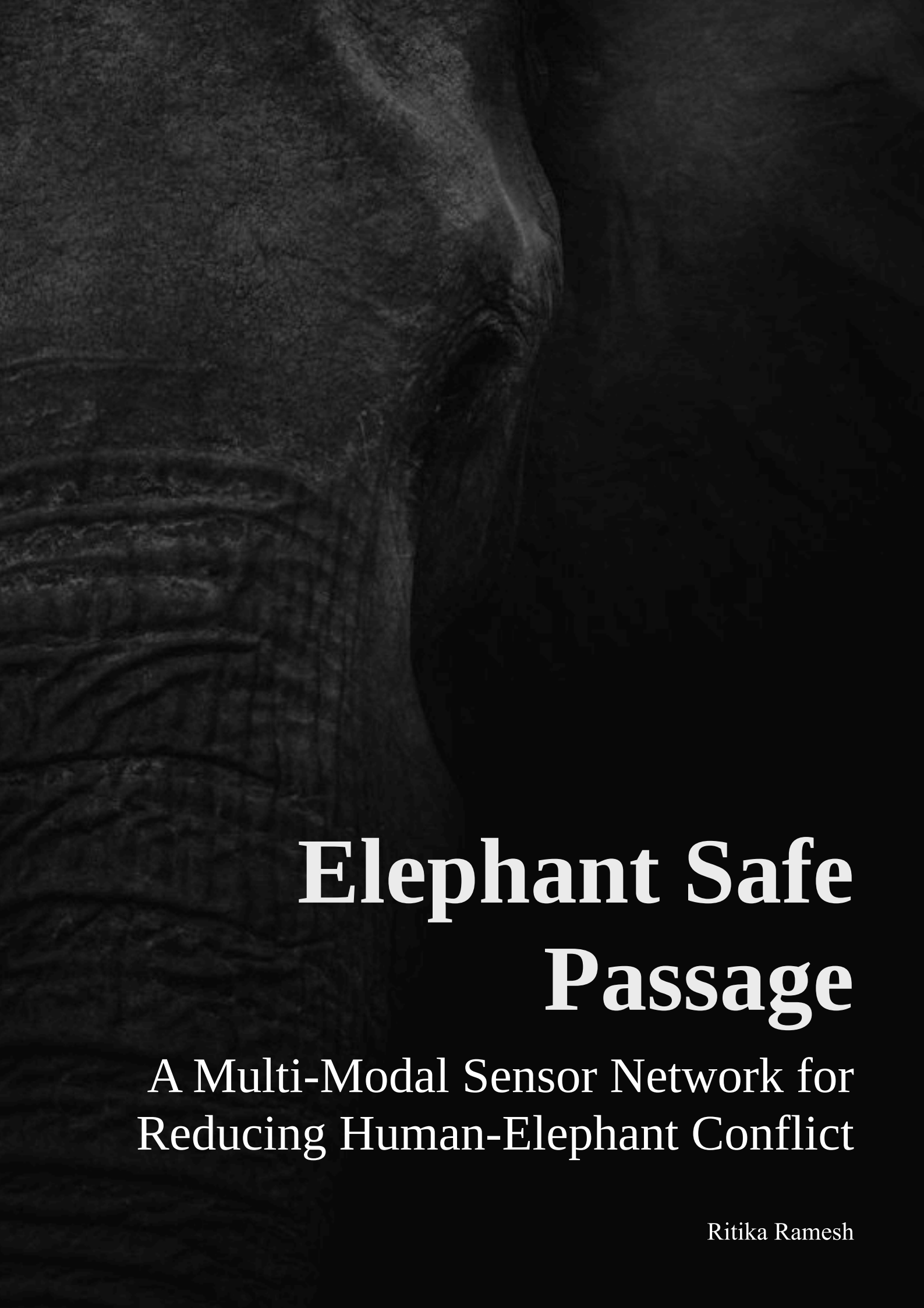




Elephant Safe Passage

A Multi-Modal Sensor Network for
Reducing Human-Elephant Conflict

Ritika Ramesh

Abstract

African Savanna Elephants are losing ground at the borders of protected areas. Human settlements there are expanding at nearly double the average rural growth rate (Wittemyer et al., 2008), and poaching keeps removing matriarchs, the elders whose knowledge of safe routes, water sources, and threat patterns holds the herd together. When a matriarch is lost, the rest of the herd loses years of decision-making memory with her (McComb et al., 2000; Bradshaw, 2009). Most anti-poaching technology responds to this with surveillance. GPS collars, drones, ranger dashboards. The elephants get tracked, the rangers get informed, and the herd itself never finds out what the system knows.

