Farmer-Elephant Coexistence: Unmanned Aerial Vehicles (UAVs) for Reducing Elephant Crop-Raiding

Final Report to the International Elephant Foundation, June 2016

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2. Background on overall and specific conservation needs

Farmer-Elephant Coexistence: Unmanned Aerial Vehicles (UAV) for Reducing Elephant Crop-Raiding contributes to the efforts of the Government of Tanzania and local communities to develop and employ a holistic strategy for diminishing human-elephant conflict (HEC) with the goal of protecting lives, livelihoods, and elephants in high conflict zones. Conflict among elephants and people is widespread throughout Tanzania (Hoare 2007, WCS 2009, TAWIRI 2010) and results in people being killed or injured and livelihoods threatened, along with numerous retaliations against elephants through spearing, arrows, snaring, and poisoning. Besides these obvious acts against individual elephants, HEC causes a far greater, but subversive, threat to elephants, and wildlife, in general, in that it foments in a large percentage of African communities a hatred for wildlife that manifests through these communities either passively condoning extermination of wildlife or in many cases actively supporting its extirpation (Osborn & Parker 2002, Parker *et al.* 2007, Nelson *et al.* 2003, Kumar 2013). Ultimately, local people who live within natural landscapes where elephants still occur must become defenders of wildlife and pioneer conservation if these animals are to survive in the wild into the future.

To achieve this, the *Farmer-Elephant Coexistence Project* contributes to the efforts of the Government of Tanzania and local communities to develop and employ a holistic strategy for diminishing human-elephant conflict (HEC) with the goal of protecting lives, livelihoods, and elephants in high conflict zones. Our solutions focus on two activities; equipping wildlife managers with small Unmanned Aerial Vehicles (UAVs, or drones) to effectively manage conflict and safely drive elephants to safety when conflict occurs, and the six-year Tembo-Pilipili (Elephant-Chilli) program to bring HEC mitigation awareness and low-cost chilli fences to communities living in close proximity to elephants. Each of our activities has the goal of becoming a best practice of wildlife managers and communities who cohabitate landscapes with elephants, and we seek ways to expand the use of effective solutions to a majority of landscapes in Tanzania where human-elephant conflict occurs. Tanzania's wildlife authorities are key partners in this effort, supporting and testing approaches at every level and engaging communities in all activities.

Employing a diverse set of cost-effective, sustainable solutions for wildlife authorities and local people to use at scales that are meaningful for elephant populations is essential to achieve a state of coexistence with elephants. While not all conflict can be directly mitigated, improved tolerances of communities towards wildlife arising from proactive programs to mitigate conflict and generation of income from wildlife related activities will diminish reprisal poaching and create incentives for elephant conservation among rural communities.

3. Goals and Objectives

Here we aim to further develop and implement one important tactic—the use of UAVs for deterring elephants from crop raiding—as part of a package of broad-based solutions to help mitigate HEC to a point where communities tolerate elephants at meaningful scales, that is, where reprisal-based mortality and tacit support for poaching is reduced to levels that have low impact on the trajectory of elephant populations within priority elephant landscapes (Jones *et al.* 2009, TAWIRI 2010) and where agricultural incursions into critical elephant habitat is negligible. The focal HEC solution of this program — the use of UAVs by wildlife managers to move elephants out of crops and communities — is part of a collaborative HEC mitigation research program of TAWIRI, Wildlife Division, TANAPA, Biodiversity & Wildlife Solutions of RESOLVE, and Mara Elephant Project to test the efficacy and sustainability of UAVs as an HEC mitigation tool for wildlife managers. Now that we have sufficient evidence to show that the UAVs are effective, work well within the standard operating procedures of the rangers, and will last in the field, we

intend to scale-up the use of UAVs by ranger teams to several priority elephant landscapes and corridors within Tanzania (TAWIRI 2010) and continue to test the efficacy of this tool.

