Results of Elephant Listening Project Work 2000-2004
Kakum National Park, Ghana

Summary

The Elephant Listening Project, in collaboration with the Elephant Biology and Management (EBM) team and Dr. Richard Barnes, has worked at Kakum National Park for the past four years to investigate forest elephant calling patterns and compare these acoustic signals of elephant presence with results from dung-count transects and crop-raiding events. The goal of these efforts has been to:

1. Establish baseline information about forest elephant calling patterns in this well-protected population (including where and when forest elephants tend to call most).
2. Compare a statistical model based on calling patterns with a model based on dung-survey results to establish whether the two rather different methods are yielding similar estimates of elephant numbers.
3. Compare timing of calls with timing of crop-raiding events to determine whether elephants predictably make sounds in association with crop raids.
4. Share results of this study with park staff and public visitors to Kakum.

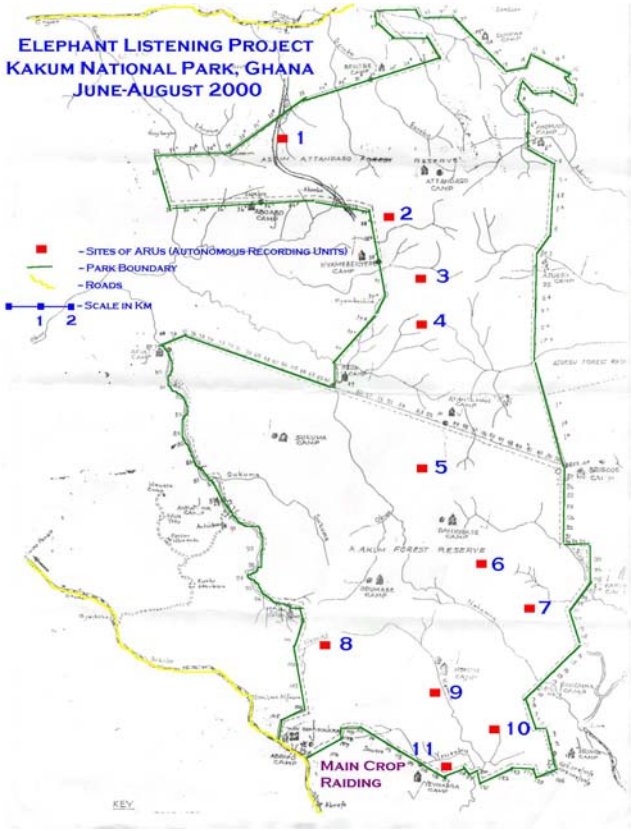
Kakum National Park provides a very good setting for investigating these questions. The forest elephants at Kakum stay in the park throughout the year and are well-protected by the park's dedicated staff and solid infrastructure. Members of the EBM team, all present in Kakum during the period when this work was in progress, were highly dedicated and knowledgeable, with practical experience in the forest and the technical expertise to set out, maintain, and retrieve recording equipment. The park's systematic reporting of crop raiding was also important to the success of this work. In addition, the Kakum visitor center hosts thousands of visitors per year (e.g., an impressive 82,000 in 2002) and provides educational information for Ghanaians and international visitors alike about the forest and its inhabitants.

Methods

2000 Field Work (Addressing goals 1 & 2)

The Kakum National Park field site provided an opportunity to monitor the resident elephants simultaneously by acoustic censusing and by dung pile abundance. Kakum is a small island park of 360 sq km, surrounded by agriculture. Sightings of elephants are rare due to the density of the forest. Dr. Richard Barnes' long-term study of elephant abundance using dung-counting techniques made this site an ideal location to conduct parallel experiments. The experimental design included 11 Autonomous Recording Units (ARUs) distributed randomly throughout the park (see Figure 1). Each unit recorded continuously for 68 days at a sampling rate of 1000Hz. During the experiment, the EBM team under the guidance of Dr. Richard Barnes completed three dung transects at each ARU site: late June, mid July, and early August. This design yielded complementary data from both censusing methods for comparison.

