UoE (PhD researcher Marina Ramon and DRF Elena Bersacola) in carcass swabbing and disposal, who subsequently trained three core IBAP personnel (“surveillance team”). The IBAP/UoE team trialled out this training by successfully collecting biological samples from three dead primates in Cantanhez NP following drafted protocols (Section 3.1, Output 2; Evidence 5).

This project has generated the inter-disciplinary data required to produce the Biodiversity and Environmental Action Plan for Cantanhez National Park, Guinea-Bissau (Evidence 1). Data on leprosy in wildlife and human-wildlife interactions are included in Part 3 (Conservation threats) and the One Health approach is included as one of the priority conservation strategies proposed in the Plan. To ensure the transfer of data analysis skills required for data processing and analysis the project trained technical staff from IBAP (N=23). IBAP selected all of their technicians (100%), and four National Park directors (from four different NPs) and two technicians who have been trained in advanced QGIS by the DRF (Evidence 5), including how to monitor habitat changes such as loss of forest across different zones and how to map wildlife distributions using remote sensing and GIS. This supports IBAP’s intention to apply the techniques learnt during this project for Cantanhez NP to other terrestrial NPs across the country.

At the institutional level, this project built multi-stakeholder collaborations (from a baseline of zero) between academic institutions (UoE, RKI, CRIA), conservation managers (IBAP) and health organisations (NADEL, Cumura Hospital, AIFO, AJEC) enhancing capacity to identify and respond to zoonotic disease and disease-related conservation conflicts over leprosy (Section 3.1, Output 4). The Biodiversity and Environment Action Plan for Cantanhez NP and the One Health Leprosy Plan and published articles (Evidence 1,4,10-15) provide hitherto unreported situational knowledge and propose concrete strategy that are fundamental to understanding and coordinating activities when responding to disease and disease-related conservation conflicts.

3.3 Monitoring of assumptions

Outcome and Output level assumptions (Annex 1) were monitored and focused around 6 key areas: (1) engagement and commitment of local communities to support in project activities (e.g. training, workshops, meetings) and participatory research - *local communities remained highly committed and engaged with the project*; (2) staff at partner organisations remain employed and engaged with project - *all individuals trained in partner organisations were continuously employed*

in their posts. However, some of the health agents we intended to train in leprosy identification moved from Cantanhez NP (Section 3.1, Output 1); (3) COVID-19 situation does not worsen and restrict in person meetings and engagement - *although Guinea-Bissau still has strict entry and exit requirements, IBAP reauthorised research and in May 2021 we have been able to conduct all activities in person*; (4) political stability in Guinea-Bissau - *despite political instability in Guinea-Bissau, our project work in Cantanhez NP was uninterrupted*; (5) data on leprosy in primates is not sensationalised by media and risks of retaliatory behaviour by local people reduced by effectively shared knowledge and communication - *we avoided conservation conflicts over disease and possible retaliatory killings due to the careful way we worked with partners to manage communications with local communities including women, health authorities, and the media/social media*; (6) stakeholder willingness to incorporate project data to inform decision-making processes - *regular communication with project partners, external health organisations and local communities including women's groups ensured people were engaged in making informed data-driven conservation and health decisions*.

3.4 Impact: achievement of positive impact on biodiversity and poverty reduction

This project aimed to improve public health through increased resilience to infectious disease in local communities, with improved capacity to manage threatened biodiversity and human-wildlife interactions, at Cantanhez NP. Our framework is based on the One Health concept which describes how human health is inextricably linked to the health of animals and the viability of ecosystems. The One Health approach involves the collaboration of human, animal, and environmental researchers and health professionals and is geared towards optimising individual and community health and wellness. This initiative reflects a growing concern that rapid and irreversible rates of environmental degradation will harm human health and well-being in ways that cannot be undone or 'cured' by medical treatments.

We achieved positive impacts on poverty alleviation by increasing resilience to infectious disease outbreaks, at a community and Institutional level, through the development of one Action Plan and one Response Plan which hold the needs of people at their core (Section 3.1, Outputs 3,4; Evidence 1,10), through building collaborative relationships, local capacity building, and tailored and effective One Health training in local communities. The local health force in Cantanhez NP are now trained to rapidly identify leprosy in people from early stages and make appropriate patient referrals, with positive impacts on human wellbeing and poverty alleviation. Based on the expressed needs of local communities we purchased and installed solar panels for the main hospital in Iemberem positively impacting the treatment of people across 20 communities. The development of a leprosy response plan ensures information dissemination and effective communication chains between multiple stakeholders. Our project framework aligns with the WHO Global Leprosy Strategies' (2016–2020;2021–2030) vision, pillars and components, including to reduce transmission of leprosy, strengthen coordination and partnerships, strengthen surveillance, facilitate research on all aspects of leprosy and maximise the evidence base to inform policies/strategies/activities, surveillance and data management.