The project is comprised of two major elements (Project Objectives): the first is to provide more UAVs to wildlife managers in Tanzania, to enable expanding the use of UAVs for HEC mitigation by wildlife managers around Tarangire National Park and HEC hotspots in the Greater Serengeti Ecosystem, and to train 10 to 15 more wildlife managers in the use and maintenance of UAVs as a mitigation tool. The second is to continue to evaluate the efficacy and sustainability of the UAVs as a tool for HEC mitigation.

Project Objective 1. Conduct a fourth UAV HEC Mitigation Training Course for 10-15 additional wildlife managers in the piloting, tactics, incident evaluation, and maintenance of the UAVs. Deploy 6 additional UAVs with wildlife managers responsible for responding to HEC incidents around Tarangire National Park and in the Greater Serengeti Ecosystem, Tanzania.
Goal: Nine functional and fully equipped teams operating between Tarangire and Serengeti with trained wildlife managers

Project Objective 2. Continue to test the efficacy, cost-effectiveness, and sustainability of UAVs for HEC mitigation by wildlife managers and communities and refine Standard Operating Procedures.
Goal: Collection of sufficient elephant response data with elephants in community areas and crops to judge effectiveness of UAVs over separate landscapes and seasons and prepare and submit a paper for publication

Throughout the course of the project, we maintained our two initial objectives. We were able to train 26 game scouts, rangers, and wildlife managers (here after referred to as rangers) during a three-day intensive workshop in January 2016, and an additional 32 were present at follow up trainings in March and April, although not all of these later attendees were certified to fly. While we have not reached our goal of nine total UAV teams, we have six teams currently operating and expect two additional teams in Serengeti to be trained in June and July. The number of teams and location for deploying the UAVs was determined by WD and TAWIRI, and they felt only four teams were necessary in the Serengeti based on HEC patterns and available vehicles. Most of the conflict occurs in a small region, and the UAV teams require an existing infrastructure for HEC response. Since the initial January training, we have conducted follow-up trainings with two of these teams, and have more visits planned in June and July.

We were only able to deploy six UAVs. Officials from TAWIRI and Wildlife Division felt that only four teams would be immediately necessary within the western Serengeti region due to the concentrated raiding that takes place along the park boarder. We felt it was unnecessary to purchase an extra UAV that would not see immediate use, and instead used these saved funds to bring more wildlife managers and government observers to the workshop. The extra funds were additionally spent on a return visit to work more with ranger teams during peak crop raiding times, as described in the alternative activities section.

4. Implementation

Training and UAV deployment

To deploy UAVs and train rangers in the Serengeti project site, we arranged a January workshop in coordination with the Tanzanian Wildlife Research Institute (TAWIRI), Tanzania Wildlife Division (WD), Tanzania National Parks Associate (TANAPA), the Grumeti Fund, and Frankfurt Zoological Society. The workshop, held in western Serengeti, to train additional rangers how to operate the UAVs. Due to the

success of our pilot project in Tarangire, there was interest from WD and several Wildlife Management Areas, and the workshop brought 26 rangers and 25 observers to the Ikongoro Grumeti game reserve for the three-day course. A full list of participants and organizations participating in the workshop can be found in Appendix 1.

The workshop was led by Marc Goss and David Olson, and four of the trainers are rangers with Wildlife Division and the Mara Elephant Project. Trainers included: Marc Goss (MEP), Nathan Hahn (BWS-RESOLVE), Said Hewas (Wildlife Division – Babati), Joseph Mpuki (Wildlife Division - Burunge WMA), Dickson Njapit (MEP), Steven Ekeno (MEP), and Trey Fehsenfield (MEP). Supporting trainers included Dean Polly (Aerial Vision Africa), who led the observers group and also filmed the training, and Jonathan Konuche (BWS-RESOLVE), who instructed the groups on maintenance and data collection.

We worked with Wildlife Division and TAWIRI to decide where to permanently deploy the UAVs, based on rangers, vehicles, and patterns of HEC. Officials decided on four immediate locations and four team leaders who were particularly adept at piloting and could operate the UAVs with minimal oversight.