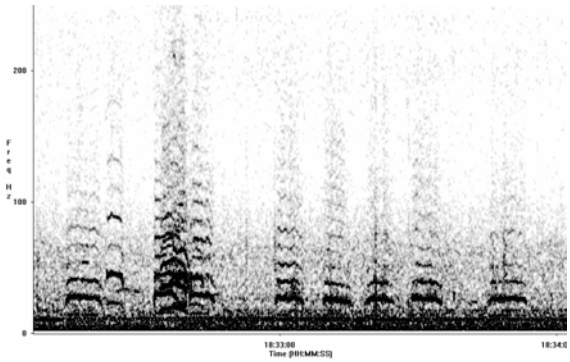
Figure 1: Deployment of Recording Units 2000



2001 Lab Work (Addressing goals 1 & 2)

The acoustic data from the 11 ARUs were brought back to the Cornell University Bioacoustics Lab in Ithaca, NY for analysis. The data were first backed up on compact disks and then analyzed with the sound analysis software developed by Bioacoustics staff. This software allows users to view acoustic data in spectrogram format (Figure 2). ELP staff developed a spectrographic criteria for elephant calls (greater than 2 seconds and less than 10 seconds, between 1Hz and 250Hz, and with some form of frequency modulation). By paging through all data from each of the ARUs, ELP staff were able to log and count all recorded elephant calls. (Note: We have now begun to test software to automatically detect elephant calls from within these long recordings so that in the future, results can be obtained much more quickly.)

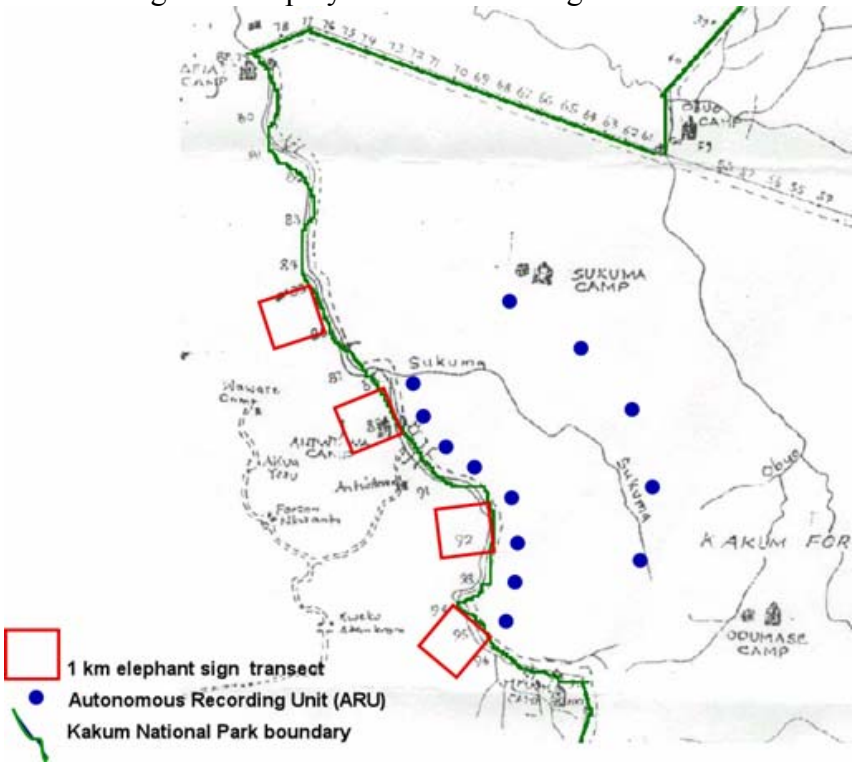
Figure 2: A series of elephant calls from Kakum in spectrogram format



2002 Field Work (Addressing goals 1 & 3)

The Elephant Listening Project and the EBM team set up an acoustic net (a tightly-spaced array of 13 ARUs) just inside the western border of Kakum 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 by park staff on a daily basis throughout this period for elephant tracks and disturbance to plantations. (See Figure 3)