A pathway to improve biodiversity has been created through increased monitoring of and building in-country capacity and engagement to monitor, the abundance and health of wildlife and conservation threats (Evidence 5). This has resulted in increased surveillance by Cantanhez NP guards and enhancing protection of threatened wildlife and critical habitats. We collected critical data on leprosy occurrence and prevalence in chimpanzees and baboons and conducted leprosy strain sequencing to determine disease transmission dynamics (Evidence 4) and developed participatory One Health training that encourages people to value the intricate relationship between human, animal and environmental health and its protection (Evidence 3). The Biodiversity and Environmental Action Plan fully integrates the conservation implications of human-wildlife interactions including disease and the One Health leprosy response plan employs strategies to avoid retaliatory killings of wildlife. Our research provides up-to-date information on leprosy in human's closest living relative, the chimpanzee, as well as other primates, in the wild.

4 Contribution to Darwin Initiative Programme Objectives

4.1. Contribution to Global Goals for Sustainable Development (SDGs)

From the project outset we have ensured participatory community involvement in public health issues to reduce gender inequality, and strengthen synergy in stakeholder (local communities, Government, NGO) decision-making (**Goals 5,10,17**). We have included women at all stages of the decision-making process (**Goals 5,10**), including project partners at Aissa Regalla (IBAP),

the PL and DRF (UoE), Amelia Frazao-Moreira and Hannah Parathian (CRIA), and PhD and MRes students (UoE/RKI), and employed and trained young Guinean women, Maimuna Jaló and Sara Quade, as DPOs. Maimuna has presented project findings at the African Protected Areas Congress (APAC) in Rwanda https://apacongress.africa/. We met with the female Minister of Health in Guinea-Bissau Magda Robalo (2019) and started collaboration with WHO's consultant in Guinea-Bissau Mireille Pereira (2021). We have worked directly with the Women's Associations, the local management committee, and the Association of Young Students of Cubucaré (AJEC) in Cantanhez NP. We have built local people's awareness/resilience to infectious disease outbreaks, including leprosy, through improved understanding of One Health, and access to improved and specialised healthcare services, and strengthening the communication of leprosy cases and surveillance system (**Goals 1,3**). We have worked with healthcare practitioners to increase the number of health workers who can identify leprosy and reduce potential stigmatisation associated with leprosy which prevents self-reporting/early diagnosis (**Goals 1,3,5,6**). Through One Health knowledge we have improved access to hygiene for all, paying close attention to the needs of women and girls, and strengthen the participation of local communities in improving sanitation management (**Goal 6**). We have directly integrated ecosystem and biodiversity values into National and local leprosy planning and have implemented targeted capacity building of stakeholders in health and conservation (**Goal 17**). The Biodiversity and health monitoring programme and Biodiversity and Environmental Action Plan underpin strategies for habitat conservation and reduce the loss of threatened biodiversity (**Goal 15**), including the CR-EN western chimpanzee. We have developed a multi-stakeholder One Health leprosy response plan for Cantanhez NP to support long-term investment in leprosy eradication actions (**Goal 1**), in particular the WHO's Global Leprosy Strategy 2021–2030 and contributed critical data on leprosy in wildlife reservoirs to work towards SDG's **Goal 3** to end epidemics of neglected tropical diseases including leprosy. Our project works towards making communities safe, resilient, and sustainable (**Goal 11**) supporting the Lancet Commission's call for a new Planetary Health paradigm which sets out to achieve the highest attainable standard of health, wellbeing, and equity worldwide through judicious attention to the human systems—political, economic, and social—that shape the future of humanity and the natural systems that define the environmental limits within which humanity can flourish.