Location	UAV
Ikongoro Grumeti Reserve	Phantom 3 Advanced + tablet
Serengeti District Council	Phantom 2
Ikona Wildlife Management Area	Phantom 2
Bunda District Council	Phantom 2
Tanzania Wildlife Research Institute (to be given to Serengeti – TANAPA or Ngorogro in June)	Phantom 3 Advanced

We conducted follow-up training with the Ikongoro Grumeti Reserve and Ikona WMA in March and April. During this time, our field coordinator worked closely with the rangers to do practical flights with raiding elephants and trained them in data collection and maintenance in more detail.

Data Collection

During training, we distributed data sheets to capture elephant behavioral responses in the presence of UAVs. These sheets help rangers to collect information about each flight and are used to determine the overall effectiveness of the UAVs with elephants over time. We were able to collect data on 15 flights in the Serengeti during March and April. We combined and analyzed this information and records on 60 flights previously carried out in Tarangire to prepare and submit short communication to the journal Oryx in May. The manuscript is under review at the time of this report.

We also discussed with rangers the best protocol for filling in data sheets to ensure accuracy and make the process as easy as possible for rangers. We have found that having assigning one ranger on the team as the enumerator to fill out and keep track of the data sheets is best to get accurate data. This means a minimum of four people are required for a UAV-HEC response team: pilot, co-pilot, driver, and data collector.

We also trialed a new data collection method using a smartphone application built with CyberTracker, which digitizes the data sheets and gives GPS location information on each elephant encounter, and also how much area the rangers cover while on patrol with the UAVs. The application was successful in tracking the patrol paths and quickly capturing data points while encountering farmers and wildlife. There

are still some issues with this method, including smartphone availability and cloud syncing. We plan to have this data collection system ready for use in the next field season.

5. Alternate Activities

After the initial workshop, we were asked to return for follow trainings with the individual teams. We were not able to conduct a practical flight demonstration with raiding elephants during the workshop, and our team agreed with officials that rangers should be trained more closely in practical flights with elephants. It is *very important to ensure that the pilots have sufficient skill to continuously herd the elephants away from the operator and other people*.

It is best to conduct workshops during the periods of raiding to increase the chances of a demonstration with elephants. Workshop size can also be limited where possible to keep the teacher-to-ranger ratio small, and we have also refined our training program to ensure we cover data collection and maintenance during the initial training. While the extra field visits were not initially planned, they have helped establish our field coordinator as a liaison and trusted source of information for the rangers, and we are able to help them trouble-shoot problems remotely in cases so far this year.

6. Conservation Outcomes

Overall, the project has established six ranger teams spread between Tarangire and Serengeti National Park. Many of the Tarangire rangers are now capable of training new rangers, creating a ranger-to-ranger training program that helped us conduct our workshop in Serengeti. In 2016 so far, we have trained 26 rangers in the operation and use of UAVs for HEC mitigation, and introduced the devices to over 30 more. Communities in Serengeti and Tarangire have also been introduced to the technique, and this has also helped strengthen the communication networks between communities and wildlife managers to report and address wildlife concerns. Based on 75 trials spanning from February 2015 to March 2016, we have found that the UAVs worked 100% of the time in moving elephants out of crop fields and community areas, and all UAVs are still operational to date.

Based on the success of the UAVs as a tool for wildlife managers, and the uptake and continued use by rangers today, we believe that UAVs can become an integral part of HEC management. This benefits both wildlife and people, as rangers can safely move elephants back to the park when called by farmers for assistance. Before the UAVs were brought to Tarangire, wildlife managers used common tactics like flashlights and air horns, in addition to more dangerous tools like chili bombs and roman candles. These put both elephants and people at risk, and usually resulted in scattering elephants back to the park. The UAVs now allow the same ranger teams to quickly “herd” the elephants back to the park boundary when they stray into fields at night.