Figure 3: Deployment of Recording Units 2002

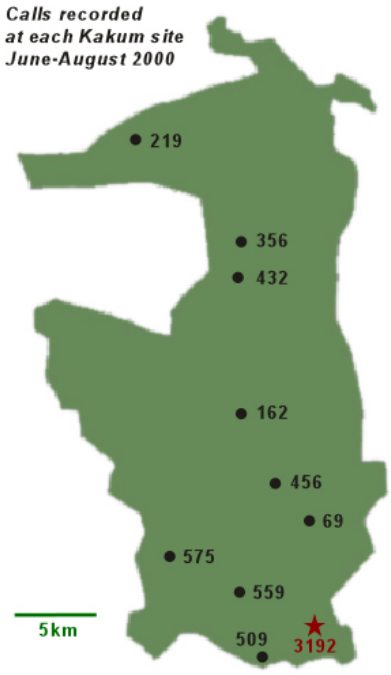


2003 Lab Work (Addressing goals 1 & 3)
In order to relate elephants' calling behavior to crop-raiding, we counted elephant calls on five of the thirteen ARUs and two crop monitoring sites during the period from June 15 to July 11, 2002, using the same data browsing protocol as in 2001.

Results

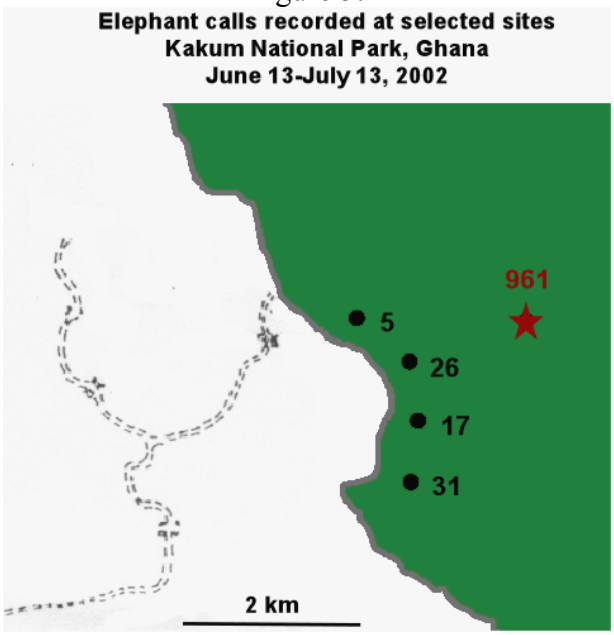
Distribution of forest elephant calls on widely spaced units in Kakum (2000 data)
The Kakum call count data from 2000 reveals a striking asymmetry in the distribution of calls throughout the park. Whereas in the mid-section of the park, very few calls were recorded, recordings from the southern section of the park contained many more calls (see Figure 4). In fact, a single unit in the south of the park contained 3,192 elephant calls, approximately five times more than at any other unit. In addition, variation in call numbers varies significantly within each 68-day period and again within each 24-hour period. Reports on weather in 2000 reveal that the streams in the northern and mid-sections of the park may have been dry – a potential explanation of the high call counts in the southern section.

Figure 4:



Distribution of forest elephant calls on a local scale (2002 data)
The Elephant Listening Project's analysis of 2002 recordings revealed 1,040 elephant calls total. 92.5% of all the calls were recorded on a single unit (see red star in Figure 5). As in 2000, a single recording unit recorded many more calls than any other. In both circumstances the most popular elephant location was close to the border of the park, and a human settlement just across the border was frequently raided.

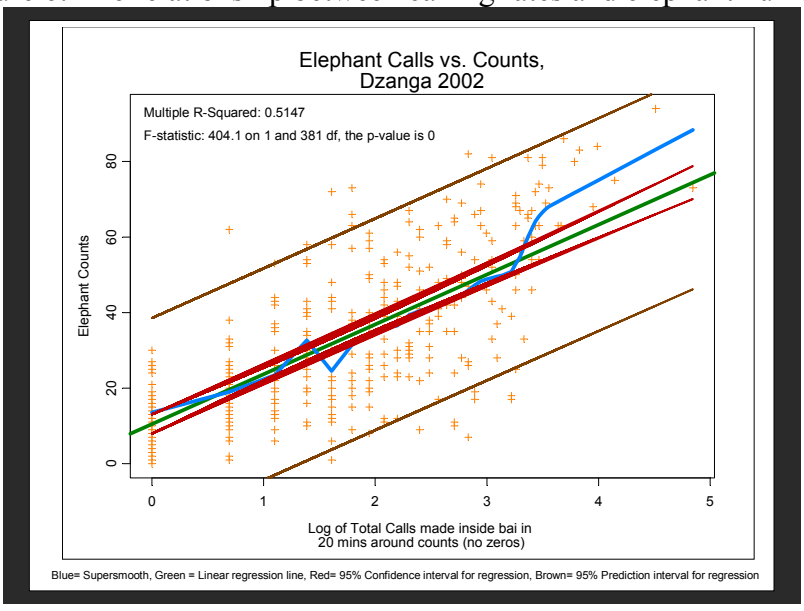
Figure 5:



Acoustic monitoring as a way to estimate elephant abundance

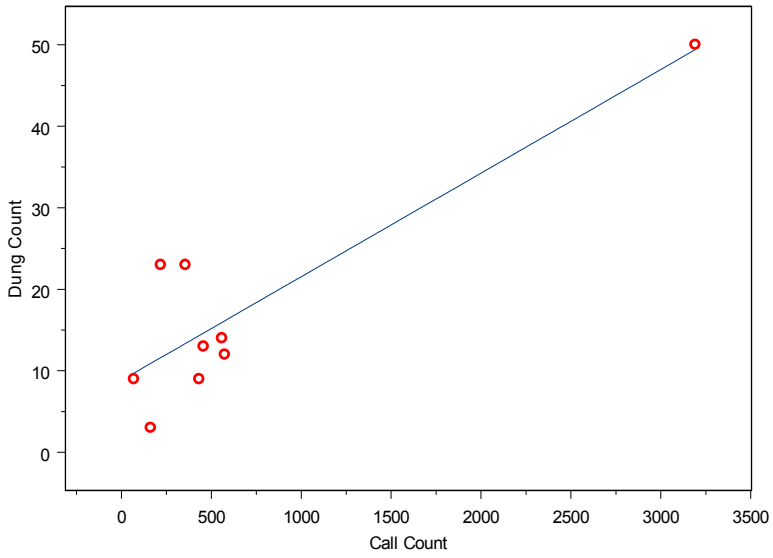
In order to estimate elephant abundance from acoustic data alone, the relationship between calling rates and elephant numbers must be well understood. Baseline data correlating elephant calls with numbers of elephants have been gathered by the Elephant Listening Project in the Dzanga National Park, Central African Republic at a forest clearing where elephants are visible and can be counted while being acoustically recorded. The results of this data collection reveal that an increase in elephant numbers is related to an increase in calling rates. This relationship allows the formation of a regression model which predicts elephant abundance from calling rates (Figure 6).

Figure 6: The relationship between calling rates and elephant numbers



Once we have completed the task of predicting elephant abundance in the area monitored by each of the recording units at Kakum, we will be able to make an estimate of the number of elephants in the full park based on acoustics alone. A comparison of estimates of elephant abundance based on acoustic recordings (ELP), counts of dung piles (Barnes and EBM), and differences in the DNA composition in sampled dung (Eggert) now becomes possible. An initial comparison of the acoustic method to the dung method reveals a rough positive correlation in the raw data (Figure 7).

Figure 7: The relationship between dung counts and call counts



R-Squared: 0.7799
F-statistic: 24.81 on 1 and 7 degrees of freedom
P-value is 0.0016

Calling patterns in relation to crop raiding

The main crop-raiding areas in the 2000 field season were close to the recording units with the highest call counts, suggesting a positive correlation between high calling rates and crop-raiding behavior. However, because crop-raiding data were not systematically collected during the 2000 field season, the correlation cannot be quantified.