4.2 Project support to the Conventions or Treaties (e.g. CBD, Nagoya Protocol, ITPGRFA, CITES, Ramsar, CMS, UNFCCC)

This project has improved the capacity of Guinea-Bissau to meet its obligations under the Convention on Biological Diversity (CBD) under CBD's core principles and in particular CBD Aichi Biodiversity Targets for the programme of Work on Forest Biodiversity. Dr Abilio Rachid Said and Dr Justino Biai are both named as IBAP project partners and CBD focal points in Guinea-Bissau. Both have attended Darwin workshops and meetings, and the PL is in regular email contact with both. Our project has contributed through (1) increasing local biodiversity and wildlife health monitoring capacity in the most biodiverse terrestrial NP in Guinea-Bissau and increasing knowledge of leprosy and other infectious diseases in wildlife (**Targets 2,19**). The **CMS** Concerted Action on Chimpanzee Culture was approved, and our project has increased knowledge and protection of this CR-EN species. Our approach will be used as a model for Guinea-Bissau's four other terrestrial NPs; (2) Conducting long-term monitoring of biodiversity health and abundance (**Target 12**) to identify and improve protection of remaining forests, including mangroves, and wildlife hotspots to promote biodiversity and protection of ecosystems that provide essential services (**Targets 5,11,14**); (3) Monitoring leprosy prevalence and distribution in primates and reducing opportunities for human-to-wildlife/wildlife-to-human disease transmission through research-led mapping (**Targets 2,12**); (4) Increasing the resilience of communities by adopting an ecosystem-mediated strategy for health promotion based on One Health - reducing environmental damage which may be having a detrimental impact on human health, especially vulnerable sub-populations such as the poor, socially disenfranchised, children and the elderly (**Targets 3,14**); (5) Respecting traditional knowledge and management systems (**Target 18**). Since Cantanhez NP was formed in 2008 the local population continues to play a role in land use management. People represented by chieftains, Women's Associations, Land Management Committees, Youth Associations, and elders have played a crucial role in developing Action Plans to improve biodiversity conservation and promote health through reducing disease transmission risks (**Target 18**); (6) Understanding local knowledge and

perceptions of disease transmission and local healthcare services (traditional and public) to inform public health strategy (**Targets 18,19**); (7) Ensuring participatory community involvement in public health issues to reduce gender inequality, and strengthen synergy between local communities, NGOs, and Government in decision-making (**Target 18**); (8) Strengthening capacity and knowledge to respond quickly and effectively to infectious disease outbreak (**Target 19**); (9) Strengthening long-term readiness for potential public zoonotic threats and disease-related conflicts through the multi-stakeholder One Health leprosy response plan that includes mitigation of conservation conflicts and disease risk (**Target 17**); (10) making datasets on humans and wildlife leprosy available e.g. for the WHOs Global Leprosy Strategy 2021–2030 (**Target 19**).

4.3 Project support to poverty reduction

As detailed in Sections 3.1, 3.2, 4.1 and 4.2 this project has implemented a range of One Health initiatives that can have positive impacts on poverty alleviation and resilience to infectious disease outbreaks at the local community and Government level. The project provided increased capacity to empower local communities with knowledge on One Health and increased decision-making. We have taken a participatory approach to examining One Health that is meaningful to local people and provides an opportunity for people to learn from each other's experience with high information retention. This approach (research article currently in preparation) represents a fundamental shift in the way conservation and health practitioners communicate issues on One Health. Leprosy is known as the disease of poverty, and although it is not an emerging disease it is the oldest known disease associated with humans. Health professionals (N=42) across Cantanhez NP gained increased professional knowledge and capacity to identify leprosy cases, including at the early stages, and knowledge of free treatment and how to make appropriate referrals of leprosy cases to Cumura. IBAP DFOs (N=10) involved in this project have benefited through enhanced professional skills as a direct result of this project. Eight local collaborators were employed in leprosy monitoring of rural communities in Cantanhez NP with increased household income via monthly salary and increased professional skills. Local IBAP collaborators (N=8), health agents (N=8) and local communities across Cantanhez NP have an increased awareness of zoonotic disease transmission and increased capacity to report carcasses of wild animals. The "surveillance team" (N=3) has the capacity to take samples safely following a strict protocol. The local population in Cantanhez NP will benefit from evidence-based multi-stakeholder policies to improve environmental and human wellbeing in Cantanhez NP, including the One Health environmental management plan and the One Health leprosy response plan.