We believe the use of UAVs by wildlife managers is just one tactic, albeit a potentially important one, that can be employed as part of a diverse toolkit of solutions to effectively reduce the impacts of HEC in various HEC situations. The use of UAVs by wildlife managers certainly makes moving elephants from crops safer for rangers, farmers, and elephants; this alone is a compelling reason to expand their use throughout Africa’s HEC hotspots. The increased efficiency of wildlife managers in reducing HEC improves relations among farmers and government and, hopefully, tolerances towards wildlife. Our project supports and helps implement Tanzania’s Elephant Management Plan (TEMP 2010–2015 [TAWIRI 2010]) Strategic Objective 1: Human-Elephant Conflict Objectives:

1. Enhance research and monitoring of HEC incidences and mitigation;
2. Expand the use of HEC mitigation methods/techniques in affected areas by 50%;
3. Promote development and implementation of participatory land-use planning in elephant ranges taking into account elephant movement patterns; and (Objective 4 is not relevant)
4. Promote cross-sector and scaled-integration of HEC mitigation strategies.

7. Problems

No major problems occurred during this grant period. We did discover that the newest UAV models we were testing (DJI Phantom 3) are not as well suited for the field as previous models, and their cameras are easily damaged during normal flight. In the future, we will deploy models without a camera, as cameras are not essential for flying with elephants, especially at night when most raiding occurs.

Additionally, we have now received requests for more UAVs to equip new teams in Ngorogoro Conservation Area and other areas around Serengeti. To truly scale the project, we will need to assess cost-effective strategies to get large numbers of UAVs to project sites. We are currently working to leverage distributor contacts who can source older models and parts, which should help account for the price differences and make no impact on the function of the UAVs for the project.

8. Project Evaluation

We used two basic metrics to determine the success of the UAVs as a short term HEC mitigation tool: 1) Is it effective in moving elephants away from crop fields and other areas where homes are present? and 2) Are rangers able to use it on a regular basis and see value in it as a tool?

Based on the successful workshop and continuing reports from the field, this new project site has far exceeded expectations, as there are many opportunities for the rangers to use the UAVs to move elephants out of crop fields. We will be able to more accurately assess the placement of the UAVs in following seasons based on the data collected and locations of HEC incidences. Already, we have received feedback from rangers in the Ikongoro Grumeti Reserve that they could use a second UAV, given the amount of conflict, and access to a second vehicle. Initial reports also indicate that all the UAVs are still in good condition and that the rangers were able to do basic maintenance after a few crashes that were reported. We have learned that UAVs can withstand tough field conditions and last more than one harvest/raiding season; many of the parts that do break, such as propellers and landing gears, are easily replaceable. Our debriefing sessions have also found that rangers are excited to use the new tool and feel that it adds real value to their work. Both wildlife managers and government officials realize the value of the tool in moving elephants out of crop fields, and they saw it has a more effective and safe way to move elephants.

In the long term, we will continue to monitor both of these metrics to ensure that elephants continue to respond rapidly to the approaching UAVs and rangers continue to see value in the tool. Another key aspect for any mitigation strategy is cost. Because a single UAV can cover a large area, and they are able to last over multiple seasons, we believe they are cost-effective tools for rangers. Part of our data collection includes documenting maintenance costs and repairs, and we will continue to assess the practical use of the drones.

9. Next Steps

Already, we have received a request from Wildlife Division to assist in the set up of a UAV response team in Ngorogoro Conservation Area. Now that officials within several government organizations support the mitigation method, we are exploring ways to get direct government support for the project and integrate it as part of the best practice toolkit for HEC management in Tanzania. Over the long-term, we hope, through our UAV initiative and our chili fence program (reports are available upon request) to spark change in the attitude of communities towards elephants in priority elephant landscapes and to cultivate in them a greater tolerance for elephants throughout Tanzania and across Africa. Considering that current estimates show that 70% of all wildlife live outside of protected areas, this is a key objective for conserving wildlife in the wild.

