FINAL PROJECT COMPLETION REPORT

I. BASIC DATA

Organization Name: Cornell University

Project Title: Acoustic Monitoring of Forest Elephants

Date of Report: December 2003

II. OPENING REMARKS

Provide any opening remarks that may assist in the review of this report.

The following report covers the first year in a project that was envisioned for CEPF as a 3-year project.

In this granting period we report on the results of an effort to determine whether the vocalizations of forest elephants could be used as early warning of crop-raiding in areas where this presents a problem. This experiment was anticipated in our project output 6. As it yielded some significant results to which we refer repeatedly in this report, I will give the details here.

We set up an acoustic net (a tightly spaced array of 13 autonomous recording units (ARUs)) just inside the border of Kakum National Park, Ghana in an area where crop-raiding occurs frequently, and recorded continuously from June through August 2002. The spacing between adjacent units was roughly 3/4 km and there were two layers of units, so that if elephants called as they approached farms on this part of the border between park and agricultural land they would be detected. Four 1-km^2 agricultural plots were monitored on a daily basis throughout this period for elephant tracks and disturbance to plantations.

In order to relate elephants' calling behavior to crop-raiding, we sub-sampled the data on five ARUs (labeled 1-5 in figures 1 and 2) and two crop monitoring sites (labeled farms A and B) during the period between June 15 and July 11.

Our analysis revealed 1,040 elephant calls and 8 crop-raiding events, 4 at each of the two farms.

The specific timing of crop-raiding events during this period appears to be random in relation to the timing of calls. But surprisingly, 92.5% of all the calls were recorded on Unit 5, which was not the closest unit to either raided farm.

The most likely interpretation is that elephants were gathered near unit 5 throughout our recording period because this location coincided with an elephant resource near the edge of the park; and that every now and then, whether with a plan or just as the result of wandering, some of the gathered elephants emerged from the forest into the nearby fields.

This finding is reminiscent of our finding in 2000, when we recorded over a 2 ½-month season from a more widely spaced array. Then, too, a single recording unit accounted for most of the calls we recorded. In that circumstance, too, the popular elephant location was close to the border of the park, and a human settlement just across the border was frequently raided.

III. ACHIEVEMENT OF PROJECT PURPOSE

***Project Purpose**:*
Improved capacities of governments, academic institutions, and conservation organizations to assess, monitor, and manage elephant populations.

Planned vs. Actual Performance

Indicator	Actual at Completion
Purpose-level:	
1. Conservation monitoring and management in region improved through use of acoustic technologies.	Our 2002 fieldwork in Kakum National Park, Ghana resulted in the finding that elephant vocalizations were invariably recorded on microphones within five kilometers of crop-raiding sites during the several-day period preceding raids. However, while these vocalizations indicated the presence of elephants in the area, there was no obvious correlation between vocal patterns and the day or hour of raiding. 92.5 % of the 1040 calls recorded during the period selected for analysis (a period in which 8 raids occurred) were picked up on a single microphone which was 2 kilometers from the park border near the farm that was raided. Four other microphones were closer to the farm than the one on which most calls were recorded. The parsimonious explanation for these findings is that elephants were congregating at a resource (we might call this a hotspot) that happened to be near the park border. The two farms near this resource were repeatedly raided, while other farms equally close to different sections of the park border were not (see figures 1 and 2). While it was not part of our mission to study human hunting or the use of guns in elephant deterrence, our recordings also documented many gunshots after dark – mostly between 8:00 and 10:00 PM (See

	figure 3). We found, for instance, that 78 shots were picked up on our array on July 3. The multiple records of the same shots on different units indicate that the range of our recording units was several kilometers for such sounds. Their prominence in our recordings indicates the potential of acoustic monitoring for documenting human behaviors that undoubtedly affect elephant distribution and behavior.
2. Protected area management plans in Ghana and Cote d'Ivoire guided by information acquired with acoustic technologies.	The above findings have not yet been conveyed to the Ghanian and Ivoirian park officials. We will get them to Cletus Nateg, Director of Kakum, and will seek contact with the appropriate officials in the Cote d'Ivoire, on the thought that the locations of elephant hotspots offer a fair predictor of the likelihood of crop-raiding. While this result emerged as the consequence of an acoustic study, dung counts also offer an indication of the locations of elephant hotspots. We know this from our 2000 Kakum study, in which large numbers of dung piles in certain circumscribed areas (hotspots) corresponded with large numbers of calls. We recommend that park managers be made aware of elephants' tendency to congregate tightly and raid crops in the vicinity of their hotspots, and gather information on whether farms in other areas are less afflicted. The next step toward a helpful policy is to identify the attractive resource that characterizes each hotspot and to study the seasonality of elephant congregations there. Acoustic methodology may be useful in this inquiry as our recordings cover large time spans and areas without disturbing natural behavior.
3. Elephant populations in at least 2 West African countries (Ghana, Cote d□Ivoire) known and described by size and age/sex structure; movements, behaviors, and habitat use identified; and management programs underway reflecting these biological & ecol prmts	The groundwork for this study was laid in the C.A.R., a field site where elephants are visible and can be counted by eye. The validation of the use of acoustic information as indicators of population abundance was accomplished in Kakum Park with the help of CI's Elephant Biology and Management team. More work – simplification of the recording tools, automatic detection of calls and