Elephant Safe Passage takes the opposite approach. It is a network of small, rock-shaped sensor nodes called Sentinels that sit along sanctuary borders. Each Sentinel watches for three signals tied to human incursion: radio frequency emissions from phones and electronics, acoustic signatures from vehicles and gunshots, and seismic vibrations from foot and vehicle traffic. When two of those signals fire together, the Sentinel emits a low-frequency infrasonic alert. Nearby elephants hear it. Humans cannot. The herd is warned first, and the matriarch decides what to do. A secondary app handles the human side of the same event. When a Sentinel fires, rangers receive a notification with the node's location, which sensors triggered, and a low-resolution image from an outward-facing camera that activates only after the alert. The image is for tracking the humans, not the elephants. The system records no data about the animals it is designed to protect.

The design draws on prior elephant behavior research, an ethogram of stress and stability indicators, and GPS movement data from three elephants tracked in Etosha National Park, Namibia between 2008 and 2010. It also builds on three decades of playback research showing that elephants respond to low-frequency cues in their environment. The Sentinel is not inventing a new language. It speaks one the herd already uses.

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Introduction

African Savanna Elephants are running out of room. Human settlements keep growing at the edges of protected areas, sometimes at nearly double the average rural growth rate (Wittemyer et al., 2008), and the friction zones between sanctuary land and human activity are getting tighter every year. Poaching is one of the sharpest expressions of that friction, and it does not just kill individual elephants. It removes matriarchs, the elders who hold the herd's memory of safe routes, water sources, and threat patterns (McComb et al., 2000). When a matriarch is killed, the herd loses years of knowledge along with her.

Most existing anti-poaching technology is built for humans. Drones, GPS collars, ranger dashboards. These tools track elephants so that people can intervene on their behalf, which sounds reasonable until you notice that the elephant is never actually the user. They are the subject of surveillance, not the recipient of information.

This project takes a different approach. Elephant Safe Passage is a network of small, landscape-blended sensor nodes called Sentinels that listen for signs of human incursion at the edges of protected areas. When a Sentinel detects a likely threat through a combination of radio, acoustic, and seismic signals, it emits a low-frequency infrasonic alert that nearby herds can hear and humans cannot. The elephants get the warning. The herd decides what to do with it.

This document walks through the research that led to the design, the spatial data that shapes where Sentinels get placed, the system itself, and a scenario that follows a herd through an incursion event. It builds on prior research into elephant behavior, an ethogram of stress and stability indicators, a spatial-context behavior mapping method, and GPS movement data from three elephants tracked in Etosha National Park. The argument running through all of it: designing for an animal means designing inside their world, in a modality they already use, and leaving the decision with them.

Background & Prior Research

Why elephants, and why this conflict zone

African Savanna Elephants are a keystone species, which means they shape the ecosystems they live in. They live 60 to 70 years inside female-led groups that split and rejoin depending on what resources are available and what is going on socially. The oldest females hold most of the knowledge the rest of the group depends on (McComb et al., 2000; Poole & Granli, 2009). When a matriarch is lost, the herd loses years of accumulated memory about water, safe routes, and threats. Younger elephants left behind act disorganized, make worse decisions, and show signs of stress for years afterward (Bradshaw, 2009).

This matters here because the borders of protected areas are where elephants are most exposed. Human population growth at the edges of African protected areas runs at nearly double the average rural rate, which means the friction zones keep tightening (Wittemyer et al., 2008). Poaching is the sharpest version of that friction. It removes matriarchs, fractures herds, and produces orphans who struggle to reintegrate into wild social structures.

How elephants already communicate

Elephants are not waiting for technology to warn them about danger. They already have a working system. Adult females can recognize the infrasonic contact calls of roughly 100 other individuals across 14 family groups, and they use those calls to coordinate group movement, locate kin, and assess threats across distances of several kilometers (McComb et al., 2000). They communicate through more than 200 documented signals across visual, acoustic, tactile, and chemical channels (Poole & Granli, 2009). They pick up low-frequency vibrations through their feet, a behavior called seismic listening, which lets them detect distant herds, weather systems, and approaching threats long before any human-built sensor would register them.