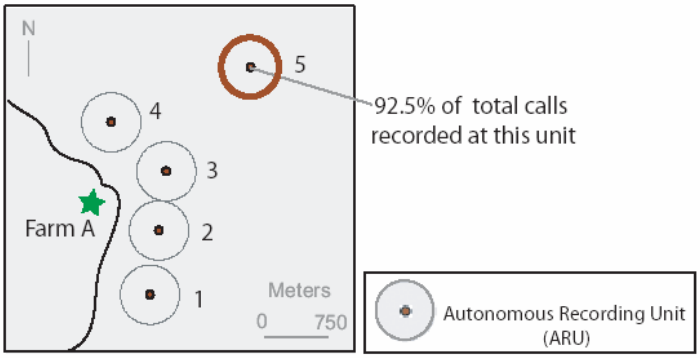
In 2002, however, crop-raiding was monitored daily by Kakum staff in 1km^2 border farm areas surrounding the park, allowing a more formal comparison of the timing of crop raids and calls. This analysis revealed 1,040 elephant calls and 8 crop-raiding events, 4 at each of two farms. While these vocalizations indicated the presence of elephants in the area, there was not a precise correlation between vocal patterns and the day or hour of raiding. Furthermore, 92.5% of all the calls in our subsample were recorded on Unit 5, which was not the closest unit to either raided farm (Figures 8 and 9): it was, however, within 4 kms of both. This coincidence could be interpreted in either of two ways: 1) An elephant resource in the vicinity of Unit 5 attracted the elephants toward the edge of the park, increasing the chance that they would discover the nearby crops and raid them. Or,

2) the crops themselves were the primary attraction, and Unit 5 acted as a staging place for the elephants' periodic raids.

Areas farther from the farms were not sampled acoustically, nor were the ecological features of the recording unit locations noted to make it possible to distinguish between these two interpretations. The difference has management significance, which will be discussed in the conclusion section.

Figure 8:

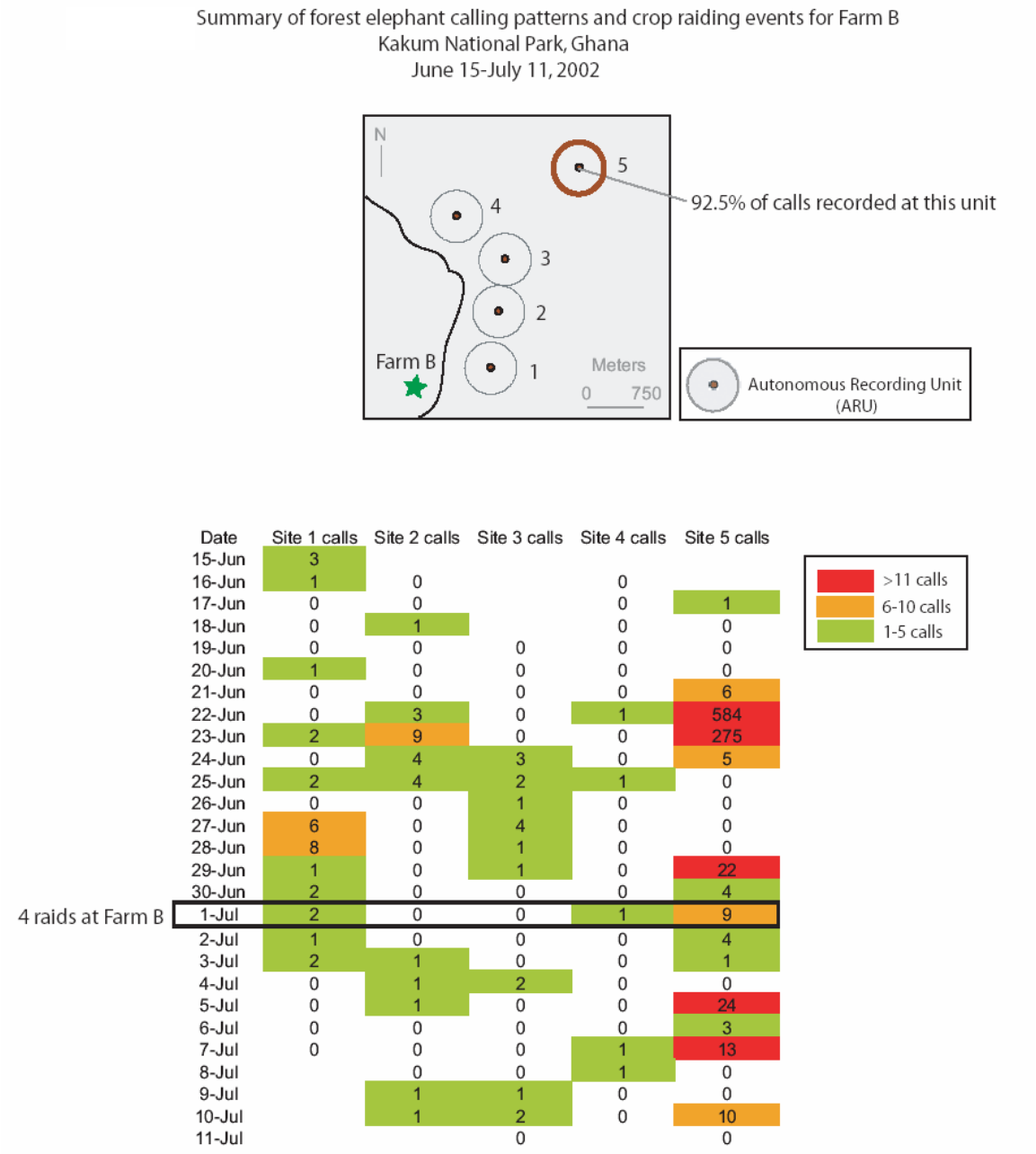
Summary of forest elephant calling patterns and crop raiding events for Farm A
Kakum National Park, Ghana
June 15-July 11, 2002