Each method we test has the goal of becoming a best practice for wildlife managers. Managing HEC requires a diverse set of strategies for rangers and communities that can work sustainably at scale. he We believe the best and quickest way to achieve this shift in management and attitudes towards wildlife is to have key wildlife countries, such as Tanzania, develop and test HEC solutions, adopt them as policy, and employ them as a best practice in all key elephant landscapes thereby building a foundation for promoting and sharing effective approaches with their counterparts in other countries throughout Africa.

10. Human-Interest Story

In June of 2015, we traveled to Tarangire to collect project data on both UAVs and chili fences for our Human-Elephant Coexistence project. We were camping with rangers in the Burunge Wildlife Management Area, which is a 600km^2 piece of community-managed land that connects Tarangire and Lake Manayara National Parks to form an important migratory corridor for elephants. As a result, it's a hotspot for conflict, as elephants are constantly moving through a patchwork of fields, dirt roads, and the main highway to Arusha. In fact, our camp was situated on the edge of a major pathway, and during the two weeks there, we saw elephants moving past our camp, and just inside the national park, on the way to their nightly raids. They're smart enough to know the boundaries of the park, and that they can move freely inside.

On our first night out, we had not been able to get power going at the camp, so we were down to only two batteries for the drones after a full day of training. It was bad timing, as elephants were very active that night, and we started getting calls early, at 8pm. After several hours of driving, and a couple of quick flights, we were out of juice. But of course the elephants don't care if you have batteries or not, and we kept on driving.

Just past 3 am, we received another call. Two bulls were causing problems in a field just two kilometers away, and we'd have to move them without the drone. As we drove the dirt road, you could feel the tension in the vehicle. This was nothing new to them, but everyone still knows that dealing with aggressive bull elephants at night is never something to wish for. At the sight of a light waving in the distance, we turned off the dirt track and started driving through fallow fields towards the waiting farmers. They pointed towards the direction the elephants had gone, and we took off.

All of a sudden, we were in an open field and the two bulls were only a few hundred feet away. They turned quickly, ears spread and trunks up. As one trumpeted, the rangers sprang into action, blasting an air horn and turning on a powerful strobe light. The car revved forward as a chili bomb exploded near one of the bulls, and we drove directly towards them. Just as it seemed we were going to run right into them, they turned and sprinted from the field with tails up. The strobe kept going as we crashed through the

bush, just catching glimpses of elephant butts towering above us only a few feet ahead. Within a minute we had lost both elephants, but had managed to push them from the field.

Up until this point, I had heard stories about these tactics, but had never witnessed them first hand. This is the moment I understood why these rangers liked the drones so much. After so many years putting themselves in between elephants and crops, they could now stay at a safe distance and let the drone do the work.

11. Project Summary

Farmer-Elephant Coexistence: Unmanned Aerial Vehicles (UAV) for Reducing Elephant Crop-Raiding contributes to the efforts of the Government of Tanzania and local communities to develop and employ a holistic strategy for diminishing human-elephant conflict (HEC) with the goal of protecting lives, livelihoods, and elephants in high conflict zones. The focal HEC solution of this program — the use of UAVs by wildlife managers to move elephants out of crops and communities — is part of a collaborative HEC mitigation research program of TAWIRI, Wildlife Division, TANAPA, Biodiversity & Wildlife Solutions of RESOLVE, and the Mara Elephant Project to test the efficacy and sustainability of UAVs as an HEC mitigation tool for wildlife managers.

After a successful pilot program at Tarangire National Park, we received a grant from the International Elephant Foundation to expand the program to Serengeti National Park. Under the grant, we were able to train 26 game scouts, rangers, and wildlife managers from around the Serengeti during a three-day intensive workshop January 2016. The workshop was led by Marc Goss from the Mara Elephant Project, along with four rangers previously trained to operate the UAVs. From this training, we were able to equip two existing ranger teams with UAVs to respond to HEC incidents, with two more planned in the next month.