This is the channel Elephant Safe Passage uses. The system does not teach elephants anything new. It speaks to them in a frequency range they already use.

Four Behavioral Indicators

Designing for an animal raises an obvious question: how do you know if it is working? You cannot ask an elephant whether a Sentinel made her feel safer. What you can do is watch how the herd behaves, because elephants signal stress and stability through posture, contact, and attention. Subtle postural shifts reveal how elephants are reading and responding to their surroundings (Poole & Granli, 2009). Four behaviors anchor the evaluation framework for this project. Each one points to something specific about how a herd is reading its environment, and together they give a way to measure whether the Sentinel system is reducing friction or just adding to it.

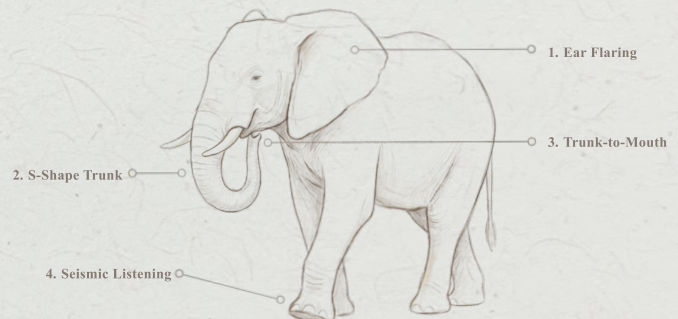


Figure 1: Elephant annotation diagram with 4 indicators

Ear Flaring. Ears spread wide, head elevated. A threat response that indicates the elephant is on high alert. This behavior is most common near roads and human activity. A successful Sentinel deployment should reduce ear flaring frequency in friction zones, because the herd has more warning and more time to relocate before a threat is in visual range.

S-Shape Trunk. The trunk lifts and curves into an S shape as the elephant investigates an unfamiliar scent. It spikes near roads and human settlements, where unknown smells like diesel, smoke, and human bodies accumulate. Like ear flaring, this is a vigilance behavior. A drop in S-shape trunk in monitored zones suggests the herd is moving through the landscape with less defensive scanning.

Trunk-to-Mouth. One elephant places the tip of its trunk into another's mouth. This is a reassurance gesture and one of the strongest indicators of social bonding in elephant herds. It shows up most when elephants are moving together in protected social zones, where the group is calm enough to maintain physical

contact while walking. A stable rate of trunk-to-mouth contact in Sentinel-monitored zones suggests the system is not introducing new stress.

Seismic Listening. The elephant stands very still, weight shifted forward onto its front feet, and picks up low-frequency vibrations through the ground. This is how elephants detect distant herds, weather systems, and approaching threats over long distances (McComb et al., 2000). The Sentinel system builds on this behavior directly. Its infrasonic alerts are designed to register through the same sensory channel that elephants already use to listen to the landscape.

What success looks like

Ear flaring and S-shape trunk should decrease in monitored zones. Trunk-to-mouth contact should stay stable or increase. Seismic listening should remain a natural, integrated behavior. Those patterns indicate the Sentinel system is returning warning time to the herd without disrupting how they already read the landscape.

Movement Patterns in Etosha

Where elephants actually move

Designing a sensor network for a 22,000 square kilometer protected area raises an immediate question: where do you put the nodes? Coverage matters, but so does precision. A Sentinel only earns its place in the landscape if it sits where elephants actually travel and where incursion risk is real. This project uses GPS tracking data from three African Savanna Elephants in Etosha National Park, Namibia, collected between 2008 and 2010 (Tsalyuk et al., 2018). The collars recorded coordinates roughly every 10 seconds, producing 351,151 individual location points across the three animals. For this document, the three elephants are referred to by name rather than collar ID: Tano (LA1), Zola (LA3), and Mireya (LA5).

Tano ranged widest, covering the largest spatial area across the northern and western reaches of the tracked zone. He represents the kind of elephant whose movement crosses the most varied terrain and the most friction edges. **Zola** was tracked the longest, with consistent data across 23 months. Her movement pattern shows what a stable, year-round resident looks like in this landscape. She anchors the southeastern zone. **Mireya** had the smallest range, concentrated in one corner of the tracked area. Her data covers 9 months before her collar went dark.