4.4 Gender equality

The lead organisation, UoE, has been strongly committed to guaranteeing equal opportunities from initial consultation to final evaluation and this has resulted in strong engagement by women. We have prioritised the representation of females in this project at all levels, including as project partners, the Women's Associations in Cantanhez NP, and the WHO consultant for Guinea-Bissau, Mireille da Rosa Fernandes Pereira. The strong female leadership shown on this project was commented on positively by Guinea-Bissau's female Health Minister during a meeting in 2019. This project is supporting and working closely with Bissau-Guinean, Aissa Regalla at IBAP, who is a strong female advocate for the inclusion of local women in biodiversity conservation in Guinea-Bissau. We employed two young and highly talented female graduates as Darwin DPOs, Maimuna Jaló, (IBAP) and Sara Quade (NADEL). The research article "*Leprosy in wild chimpanzees*" which used data collected during this project was published in *Nature* in 2021. The article includes eight African Nationals as co-authors including two females, one of whom is Aissa Regalla. High impact collaborative publications support academic development and foster productive dialogue and relationships. We published a second research article in *Frontiers in Conservation Science* with 11 female authors (of 19), 3 of whom are from Guinea-Bissau and in 2021 we published a third review and synthesis article in the journal *People and Nature* titled "*Envisioning a resilient future for biodiversity conservation in the wake of the COVID-19 pandemic*" with three female co-authors from Darwin project including project partner Aissa Regalla). We have ensured the opinions and needs of women and girls have been fully represented throughout the project. For example, for qualitative data collection, we worked with women to identify perceptions of disease and health services, as well as women-specific healthcare needs. For questionnaires (Section 3.1, Output 1), out of 101 persons interviewed, 51 were female. The importance of women in disseminating and campaigning for health-related

improvements is well known to all project partners including NADEL. However only one of the 46 Cantanhez health personnel trained by Cumura identified as female (Section 3.1, Output 1). Four of the 8 community health agents (Health DFOs) involved in participatory mapping and the One Health trial campaign were female. Importantly, we trained the first female resident of Cantanhez NP (Fatumata Nbalo Camará, resident of Camecote) to be employed in ecological research (1 of the 6 local collaborators monitoring leprosy). We wanted higher female representation in paid positions in Cantanhez NP but mostly these positions were already filled prior to the start of this project, and we needed to follow local customs However, when we had autonomy, we ensured gender parity. For example, of 142 participants in the One Health training, 73 women and 69 men (Section 3.1, Output 1). We have tried to ensure that all meetings and workshops were held at times when female representatives were able to participate, however this did not always ensure female participation. For social reasons, local women are sometimes reluctant to share their opinions during large meetings and workshops, and this was our experience in larger management committee meetings. To tackle this, we held additional all-female focus group meetings (Section 3.1, Output 3) to ensure their opinions are incorporated into our conservation and health strategies. We expect that the assumptions regarding gender for this type of work (typically undertaken by men) to change because of the increased employment of Guinean female researchers. An increase in female researchers, particularly Guinean women, will encourage more local women to consider employment and career opportunities in conservation.

4.5 Programme indicators

- **Did the project lead to greater representation of local poor people in management structures of biodiversity?**

Local communities have been fully engaged in participatory data collection and biodiversity surveillance, as well as discussions on resolving conflicts around negative human-wildlife interactions and disease leading to greater awareness of conservation threats and strategies for planning, including One Health (see Section 3.1 Output 1-4). Participatory meetings and workshops have ensured local communities have had a voice and contributed to the development and agreement of Action Plans.

- **Were any management plans for biodiversity developed and were these formally accepted?**

The Biodiversity and Environment Action Plan was accepted by IBAP (Section 3.1 Output 3), and the One Health Leprosy Plan was co-written with the Ministry of Health and head of Cumura hospital (Section 3.1 Output 4).

- **Were they participatory in nature or were they 'top-down'? How well represented are the local poor including women, in any proposed management structures?**

Action Plan development involved a combination of top-down government initiatives and bottom-up processes where local communities have participated in data collection that has informed strategies and have been consulted throughout the data collection and planning process to determine what conservation and development strategies, including those that consider the costs and benefits of coexisting with wildlife and One Health, would work in the context of Cantanhez NP. Leprosy is known as the disease of poverty and the training we provided to health workers alongside the One Health leprosy plan will help poor people seek free available health care.

- **How did the project positively influence household (HH) income and how many HHs saw an increase?**

This project sought to improve the health of people and was not focused on monetary income. However, we employed numerous local persons throughout his project.

- **How much did their HH income increase (e.g. x% above baseline, x% above national average)? How was this measured?**

As above.