	discrimination of call types, establishment of a sampling procedure, and the refinement of a model for predicting numbers and health from acoustic information – still lies ahead before the program can be implemented. If funded we anticipate that the program will be ready for widespread use within three years.
4. National elephant conservation strategies implemented in 3 West African countries, with appropriately trained personnel leading projects and carrying out monitoring activities.	October 2003 workshop began this discussion. Since then we have been researching the extension of our monitoring program into other areas in the region.
5. Elephant crop raiding reduced from baseline established in course of this project, using a range of tools including acoustic technologies, community-level monitoring, protected area outreach, and improved agency management plans.	As suggested in Purpose level indicator #2, knowledge of the locations of resources that are attractive to elephants will probably offer the best way to plan the settlement of areas adjacent to parks containing elephants and reduce the disturbance of crop raiding.
6. Bioacoustic capacities (detection and analysis) established within at least 2 institutions in Upper Guinea Forest Hotspot, and interagency agreements for use of technology and information endorsed.	This is much to be desired and is planned for the future. For now it is helpful to know that CI's Elephant and Management Team completed its training after several years of work with Dr. Richard Barnes and that the training included an acoustic dimension using our tools.

Describe the success of the project in terms of achieving its intended impact objective and performance indicators.

Crop raiding: In its first year the CEPF project established an aspect of forest elephant behavior – their tendency to concentrate in hotspots – whose recognition should help park managers predict where elephant crop raiding will occur. Next steps will involve discouraging new human settlement near elephant hotspots, and engaging current settlers in the analysis of the environmental attraction and of seasonal patterns of crop raiding.

Monitoring and population estimation: All stages in this work to date have underscored the promise of acoustic technology for monitoring elephant presence, movements, composition and density. No other methodology is so comprehensive over time and space and non-invasive. As we have developed this methodology for elephants we have been aware that prolonged acoustic recordings potentially offer a window on the lives and abundance of many animals and thus an indicator of biodiversity.

The magnitude of the need for such information related to forest elephants is particularly brought home by the latest African Elephant Status Report, released by the IUCN's African Elephant Specialist Group on November 26, 2003. The press release reads:

"Central Africa may harbor between 16,500 and 196,000 elephants while the smallest and most fragmented populations are found in West Africa, ranging from a definite 5,500 to a speculative 13,200 elephants."

Were there any unexpected impacts (positive or negative)?

Within the bounds of what we intended to do in the first year, everything went as planned.

IV. PROJECT OUTPUTS

***Project Outputs**:*

Output 1: A working model for estimating relative abundance of elephants from acoustic information.
Output 2: A working model for estimating health (age, sex, composition and presence/absence of reproductive activities) of elephant populations from acoustic information.
Output 3: Development/refinement of modestly priced, easy -to-use generic acoustic recording units (ARUs) to serve as the basis of terrestrial acoustic monitoring projects for any vocal species.
Output 4: West African conservationists trained in acoustic technology
Output 5: Analysis of feasibility of acoustic monitoring as a tool for predicting elephant crop raiding.
Output 6: If crop-raiding is predictable from acoustic behavior, an analysis of the feasibility of a system that would monitor elephants' locations and calls in real time to provide early warning of impending crop-raiding.
Output 7: Published article for general readers on the results of the above efforts to use the vocalizations of forest elephants as indicators of population size and condition, and as information for reducing conflict between wildlife and humans.
Output 8: Dissemination of information from this project into public environmental education programs and exhibits.