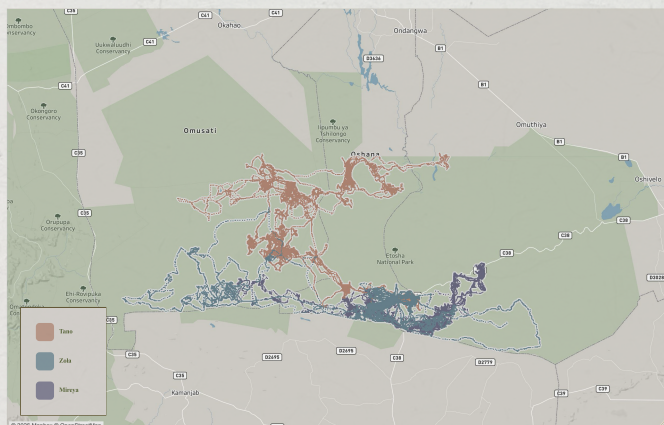


Figure 2: GPS movement paths for three elephants tracked in Etosha National Park, 2008–2010. Orange: Tano. Blue: Zola. Purple: Mireya. Data source: Tsalyuk et al., 2018.

The map shows three patterns that matter for Sentinel deployment.

Shared activity zones. All three elephants converged in the central and southeastern parts of the park. These overlap zones almost certainly correspond to key resources like water holes, mineral licks, and shaded vegetation. Elephants do not wander randomly. They go where resources are, and they return to the same places across seasons (Douglas-Hamilton et al., 2005).

Individual ranging behavior. Despite the shared zones, each elephant has a distinct territory. Tano covers wide ground, Zola holds the southeast, Mireya stays compact. Sentinel placement cannot rely on a single average pattern. It has to account for both shared corridors and individual variation.

Corridor structure. The visible threads connecting different parts of each elephant's range match what Douglas-Hamilton et al. (2005) called "travel corridors," routes between home sectors. Elephants move faster through corridors than they do in core zones, which Douglas-Hamilton interpreted as evidence that they perceive corridor travel as higher risk. Corridors are where Sentinels matter most.



Figure 3: Monthly GPS point counts for Tano, Zola, and Mireya, 2008–2010. Data source: Tsalyuk et al., 2018.

Spatial data tells you where. Temporal data tells you when. During the overlapping months (October 2008 through June 2009), all three elephants moved at similar rates, mostly in the 7,500 to 9,000 GPS points per month range. That consistency suggests shared environmental drivers like seasonal water availability and vegetation patterns are setting a baseline level of movement across the landscape. Mireya's data ends sharply in June 2009. Tano's drops out after October 2009 with a brief blip in January 2010. Zola is the only one tracked continuously across all 23 months, which is why she anchors the long-term picture.

These tracking gaps are not behavioral. They reflect collar malfunctions or end-of-deployment. The gaps matter for interpretation, and they matter for design. Any sensor network deployed across a protected area will face the same problem. Hardware fails, batteries die, signals drop. The Sentinel system has to assume that some nodes will go dark, and the network has to remain useful even when individual sensors are offline.

What this means for Sentinel placement

Three deployment principles come out of the movement data.

Cluster Sentinels along shared corridors. The overlap zones in the southeastern park are where multiple elephants travel. A Sentinel on a corridor used by one elephant protects one elephant. A Sentinel on a corridor used by many protects many.

Place Sentinels at friction-zone boundaries. The corridors that elephants traverse the fastest are the ones they perceive as most dangerous (Douglas-Hamilton et al., 2005). These are the points where warning time matters most, and where Sentinels should sit.

Build for redundancy. Tracking gaps in the GPS data make it clear that no single sensor stays online forever. Sentinels should be placed densely enough that the loss of one or two nodes does not break the alert network.

The Design Problem

Most anti-poaching technology treats elephants as data points. GPS collars track them, drones photograph them, ranger dashboards plot their locations in real time. These tools are useful, but they share a structural assumption: humans get the information, and elephants are the subject of it. The elephant is monitored. The ranger is informed. The decision is human. This works until it does not. Rangers cover enormous territory. Response times are measured in hours, not minutes. A poaching crew that reaches a herd before a ranger does is already too close, and the elephants have no warning until the moment of contact.