4.6 Transfer of knowledge

This project has used multiple approaches to increase awareness and transfer knowledge to different audiences including conservation practitioners, policy makers, and the public (both in Guinea-Bissau and Internationally). The production of Action Plans will ensure the findings of this project are incorporated into conservation and health policy at the Government level. Both the PL and DRF actively contribute to conservation policy through working with IUCN Primate Specialist groups on taxa-focused Action Plans. The PL is an active member of the IUCN SSC Primate Specialist group Section on Great Apes. The PL and DRF used information gathered as

part of the Darwin project in the development of the IUCN western chimpanzee Action Plan (2020) and DRF co-authored the Temminck's Red Colobus IUCN Red list assessment (2020) https://www.iucnredlist.org/species/18247/92648587. Data on western chimpanzees collected as part of the Darwin project contributed to information on the APES wiki page https://wiki.iucnapesportal.org/index.php/Cantanhez_National_Park, with the PL a co-author on a paper detailing this conservation initiative https://onlinelibrary.wiley.com/doi/10.1002/ajp.23213. The A.P.E.S. Wiki is a platform for site-level information on ape status and conservation. The wiki provides summarised and standardised information about ape population status, threats, and conservation and research activities in an accessible way. Our "*Leprosy in wild chimpanzees*" paper in *Nature* received strong international media attention and highlighted the impact of this ancient infectious disease on people and willdife (Annex 7 Table S3).

IBAP and UoE trained the first two Bissau-Guinean scientists in great ape conservation equipping them with the skills needed to secure and succeed in their future conservation employment. Américo Sanhá now has the skills and CV to conduct an MSc in Biodiversity Conservation and we are working closely with him to secure funds and a position. Sara Quade is working on PhD applications and Maimuna Jalo is keen to continue working in the conservation sector in Guinea-Bissau. Maimuna presented project One Health findings at the APAC in Kigali. Data from the Darwin project has also been used to teach 3rd year Bioscience students on the module "Primate Biology and Conservation" (BIO3426) and Conservation and Biodiversity MSc students at the University of Exeter (UK) encouraging a more inclusive and forward-thinking approach to conservation. Many students reported this content changed their entire way of thinking about conservation to include the needs of people and wildlife. Darwin project data have been analysed for 3 BSc and 10 MSc projects (12 of 13 were female from the UK, US, Canada). The training of all DFOs, DPOs, and research assistants was underpinned by robust scientific methods that were adapted to the local context to ensure rigorous data collection standards and quality, and the regular sharing of reports between project members.

As an extension to this Darwin project, we applied for an emergency Darwin COVID-19 grant and produced diverse education materials to educate International and national people on One Health (Fig 9), and reduce infectious disease spread between tourists and local communities and great apes: www.protectgreatapesfromdisease.com. Our peer-reviewed publication titled "*Fostering compliance with preventive measures to reduce the risk of anthropogenic disease transmission to wild African great apes in tourism*" is currently in press in *People & Nature*, and we published a paper on "*Protect Great Apes from Disease: Freely Available Education Materials for Research and Tourism*" in *African Primates* (Evidence 13,14). The 'Protect Great Apes from Disease' video was submitted via Film Freeway by our videography collaborators, One Health Productions, in collaboration with Conservation through Public Health, Uganda (June 17th 2022).

Figure 9. Educational materials developed on One Health and the impact of infectious disease on people and wildlife including nonhuman great apes.

4.7 Capacity building

Capacity building was a core component of this project, and focused on building knowledge, skills, and providing opportunities across three levels of organisation as defined by the United Nations Development Program. *Individuals*: The skills and knowledge of three young Guinean researchers has been significantly strengthened, with clear pathways to continue academic training and employment opportunities in conservation. The capacity within local communities has been enhanced through a diverse program of inclusive leprosy and One Health training. This has included leprosy identification and treatment training; knowledge sharing on one health;

training in scientific data collection (social and biological sciences) and data analysis & sample collection and storage building expertise; training in writing reports and presentations. The Darwin DPOs have especially benefitted from intensive scientific training from the DRF and PL. *Institutions*: capacity for multiple individuals within institutions in Guinea-Bissau (IBAP, NADEL, Cumura) has been enhanced through development of training materials and survey protocols for human health and wildlife health and abundance; the development of Action and Response Plans to aid inter-disciplinary comprehension; co-delivery of stakeholder workshops and meetings that has shared best practices and knowledge in One Health; transfer of knowledge to all levels of local, regional, and national government through the dissemination and sharing of project reports and data. *Society*: This project provides society with the knowledge (and data) to make more informed decisions by promoting One Health concepts and awareness for the protection of the natural environment and threatened wildlife. An emphasis on participatory research and data collection has also ensured that there has been transfer of knowledge and expertise, with high-level of engagement by local communities, including decision-making.