Planned vs. Actual Performance

Indicator	Actual at Completion
Output 1:	
1. Cross-validation of acoustic abundance model with dung counting model.	A general correspondence between raw acoustic and dung-count data is immediately apparent. We are using a new set of data to verify the listening radius of the ARUs, after which an acoustic model relating calling rates to abundance can be completed. The results from this model will be compared with the results of the dung-count model designed by Richard Barnes.
2. Cross-validation of acoustic abundance model with dung DNA capture/recapture	Estimates of elephant numbers in Kakum Park resulting from application of the DNA

model.	capture/recapture model made by Lori Eggert in 2003 will be compared to estimates resulting from the acoustic model. Kakum is a closed system with little if any immigration or emigration or poaching; therefore this comparison can be made even though the data sets were collected in different years.
3. Sampling protocols developed for acoustically monitoring elephants in densely forested habitats.	Information on detection radius was gained from analysis of Kakum data. Gunshots were heard across the entire array, revealing that the minimum detection radius for gunshots of this type is 2.5 km.
4. A peer-reviewed publication presenting methodology and results of pilot field seasons (2000 and 2002) focused on acoustic assessments of forest elephant abundance. To be completed in 2004.	To be completed in 2004.
Output 2:	
1. Development of methodology to sort and classify elephant calls in large data sets automatically and relate them to visually confirmed demographic information.	Much progress on this front. A customized software program has been built for measurement and classification of elephant calls; currently we are working on a set of 150 calls to establish the extent to which selected parameters enable us to subdivide these calls into functional types which can be used as predictors of group composition and behavior. For example, calf distress calls, male musth rumbles, female estrous calls.
2. Cross-validation of acoustic health model with dung DNA capture/recapture model, which includes information on sex.	See output 1, # 2.
3. Peer-reviewed paper on techniques for determining demography and behavior of forest elephants from acoustic information. To be completed in 2005.	Analysis underway. To be completed in 2005.
4. Peer-reviewed paper relating forest elephants' calling patterns to their behavior in breeding and non-breeding seasons and summarizing implications for acoustic monitoring. To be completed in 2005.	Analysis underway. To be completed in 2005.
Output 3:	
1. Second generation (improved version) ARU, tested and refined by mid-2005.	The ARU technology has significantly improved since 2002. It can now be programmed to sample only at certain times of day, and the hardware is undergoing a redesign for minimization of power consumption and increased

	computing capacity. A new ARU version, to be tested in a 2005 filed expedition, will contain an automatic elephant call – detector enabling us to record only elephant calls and thus save battery power, disk space, and analysis time.
2. ARU instruction manual produced by end of 2005.	To be completed by the Bioacoustics Research Program, hopefully in 2005.
Output 4:	
1. Workshop to design training program for local users of acoustic methodology for monitoring elephants and other species.	To occur when the methodology is ready – estimated early 2006.
2. Collaboration with West African local institutions	To occur when the methodology is ready – estimated early 2006. We are planning to meet with other forest elephant researchers in early 2004; one of the items for discussion will be to identify potential West African sites and collaborations.
3. On-site workshop to implement training program for local users of acoustic methodology in a pilot field site.	To occur when the methodology is ready – estimated early 2006.
4. Preliminary implementation: a team of potential trainers experienced in acoustic unit deployment, recovery and preliminary data analysis, by mid-2005.	Initial training of Elephant Biology and Management team was carried out in 2000 and 2002. The members of this team are now trained to select suitable sites, then deploy, maintain and recover recording units. Further training to occur when the methodology is ready – estimated early 2006.
Output 5:	
1. Report detailing results of study of acoustic correlates of crop raiding. Data collected in Kakum, Ghana in 2002 and analyzed in 2002-3, for the purpose of learning whether crop-raiding is predictable from acoustic behavior.	Report submitted here. This will be prepared for Kakum officials and for publication in a scientific journal.
Output 6:	
1.Report summarizing the feasibility of a system that would monitor elephants' locations and calls in real time to provide early warning of impending crop-raiding.	Technically, such a system is currently being designed in the Bioacoustics Research Program for monitoring right whales in real time. Modifications to adapt the program for elephants are feasible. However, our findings in Kakum in 2002 suggest that elephants calls are not good indicators of the specific timing of crop raiding, although they do indicate the proximity of elephants which may eventually raid crops. We question the practicality of deploying a real-time

	detection system for this purpose.
Output 7:	
1. Review and publication of the article.	An in-depth version of the report submitted here will be prepared for publication in a scientific journal.
Output 8:	
1. Contribution to Kakum exhibit in Ghana	We have developed a video presentation which we will provide to the Kakum Visitors' Center once the wherewithal for powering and displaying it are in place.
2. Contribution to two National Geographic Radio Expedition programs on NPR (prepared by Alex Chadwick from material gathered during his visit to Dzanga project in February 2002)	A two-part series on the Elephant Listening project's work was featured on NPR in September 2002.
3. Contribution to a special 4-program BBC Natural History radio series for an "Elephant Day" planned to be aired in October 2002 (as a result of Grant Sonnex's visit to elephants with K. Payne in October 2001)	The "Elephant Day" radio series did not materialize, but a separate BBC program featuring Katy Payne's elephant work was aired in 2002.