There is a second problem with the surveillance model. The information flow is one-directional. Data moves from elephants to humans, never the other way. The herd never knows what the system knows. If a sensor network detects a poaching crew entering a protected area, that information is useful to a ranger forty kilometers away, but the elephants four hundred meters from the crew have no idea it is coming.

The behavioral evidence makes the cost of this clear. Stress behaviors like ear flaring, S-shape trunk scanning, and defensive clustering spike near human infrastructure (Poole & Granli, 2009). Herds move significantly faster through unprotected corridors, evidence that they perceive those areas as dangerous (Douglas-Hamilton et al., 2005). When matriarchs are lost to poaching, the herd's accumulated knowledge of safe routes and water sources goes with them, and the remaining elephants show disorganized movement and elevated stress for years (Bradshaw, 2009). The elephants are reading the landscape constantly. They are already trying to make decisions about where to be safe. The information they need to make those decisions better is not reaching them.

The design question this project addresses

How might a sensor network for human-elephant conflict zones deliver threat information to the elephants themselves, in a sensory modality they already use, while keeping humans in a supporting rather than central role?

Three constraints follow from this framing. **The system must speak in elephant.** Any alert mechanism has to use a channel the herd already reads. Audible alarms, lights, or other human-coded signals fail this test. Infrasound passes it. So does seismic vibration. These are the sensory modalities elephants use to communicate over long distances and detect distant threats (McComb et al., 2000).

The system must respect existing herd behavior. A successful design supports the matriarch's leadership rather than overriding it. It gives the herd information and leaves the response decision with them. It does not push them, herd them, or condition them. The four behavioral indicators become the evaluation framework for whether the system is working. **The system must work in real landscapes.** Etosha covers 22,000 square kilometers. Battery, signal coverage, hardware failure, and false positives are all real. The deployment has to be dense enough to provide warning time but light enough to maintain.



Figure 4: A matriarch leads her family through the savanna. Decades of accumulated knowledge inform where the herd goes, when, and how.

Concept Development

Starting point: a single-signal alert

The first version of this concept was simpler. A network of devices placed along sanctuary borders that would detect mobile phone signals from poachers and emit an infrasonic alert to nearby elephants. Phones are nearly universal, even among poaching crews, and detecting radio frequency emissions is technically straightforward. The infrasonic alert would warn the herd in a frequency range only they could hear. The idea held together at first glance, but it broke down on closer inspection.

Phone detection alone is too narrow. Experienced poaching crews know about RF detection. They leave phones at vehicle staging points, use radios on different frequencies, or go fully dark. A system that depends on phones catches casual or opportunistic intrusions and misses the more organized ones, which are exactly the threats that matter most.

False positives would overwhelm the system. Phones in a protected area are not always carried by poachers. Rangers, researchers, tour vehicles, and conservation staff all carry phones. Without a way to tell authorized signals from unauthorized ones, the Sentinels would fire constantly, the elephants would lose trust in the alerts, and the system would defeat itself.

One signal cannot describe a threat. A phone signal tells you something electronic is nearby. It does not tell you whether that something is a person on foot, a vehicle moving fast, or a forgotten device on a researcher's belt. The system needed more than presence detection. It needed enough information to make a confident judgment about whether an incursion was real.

What the herd already does

Elephants do not rely on a single sense to assess threats. They listen for low-frequency calls from other herds (McComb et al., 2000), pick up ground vibrations through their feet (Poole & Granli, 2009), read scent on the wind, and watch the behavior of other animals. Their threat assessment is multi-modal because no single signal is reliable on its own. A sensor network that protects elephants should work the same way.

From single signal to sensor mesh

The concept evolved into a multi-modal system. Each Sentinel listens for three independent signals tied to human incursion: radio frequency emissions from phones and electronics, acoustic signatures from vehicles and gunshots, and seismic vibrations from foot and vehicle traffic.

A single signal alone does not trigger the system. When two or more fire together within a defined time window, the Sentinel emits the infrasonic alert. This two-of-three threshold cuts false positives sharply. A researcher's phone alone does not fire it. A vehicle engine alone does not fire it. But a phone signal plus a vehicle engine plus footsteps, in the same place at the same time, is a confident detection.

The seismic channel does a second piece of work. Seismic listening is how elephants detect distant herds and approaching threats through the ground (McComb et al., 2000). A Sentinel that uses the same channel is not introducing a new sense. It is amplifying one the herd already trusts.