5 Sustainability and Legacy

The legacy of this project has been ensured through an integrated and collaborative program of training, research, stakeholder engagement, and awareness raising that has reached a wide audience. This project that integrates biodiversity conservation and public health in response to leprosy is the first of its kind in Cantanhez NP. This has meant that project partners and other stakeholders including the local communities have remained engaged and positive about the work. The One Health trial campaign demonstrated strong acknowledgement of the importance of a One Health approach to understanding and tackling infectious diseases outbreaks, and critical retention of knowledge. And for leprosy One Health is key to inform disease prevention, awareness campaigns and policy development for shared landscapes where humans and wildlife overlap in their use of space and resources.

By investing in capacity and engagement of local communities and project partners, including employed personnel, our goal is to strengthen the sustainability and legacy of the project. Our activities were designed to increase future resilience through training and capacity building so that in the potential absence of future funding our project partners and local collaborators have a strengthened knowledge base from which to build and continue key activities. Over the three years, the project has intensively trained three young Guinean DPOs who are all passionate about conservation and One Health. Training of other conservation personnel (detailed in Section 3.1 Output 2). Our project tackles many of the major challenges outlined in the WHO Global Leprosy Strategy 2021–2030 (https://apps.who.int/iris/handle/10665/340774) including cutting-edge research on wildlife and human dimensions of leprosy; reducing delays in detection; strengthening capacity and leprosy expertise; ensuring meaningful engagement of relevant stakeholders; reducing stigma in healthcare settings through knowledge and training; developing a communication and surveillance system; providing suggestions for information systems to report leprosy cases. Our research provides the latest information on leprosy in wildlife in Africa. This Darwin project has equipped Guinean organisations, including IBAP, with the skills and equipment to conduct monitoring, control, and surveillance missions (e.g., training in patrol planning, execution and reporting, and GPS and camera traps). This project has provided local communities with employment opportunities linked conservation and One Health (health agents, research assistants), and we have improved health personnel's ability to identify leprosy, direct patients for free treatment, and access to basic health services such as light in the main hospital in Iemberem. Beyond Guinea-Bissau, other west African countries are interested in the survey methods we adapted for use in forest-agricultural mosaics which has resulted in the development of new collaborations (e.g. IUCN Action Plan meeting in Liberia, September 2022). Building on achievements in this Darwin project, we are applying for further funding (including PLs application to the ERC with Darwin project partners).

6 Lessons learned

The COVID-19 pandemic has demonstrated the need for flexibility and preparedness in the case of most exceptional circumstances. We recommend that projects prioritise building in-country expertise and field supplies (e.g. batteries, SD cards, camera traps, GPS) are taken to field sites

as early as possible to ensure they are accessible by Guinean partners if travel between Europe and Africa is restricted.

6.1 Monitoring and evaluation

Monitoring and evaluation were intrinsic components of this project and we continually responded to new developments with our project partners, including adjusting the project in response to MTR feedback. We committed to many M&E best practices, including SMART indicators; annual M&E meetings and workplans; meetings and reporting to all partners (including meetings every 2 months with all partners); activities to establish baselines and measure change; the revision of targets, activities, and timelines in response to COVID-19 to ensure project success; the routine monitoring of key project activities; and half-year and annual reports.

6.2 Actions taken in response to Annual Report reviews

In our revised logframe we fully considered all the points raised in the Mid-Term-Review that were feasible to achieve within the available timeframe and budget. All points were fully discussed with project partners. We consulted our project partners and adapted the Outputs and logframe based on feasibility and time, and what we thought was logical and most appropriate and useful considering our areas of expertise and collaborations within Guinea-Bissau. Revisions were made to Output One because of the COVID-19 and Ebola situations, COVID-19 delays and in response to MTR comments. We originally planned to develop and implement a public health campaign across Cantanhez NP, involving at least 70 villages. Due to the COVID-19 and Ebola campaigns already underway across Guinea-Bissau, including Cantanhez NP (NADEL were involved in these), we made the decision to reduce the spatial scale of our campaign to selected villages, and adopt a One Health approach rather than focussing the campaign on a specific zoonotic disease. Instead, our campaign focused on One Health messages, with leprosy used as an example zoonotic disease. The reduction in scale was due to the complexities involved in delivering One Health concepts effectively and to trial messages in selected villages to avoid miscommunication, *particularly regarding the level of public health dangerousness of leprosy occurrence in wildlife for local people*. Our new One Health trial campaign approach allowed us to explore and identify effective ways to deliver One Health messages, which will be incorporated into a One Health campaign strategy report for future application, including scaling-up to Park- and Regional-levels, by health and conservation institutions working in Guinea-Bissau. We also scaled up the clinical training to involve local health agents as they were identified as being crucial to an effective response.