	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 9:



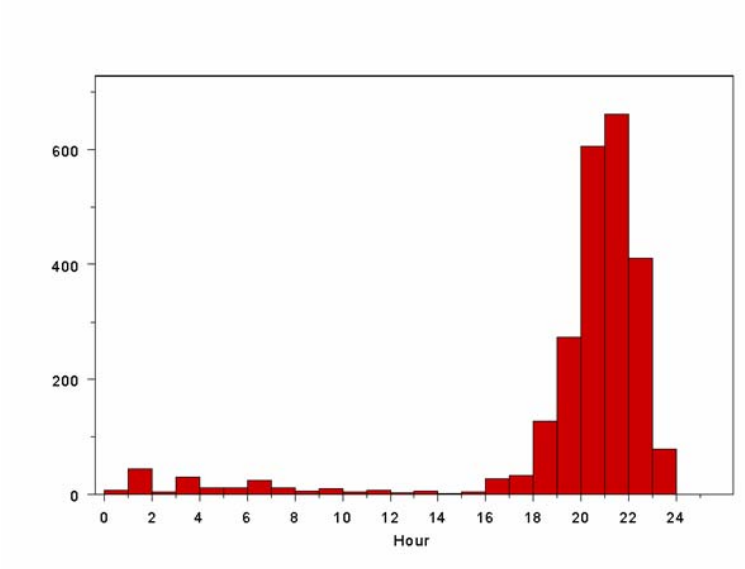
Date	Site 1 calls	Site 2 calls	Site 3 calls	Site 4 calls	Site 5 calls
15-Jun	3				
16-Jun	1	0		0	
17-Jun	0	0		0	1
18-Jun	0	1		0	0
19-Jun	0	0	0	0	0
20-Jun	1	0	0	0	0
21-Jun	0	0	0	0	6
22-Jun	0	3	0	1	584
23-Jun	2	9	0	0	275
24-Jun	0	4	3	0	5
25-Jun	2	4	2	1	0
26-Jun	0	0	1	0	0
27-Jun	6	0	4	0	0
28-Jun	8	0	1	0	0
29-Jun	1	0	1	0	22
30-Jun	2	0	0	0	4
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

Gunshots

An unanticipated result of the Kakum 2002 work is that our recordings also documented gunshots after dark – mostly between 8:00 and 10:00 PM (see Figure 10), and sometimes quite numerous (e.g. one unit recorded 78 shots on July 3.) The fact that many of these shots were heard by more than one recorder indicates that the listening range of our recording units was several square kilometers for such sounds, and a grid of acoustic units each separated by more than 1 km from its neighbors might provide precise location of gunshots. The loudest recordings were nearest the park border, suggesting that the

sounds were coming from the Antwikwaa area outside the park. Richard Barnes has commented that these sounds might be bamboo cannons used in an effort to deter crop-raiders: if so, they did not completely deter raiding elephants. Given their association with poaching, the prominence of gunshots in our recordings indicates another dimension in the potential of acoustic monitoring.