Form factor: blending into the landscape

A Sentinel that looks like a piece of technology defeats its purpose. It signals to poachers that the area is monitored, and it disrupts the visual character of the landscape. The Sentinel is housed in a weathered, rock-like enclosure with sensors hidden behind a textured exterior that mimics natural stone. The form is varied across the deployment so that no two Sentinels look identical, which makes them harder to spot and disable. A solar trickle charge runs through the top surface. The goal is not concealment for its own sake. It is to keep the system inside the elephant's existing world, where it belongs.

Will the Elephants Respond?

A system built around alerting elephants only works if elephants actually respond. There is over three decades of field research on how elephants react to low-frequency playback, and the evidence is consistent. Elephants listen, and they change their behavior based on what they hear.

Playback research

Langbauer et al. (1991) ran some of the earliest playback experiments in Etosha itself. Elephants responded to recorded infrasonic calls from up to four kilometers away, freezing, scanning, and adjusting their movement direction. McComb et al. (2000) showed that adult females could distinguish the contact calls of family members, bond group associates, and distant acquaintances. Calls from strangers produced defensive bunching and ear flaring. Calls from familiar individuals produced relaxed reorientation. King et al. (2010) found that African elephants flee in response to recorded bee buzzing, a sound they associate with painful stings. The response is fast, coordinated, and includes warning rumbles to other group members.

What this means for Sentinel design

The Sentinel does not invent a new signal. It plays back patterns the herd already recognizes. The current design uses recorded alarm rumbles, the low-frequency vocalizations elephants produce to signal danger (Poole & Granli, 2009). Played through a Sentinel's infrasonic speaker, the rumble registers as a warning call from an unknown elephant and triggers the herd's existing defensive response. The sound travels through both the air and

the ground, the same way the herd receives a real alarm rumble from another elephant.

The response, not the instruction.

The Sentinel does not tell the elephants what to do. It signals the presence of danger, in a language they already speak, and leaves the response to the herd. The matriarch decides whether to move, where, and how fast. The system gives her information. She makes the call. This matters because herd decisions depend on years of accumulated knowledge that no sensor network can replicate.

The Sentinel System

Overview

Elephant Safe Passage has three connected parts. The Sentinel itself, which detects incursions and emits the alert. The infrasonic alert, which reaches the elephants. The ranger app, which tells the human side of the system what just happened. The order matters. When two of the three sensors fire together, the Sentinel emits the alert immediately. The alert is autonomous. It does not wait for a human to confirm it. After the alert, the camera activates and pushes a notification to the ranger app. The elephants are already moving before any human sees it.

The order of operations matters. When two of the three sensors



Figure 5: The Rock Device

The Sentinel node

The Sentinel is housed in a rock-shaped enclosure about 30 centimeters across, made of weathered composite material textured to match the surrounding terrain. The form is varied across the deployment so no two Sentinels look identical. Inside the shell sit three sensors, a processing unit, an infrasonic emitter, an outward-facing camera, and a solar power system. The three sensors are a radio frequency receiver tuned to common phone and walkie-talkie frequencies, a directional microphone for acoustic signature detection (engines, gunshots, voices), and a seismic geophone in contact with the ground beneath the shell. A low-power onboard chip runs the detection logic and holds a whitelist of authorized devices. The infrasonic emitter is a low-frequency speaker tuned below 20 Hz, where elephants can hear and humans cannot. The outward-facing camera activates only after the alert fires, captures a single image, sends it to the ranger app, and powers down. It never faces inward toward elephant habitat.

The infrasonic alert

A recorded elephant alarm rumble plays back at low frequency. It registers to nearby elephants as a warning call from an

unknown source. The herd responds as it would to any alarm rumble: freezing, scanning, then coordinating movement away under the matriarch's lead. The frequency stays below 20 Hz, well under human hearing thresholds, so poachers do not know the herd has been warned.