We revised Output Three and incorporated the suggestion to adapt the proposed human-wildlife interaction plan to a biodiversity and environmental management plan to promote healthy human-wildlife coexistence and strengthen multi-stakeholder decision-making capacity in Cantanhez NP. In response to MTR comments, we included participatory mapping with local people from different user groups to identify sites with high human-wildlife interaction, including locations of resources shared. This will be conducted within the same villages where we will conduct the revised One Health trial Campaign.

COVID-19 delays made the implementation of a disease and conflict response strategy unfeasible given the remaining time available as pointed out in the MTR evaluation. Output 4 was revised to focus on gathering up-to-date leprosy information on humans and wildlife to develop an evidence-based multi-stakeholder One Health leprosy response plan to inform conservation and health institutions involved in work in Cantanhez NP, including all project partners, health stakeholders (including WHO, AIFO, Cumura), and government (IBAP, Ministry of Health, Forestry Department).

7 Darwin identity

This project is recognised as a distinct project with a clear identity. As the first project to be funded by the Darwin Initiative in Guinea-Bissau, it is Nationally and locally known as “Projecto Darwin”. All project documents include a Darwin Initiative logo, which has been used in National and International conference/meeting/workshop presentations. UoE staff comprising Dr Hockings (@KJHockings) and Dr Bersacola (@hellenwildlife) promoted project activities and outputs on twitter that were linked to the Darwin Initiative social media accounts.

8 Impact of COVID-19 on project delivery

An international travel ban was enforced by the Bissau-Guinean government in April 2020; in March 2020 IBAP already halted all research activities to mitigate the spread of COVID-19 to vulnerable communities in Protected Areas, including Cantanhez NP. To ensure health and safety of project staff undertaking biodiversity monitoring activities in Cantanhez NP, we developed and implemented a COVID-19 health protocol. This allowed for the resumption of biodiversity monitoring activities by local staff (DFOs and RCs). Interviews and in person meetings with local communities originally planned to be carried out by NADEL DPO and UoE DRF had to be halted due to risks of spreading COVID-19 to residents in Cantanhez. This caused significant delays in activities related to Output 1 and Output 4, and forced us to revise our strategy several times, as well as incorporating the COVID-19 situation and context within our project framework, including changing to a One Health approach rather than focussing on specific diseases. For instance, a significant impact was on our public health campaign across 70 villages, which was planned to start in October 2020. Considering the COVID-19 national response and local campaigns ongoing, we opted instead to use a different campaign approach and delay the start until enough data were available to develop a strategy, including household interview data, information on the COVID-19 response in Cantanhez NP, as well as discussions with partners and health stakeholders. Output 1 was revised also based on MTR comments (see Section 6.2)). COVID-19 delays also made the implementation of a disease and conflict response strategy (original Output 4) unfeasible given the remaining time available. Output 4 has been revised to focus on gathering up-to-date leprosy data to develop an evidence-based multi-stakeholder One Health leprosy response plan to inform conservation and health institutions involved in work in Cantanhez NP, including all project partners, health stakeholders and government (Ministry of Health, Forestry Department). On a positive, we relied extensively on Guinean project partners and invested in building capacity to ensure project activities were achieved. We published a peer-reviewed review and synthesis article in the journal *People and Nature* titled "*Envisioning a resilient future for biodiversity conservation in the wake of the COVID-19 pandemic*" which included a case study on outcomes of COVID-19 on Cantanhez NP (co-authors from Darwin project include project partner Aissa Regalla, DRF Bersacola and PL Hockings) https://besjournals.onlinelibrary.wiley.com/doi/full/10.1002/pan3.10262

9 Finance and administration

9.1 Project expenditure

Project spend (indicative since last Annual Report	2021/22 Grant (£)	2021/22 Total actual Darwin Costs (£)	Variance %	Comments (explain significant variances)
Staff costs (see below)	[redacted]	[redacted]	-3%	
Consultancy costs	[redacted]	[redacted]	0%	
Overhead Costs	[redacted]	[redacted]	0%	
Travel and subsistence	[redacted]	[redacted]	+2%	