The grant also allowed us to complete data collection, and we have now have data on over 70 flights showing nearly 100% effectiveness at moving elephants out of crop fields and community areas. Future data collection can also incorporate GPS locations and mobile cloud technologies to monitor HEC incident locations and make patrolling more efficient. Our results are currently under peer review for publication by the journal Oryx, and we hope the strong results and success of the training model will encourage uptake and experimentation from groups across the elephant range states.

Looking forward, we intend to leverage the support of the Government and interest from rangers to scale up the use of UAVs to several priority elephant landscapes and corridors within Tanzania and continue to test the efficacy of this tool. We now have evidence to show the UAVs are effective, work well within the standard operating procedures of the rangers, and will last in the field, and we believe that the tool could become an integral part of HEC management. This benefits both wildlife and people, as rangers can eschew more dangerous tools such as chili bombs and roman candles to safely move elephants back to the park when called by farmers for assistance.

The use of UAVs by wildlife managers is just one tactic, albeit a potentially important one, that can be employed as part of a diverse toolkit of solutions to effectively reduce the impacts of HEC in diverse HEC situations. The tool certainly makes the work safer for rangers, farmers, and elephants, and this alone is a compelling reason to expand their use throughout Africa's HEC hotspots.

12. Project Description for Social Media

The Farmer-Elephant Coexistence project from RESOLVE is using UAVs to aid in diminishing human-elephant conflict (HEC). Data from over 70 flights in northern Tanzania show nearly 100% effectiveness moving elephants out of crops and communities. UAVs show good promise as part of an HEC management toolkit that can be applied at scale.

13. Partner Organizations

Tanzania Wildlife Research Institute (TAWIRI); Ministry of Natural Resources and Tourism (MNRT); Wildlife Division (WD) and Problem Animal Control Unit; Ngorogoro Conservation Area Authority (NCAA) Tanzania National Parks (TANAPA); Eastern Africa Farmers Federation (EAFF); Mara Elephant Project; Grumeti Fund; Frankfurt Zoological Society; and RESOLVE's Biodiversity & Wildlife Solutions program (BWS)

17. Publications

Hahn N., De Souza N., Mwakatobe A., Konuche J., Keyyu J., Goss M., Chang'a A., Palminteri S., Dinerstein E., Olson E. 2016 Unmanned Aerial Vehicles Mitigate Human-Elephant Conflict on the Boarders of Tanzanian Parks: A Case Study. *In Review*.

The paper is attached below.

18. Social Media and Online Presence

Biodiversity and Wildlife Solutions at RESOLVE Social Media

BWS Program page: http://www.resolv.org/site-BiodiversityWildlifeSolutions/
Facebook: https://www.facebook.com/RESOLVORG/
Twitter (@RESOLVORG): https://twitter.com/RESOLVORG

BWS WildTech Initiative: Technology for Conservation

Website: http://wildtech.mongabay.com/
Facebook: https://www.facebook.com/WildTechMongabay/
Twitter (@WildtechMB): https://twitter.com/wildtechMB

Company Name: RESOLVE, Inc.
Report Name: IEF Financial Report as of 5/31/2016
Created On: 6/28/2016

	01/01/2016-05/31/2016			
	Actual Costs	Budget	Variance	Notes
Direct Costs				
Kits (UAV, spare props, extra batteries, case, shipping, repair items)	5,764.12	7,200.00	(1,435.88)	5 UAVs
Drone Batteries	536.55	780.00	(243.45)	
Travel, Accommodation, Food	8,105.06	5,160.00	2,945.06	For workshop and 2 site visit follow ups
Training Supplies and Fuel	905.00	1,260.00	(355.00)	For workshop
Data Collection	600.00	600.00	-	
Total Direct Costs	**15,910.73**	**15,000.00**	**910.73**	
Less Resolve Contribution	**(910.73)**		**(910.73)**	
Total IEF Costs	**15,000.00**	**15,000.00**	**-**	