Figure 10: Number of Gunshots recorded at sites 5,6,7,8 combined by hour of day.



Observations relevant to the deterrence of crop-raiding

Resource hotspots or staging areas?

The data from both our Kakum field seasons show a tendency for elephants to congregate tightly in certain areas, or hotspots, and to raid crops nearby. Information from the Senior Wildlife Officer for the Kakum region, Cletus Nateg (pers. comm.) and members of the Elephant Biology and Management team (pers. comm.) indicates that most local farmers have intermittently tended fields at varying distances from the park, and the fields abutting the park border tend to be raided more often than fields more distant from the border. In relation to the farmers' desire for advance warning of impending raids, there are several precautions we may recommend. Although short-term changes in elephants' calling rates do not appear to be useful predictors of raiding, and will thus not be useful as a source of immediate advance warning, on a larger scale it may be useful that high rates of calling reveal the locations of hotspots and that these may be staging areas from which elephants leave the park on a haphazard schedule for raiding nearby crops. The question then has to do with the nature of the hotspots. If these are inherently attractive to elephants regardless of their proximity to farms, it will make sense for farmers to stop investing effort into fields close to hotspots. If, on the other hand, the hotspots are simply staging areas for crop-raiding, all border areas are equally vulnerable. Visits to areas identified acoustically as hotspots can help to distinguish between these alternatives. Knowledge of the locations of resources that are attractive to elephants both inside and

outside park areas may offer some guidance for planning human settlement and reducing crop raiding.

Trip Wires
As border farmers need immediate notification of crop-raiding by elephants to effectively prevent crop damage, the Elephant Listening Project collaborated with a Sri Lankan research team in 2002 to test a trip wire system at a farm on the western edge of the Kakum park. The trip wire system is constructed of inexpensive materials including fishing line, and a car horn. When an elephant enters a field, breaking the fishing line, the car horn sounds, alerting the farmer. Along with longer-term monitoring and identification of elephant resource hotspots, the Elephant Listening Project hopes that systems such as trip wires can help with the increasing human-elephant conflict in the Kakum region.

The need for acoustic monitoring: forest elephants and other taxa
The magnitude of the need for information related to forest elephants is highlighted 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." Such uncertainty makes very real the possibility that forest elephant numbers could decline rapidly without being detected. Our efforts to create an alternative and complementary elephant monitoring program is a response to this growing conservation need.

ELP's 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. In this way, methodology that provides detailed information on one species also can document others, and may be used in some circumstances to measure and monitor biodiversity richness.

The Elephant Listening Project is including with this report a series of recordings of elephants, gunshots, and other vocal animals recorded at Kakum, in CD and cassette tape form.

Thanks

We would like to thank Cletus Nateg, Senior Wildlife Officer for the Kakum region, and all members of the Kakum staff who have helped with this project. Okyeame Ampadu-Agyei, Conservation International's Ghana Director, Moses Kofi Sam, Coordinator of elephant programs for the Ghana Wildlife Service, and Brent Bailey, Director of CI's West Africa Program at the time this project was initiated, supported the formation of the Elephant Management and Biology team as well as ELP's work. We are grateful to the paramount chiefs in the Kakum area for their dedication to the health of the forests and the surrounding communities.

We would like to acknowledge each member of the Elephant Biology and Management Project team who worked so hard to make this project a success: Dr. Richard Barnes, Yaw Boafo, Nandjui Awo, Emmanuel Danquah, Umaru Farouk Dubiure, Emmanuel Hema, Isaac Owusu, Johnson Kemeh, Baba Usman, Kofi Kesse, Mildred Amofah Appiah, and Agathah Dolman.

The mother institution of the Elephant Listening Project is the Bioacoustics Research Program at the Cornell Laboratory of Ornithology. We are indebted to its director, Dr. Christopher Clark, and to its acoustic engineers, for the methodology and tools used in data collection and analysis, and here acknowledge much additional support of many kinds without which the work could not have been done. We would particularly like to thank Robert MacCurdy who traveled to Kakum for both deployments, skillfully engineering the recording equipment and working with the EBM team to make this project a success.

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