Describe the success of the project in terms of delivering the intended outputs.

The outputs of our first year's work were surprisingly rich in terms of our findings about the relation between elephants calling patterns and crop raiding behavior. There is much progress on our acoustic monitoring system for forest elephants. More time and more funding will be required for this program to reach fruition, but it will be a major contribution when implemented.

Were any outputs unrealized? If so, how has this affected the overall impact of the project?

Unrealized outputs are mostly scheduled for the future. Particularly challenging will be those involving coordination among West African government bodies and wildlife managers.

V. SAFEGUARD POLICY ASSESSMENTS

Provide a summary of the implementation of any required action toward the environmental and social safeguard policies within the project.

The project has no adverse Environmental, Human Health and Safety, or Social impacts.

VI. LESSONS LEARNED FROM THE PROJECT

Describe any lessons learned during the various phases of the project. Consider lessons both for future projects, as well as for CEPF's future performance.
Project Design Process: (aspects of the project design that contributed to its success/failure)

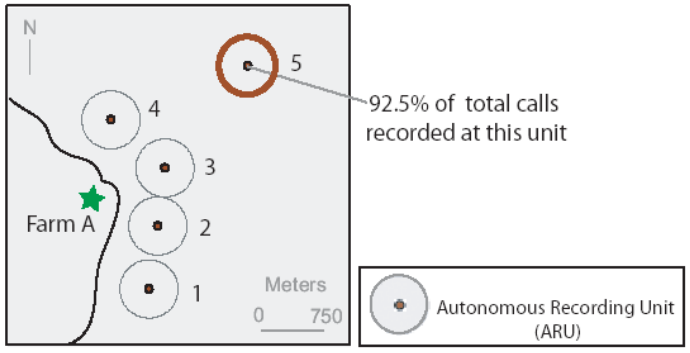
We continue to recognize that the success of this project depends on collaboration among and commitment from a diverse group of stakeholders. The immediate collaborators during the report period included the Elephant Listening Project, the Bioacoustics Research Program, CEPF, CI's West Africa program, the Elephant Biology and Management team, and Kakum National Park personnel. As we implement acoustic monitoring for forest elephants across West Africa, we will require new collaborators and sustained funding. Building such collaborations will catalyze interest in the conservation and management of this endangered species.

Project Execution: (aspects of the project execution that contributed to its success/failure)

VII. ADDITIONAL COMMENTS AND RECOMMENDATIONS

The value of this year's findings on the relation between elephants' calling behavior and crop raiding is expressed in various aspects of the report (above). In addition, the research revealed a great many gunshots near the monitored area at night (Fig 3). These were not part of the protocol as far as we can learn, but the ability of an acoustic array to detect and localize gunshots indicates a second kind of value of acoustic monitoring. Finally, our long acoustic recordings also yielded a surprising degree of information on other taxa – a precisely timed and located record of other animal vocalizations – particularly birds, insects, frogs, and primates. Thus the same methodology that provides detailed information on one species also documents others, and may be used in some circumstances as a way of measuring and monitoring biodiversity richness.

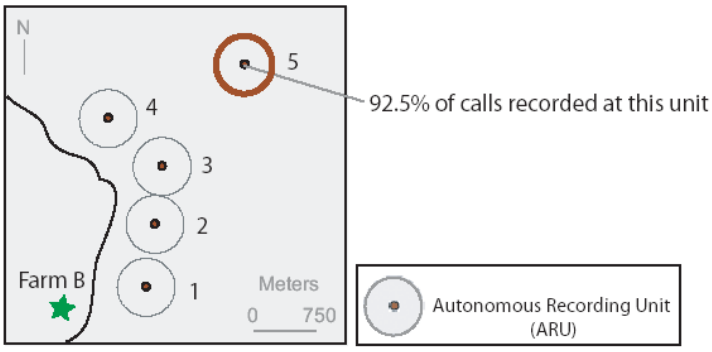
Figure 1: Summary of forest elephant calling patterns and crop raiding events for Farm A
Kakum National Park, Ghana
June 15-July 11, 2002