Operating Costs	[redacted]	[redacted]	+9%	
Capital items (see below)	[redacted]	[redacted]	0%	
Others (see below)	[redacted]	[redacted]	+4%	
TOTAL	106,619.20	106,467.85		

Staff employed (Name and position)	**Cost (£)**
Elena Bersacola, Research Associate	[redacted]
Sara Quade, Darwin Project Officer	[redacted]
Mamadu Ba Sambu, Darwin Field Officer	[redacted]
Binta So, Darwin Field Officer	[redacted]
Bacar Camara, Darwin Field Officer	[redacted]
Aua Djatara, Darwin Field Officer	[redacted]
Armando Bamba, Darwin Field Officer	[redacted]
Fatumata Camara, Darwin Field Officer	[redacted]
Tamba Brenha, Darwin Field Officer	[redacted]
Liuna Ntchane, Darwin Field Officer	[redacted]
Silvio Coelho, Darwin Project Officer	[redacted]
Maimuna Jalo, Darwin Project Officer	[redacted]
Americo Sanha, Darwin Project Officer	[redacted]
Iaia Tawel Camara, Darwin Field Officer	[redacted]
Mamadu Cassama, Darwin Field Officer	[redacted]
TOTAL	[redacted]

Capital items – description	**Capital items – cost (£)**
TOTAL	0

Other items – description	**Other items – cost (£)**
Mountain bikes for field work GPS equipment Monitoring training Fieldwork costs – bike repairs and field station costs Batteries for camera traps Fieldwork consumables	[redacted]
TOTAL	[redacted]

Project spend (indicative) since last Annual Report	**2022/23 Grant (£)**	**2022/23 Total actual Darwin Costs (£)**	**Variance %**	**Comments (please explain significant variances)**

Staff costs (see below)	[redacted]	[redacted]	0%	
Consultancy costs	[redacted]	[redacted]	0%	
Overhead Costs	[redacted]	[redacted]	0%	
Travel and subsistence	[redacted]	[redacted]	0%	
Operating Costs	[redacted]	[redacted]	0%	
Capital items (see below)	[redacted]	[redacted]	0%	
Others (see below)	[redacted]	[redacted]	0%	
Audit costs	[redacted]	[redacted]	0%	Draft figure
TOTAL	[redacted]	[redacted]		

Staff employed (Name and position)	**Cost (£)**
Sara Quadé, Darwin Project Officer	[redacted]
Mamadu Ba, Darwin Field Officer	[redacted]
Iaia Sambu, Darwin Field Officer	[redacted]
Maimuna Jaló, Darwin Project Officer	[redacted]
Américo Sanhá, Darwin Project Officer	[redacted]
TOTAL	[redacted]

9.2 Additional funds or in-kind contributions secured

Source of funding for project lifetime	**Total (£)**
Exeter - Halpin Trust Pilot project	[redacted]
Exeter - Central Institutional funds	[redacted]
Robert Koch Institute	[redacted]
CRIA	[redacted]
IBAP	[redacted]
NADEL	[redacted]
Darwin COVID-19 Response grant	[redacted]
Crowdfunding	[redacted]
Barcelona zoo/Primate Acton Fund – costs of genetics work, Marina Ramon	[redacted]
NERC GW4+ studentship (4 years)	[redacted]
TOTAL	[redacted]

Source of funding for additional work after project lifetime	**Total (£)**
ERC Consolidator (PL had got to interview stage, Nov 2023)	[redacted]
TOTAL	[redacted]

9.3 Value for Money

We prioritised cost effectiveness and efficiency when delivering this project, including sourcing materials and services locally wherever possible. This project secured 64% matched funds and we made value for money a priority. Project partners made significant commitments in staff time, overheads, consumables, laboratory analyses, international and national travel, and subsistence. This project made use of consumables, including camera traps, bikes and photographic equipment etc, from project partners and previously funded projects (e.g. Halpin Trust). Where possible, the project used freely available data including Global Forest Watch imagery and sentinel imagery. Activities were cost effective because we employed Guinean staff as DPOs and DFOs following locally appropriate pay scales with capacity building benefits. Time from all other project partners was included as matched funding. This project built on existing infrastructure in Guinea-Bissau, resulting in cost-effectiveness. This extensively reduced funds sought from Darwin and the cost effectiveness of this project.

10 OPTIONAL: Outstanding achievements of your project during the (300-400 words maximum). This section may be used for publicity purposes

I agree for the Darwin Secretariat to publish the content of this section