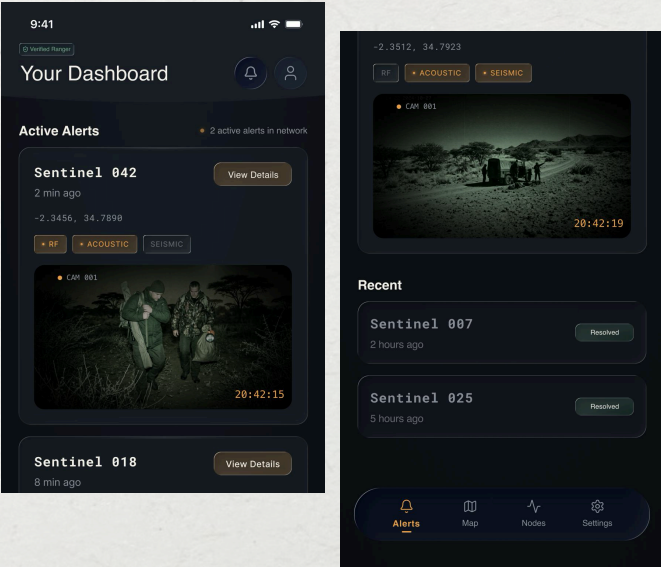


Figure 6. The ranger dashboard, showing two active incursion alerts. Each card displays the Sentinel ID, time of trigger, GPS coordinates, the two or three sensors that fired, and a low-resolution camera capture from the moment of detection. Resolved alerts appear below in the Recent section.

The ranger app

The app gives rangers enough information to respond to a confirmed incursion, without giving them anything about the elephants. When a Sentinel fires, the app pushes a notification with the Sentinel ID, GPS coordinates, which two sensors registered, a low-resolution image from the outward-facing camera, and the time of alert. The app does not show elephant locations or herd movements. The Sentinel network is one-way on the elephant side, which means rangers know an incursion happened but do not know which herd was warned or where it went. This is deliberate. The system protects elephants from poachers, not from rangers. Rangers can dispatch a response team, log incursions for pattern analysis, and manage the device whitelist to reduce false positives.

Deployment logic

Sentinels are placed using the spatial principles from the movement data. Cluster along shared corridors where multiple elephants travel. Anchor at friction-zone boundaries, where elephants move fastest and warning time matters most. Place nodes densely enough that the loss of one or two does not break the alert network.

Scenario: A Herd Encounters an Incursion

A small herd is moving along a corridor toward a water hole in the southeastern corner of the park. The matriarch leads. Three kilometers south, a vehicle stops just inside the park boundary. Two figures step out carrying rifles. They start walking north along a dry riverbed. A Sentinel sits forty meters off the riverbed. From a distance it looks like a weathered stone. The acoustic sensor catches the vehicle engine, then footsteps. The seismic sensor picks up the vibration through the ground.

The radio sensor catches a phone still on in one of the figures' pockets. The two-of-three threshold is crossed. The infrasonic emitter fires. An alarm rumble plays out from the Sentinel, traveling through the air and the ground. The poachers hear nothing.

Two and a half kilometers north, the matriarch lifts her head. Her ears come forward. She shifts her weight onto her front feet, the seismic listening posture. The adolescents stop. The matriarch turns the herd west, off the corridor and toward higher ground. At the same moment, the Sentinel's camera activates. It captures one image of the two figures on the riverbed and sends it to the ranger app. A notification lands on a ranger's phone forty kilometers away: Sentinel 042 triggered. RF, Acoustic, Seismic. Two figures detected. The ranger dispatches a response team.

By the time the team gets close, the herd is two kilometers west, in cover. The poachers find no elephants and no fresh tracks. They turn back to their vehicle and leave. The herd got the warning first. The matriarch made the call. The rangers responded to humans, not to elephants.