	Date	Site 1 calls	Site 2 calls	Site 3 calls	Site 4 calls	Site 5 calls
	15-Jun	3				
	16-Jun	1	0		0	
	17-Jun	0	0		0	1
	18-Jun	0	1		0	0
	19-Jun	0	0	0	0	0
	20-Jun	1	0	0	0	0
	21-Jun	0	0	0	0	6
	22-Jun	0	3	0	1	584
	23-Jun	2	9	0	0	275
	24-Jun	0	4	3	0	5
	25-Jun	2	4	2	1	0
	26-Jun	0	0	1	0	0
	27-Jun	6	0	4	0	0
	28-Jun	8	0	1	0	0
1st Raid	29-Jun	1	0	1	0	22
	30-Jun	2	0	0	0	4
2nd Raid	1-Jul	2	0	0	1	9
	2-Jul	1	0	0	0	4
	3-Jul	2	1	0	0	1
	4-Jul	0	1	2	0	0
	5-Jul	0	1	0	0	24
	6-Jul	0	0	0	0	3
	7-Jul	0	0	0	1	13
3rd Raid	8-Jul		0	0	1	0
4th Raid	9-Jul		1	1	0	0
	10-Jul		1	2	0	10
	11-Jul			0		0

>11 calls
6-10 calls
1-5 calls

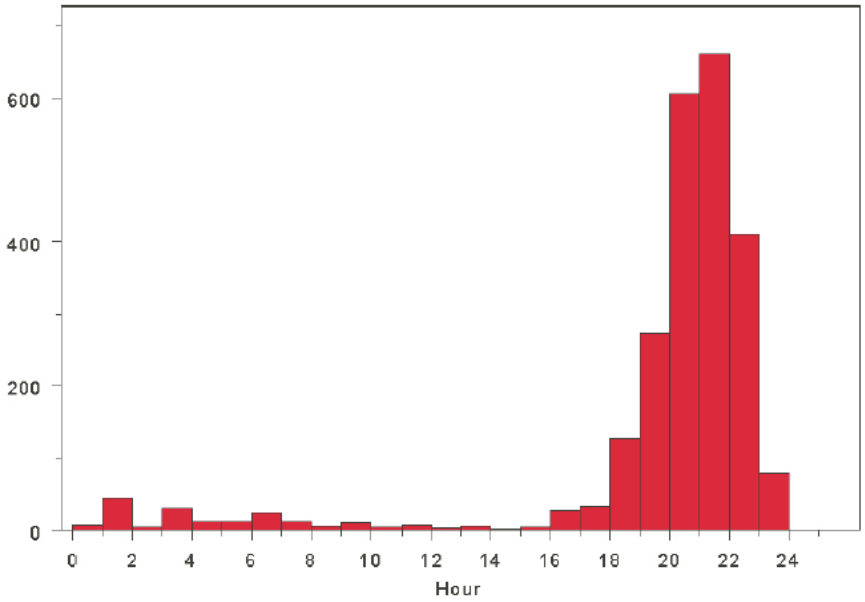
Figure 2: Summary of forest elephant calling patterns and crop raiding events for Farm B
Kakum National Park, Ghana
June 15-July 11, 2002



	Date	Site 1 calls	Site 2 calls	Site 3 calls	Site 4 calls	Site 5 calls
	15-Jun	3				
	16-Jun	1	0		0	
	17-Jun	0	0		0	1
	18-Jun	0	1		0	0
	19-Jun	0	0	0	0	0
	20-Jun	1	0	0	0	0
	21-Jun	0	0	0	0	6
	22-Jun	0	3	0	1	584
	23-Jun	2	9	0	0	275
	24-Jun	0	4	3	0	5
	25-Jun	2	4	2	1	0
	26-Jun	0	0	1	0	0
	27-Jun	6	0	4	0	0
	28-Jun	8	0	1	0	0
	29-Jun	1	0	1	0	22
	30-Jun	2	0	0	0	4
4 raids at Farm B	1-Jul	2	0	0	1	9
	2-Jul	1	0	0	0	4
	3-Jul	2	1	0	0	1
	4-Jul	0	1	2	0	0
	5-Jul	0	1	0	0	24
	6-Jul	0	0	0	0	3
	7-Jul	0	0	0	1	13
	8-Jul		0	0	1	0
	9-Jul		1	1	0	0
	10-Jul		1	2	0	10
	11-Jul			0		0

>11 calls
6-10 calls
1-5 calls

Figure 3: Number of gunshots by hour detected at recording sites
Kakum National Park, Ghana June 15 - July 15, 2002



Most gunshots are made between 8pm and 10pm local time.