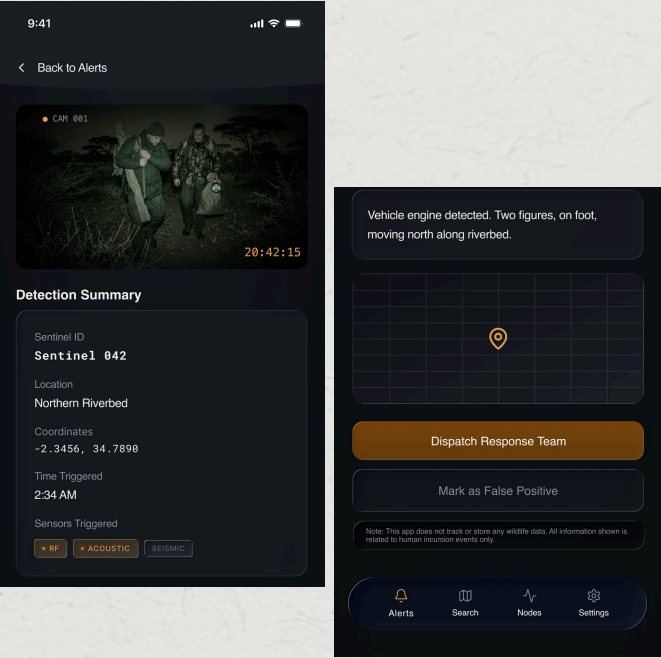


Figure 7. The alert detail view, opened when a ranger taps "View Details" on an active alert. The full camera capture sits at the top with a timestamp. Below it, the Detection Summary lists the Sentinel ID, location, coordinates, time triggered, and the sensors that fired. An auto-generated description summarizes what the system detected. The ranger can then dispatch a response team or mark the alert as a false positive. A privacy note at the bottom confirms that no wildlife data is included.

ACI Connections

Animal-Computer Interaction asks how technology can serve animals as users in their own right (Mancini, 2011). The animal is not a subject or beneficiary downstream of a human. The animal is the user. Elephant Safe Passage tries to take that seriously across four design decisions.

The elephant is the primary user. The Sentinel's infrasonic alert fires autonomously, without human review, because the herd is the audience that matters most. The ranger app is a secondary loop.

The system uses the animal's existing sensory modality. Infrasound and seismic vibration are not arbitrary signal choices. They are what elephants already listen to. The system speaks a language the herd already speaks fluently.

The system gives information, not instructions. The Sentinel announces a threat and leaves the response to the matriarch. The system supports her judgment instead of overriding it.

The system declines to surveil its user. The Sentinel network does not track elephants, log herd movement, or store data about the animals. Most conservation technology collects animal data by default. Elephant Safe Passage treats elephants the way a thoughtful system would treat any user.

These are framing choices, not technical innovations. The system could have collected elephant location data. It could have used audible alarms. It could have included human verification before the alert fired. Each of those would have made it more legible to humans and less useful to elephants. The decisions all flow from a single commitment: the elephant is the user.

Limitations & Future Work

Limitations

Thresholds need tuning. The two-of-three trigger is a starting point, and real deployment would mean adjusting it based on local conditions. Habituation is a risk. If the alert fires too often, the herd may stop responding, so ongoing behavioral observation would be needed. The system depends on ranger infrastructure: phones, coverage, and the capacity to respond. Some protected areas do not have that. The Sentinel protects elephants in the moment but does not address the deeper conditions that drive poaching.

Poachers can adapt. A crew that reduces its signal footprint enough could evade detection. The system raises the cost of going undetected, not the certainty of being caught. The form factor is conceptual. Real production would need materials testing, weatherproofing, and field durability work outside the scope of this project.

Future Work

A pilot deployment would test the system against the four behavioral indicators. A drop in vigilance behaviors and a stable rate of social bonding would show the system is working. A longer movement dataset would reveal seasonal patterns that could shape battery management. The same logic, multi-modal detection plus alerts in the animal's native sensory channel, could work for forest elephants, rhinos, and large carnivores. The most durable conservation systems are designed with the people who live near them. Future iterations should involve communities adjacent to protected areas in deciding where Sentinels go.

Conclusion

Designing for an animal means treating them as a user, not a subject. Elephant Safe Passage tries to demonstrate what that looks like in practice. A sensor network that listens for human incursion, an infrasonic alert that reaches the herd before any human sees it, a ranger app that handles the human-to-human response without ever pointing a camera at an elephant.

The technology in this system is not new. Multi-modal sensor mesh, infrasonic emitters, app-based ranger response, low-resolution remote cameras. All of these exist. What is new is the order in which they fire and the question they are organized around. The Sentinel emits its alert autonomously because the herd is the user that matters most. The ranger app comes second.

The camera comes after that.

Most conservation technology assumes that helping an animal means collecting more data about it. Elephant Safe Passage makes the opposite case. Sometimes helping an animal means giving them something, not taking something from them. The

Sentinel gives the herd warning time. Everything else is in service of that.

If a system like this were ever deployed, the test of whether it worked would not be in dashboards or detection rates. It would be in how the herd moves. Less defensive scanning at the friction edge. More trunk-to-mouth contact along the corridors. The matriarch leading the way she has always led, with a little more information at her disposal. The elephants in the foreground. The technology nowhere to be seen.

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