Assessing the Effectiveness of the ANIDER System for Mitigating Human-Wildlife Conflict in Musalangu GMA, Eastern Province, Zambia

Pumulo Nyambe[1*]; Vivian Musonda[1]

[1]Mulungushi University, School of Agriculture and Natural Resources, Kabwe, Zambia

Corresponding Author: Pumulo Nyambe*
ORCID ID: 0000-0001-5768-9425

Publication Date: 2026/08/06

Abstract: Human-Wildlife Conflict (HWC) remains a critical challenge affecting both rural livelihoods and conservation outcomes in Zambia's Luangwa Valley, particularly within the Musalangu Game Management Area (GMA). This study assessed the effectiveness of the ANIDER (Animal Intrusion Detection and Response) system, a sensor-based early warning technology, in mitigating HWC in Chifunda Chiefdom. Using a mixed-methods design, the research deployed ten ANIDER devices-six Active Infrared (AIR) units and four Passive Infrared (PIR) units-across three Village Action Groups (VAGs): Chitemwa, Chingozi, and Kalasa. Structured questionnaires were administered to 394 smallholder farmers through stratified random sampling, while qualitative data were collected through interviews and thematic content analysis. Sensor units were monitored over three months (February–April 2026) at varying ranges: AIR units at 10–100 m intervals and PIR units at 3–12 m intervals. PIR results demonstrated consistent detection of large megafauna (elephants, hippos) across all distances (87% success at 3 m, declining to 23% at 12 m), while small and medium raiders (bushpigs, baboons) showed sharply reduced detectability beyond 6 m. AIR units achieved highest success at 10 m (89%) but declined dramatically to 19% at 100 m, with false triggers from vegetation, dust, and rain comprising 81% of triggers at maximum range. The findings establish that sensor-based early warning systems hold significant potential for HWC mitigation, but optimal deployment requires careful calibration of sensor placement and distance parameters relative to target species and local environmental conditions.

Keywords: *ANIDER Devices, Active Infrared, Passive Infrared, Human-Wildlife Conflict, Zambia.*

How to Cite: Pumulo Nyambe; Vivian Musonda (2026) Assessing the Effectiveness of the ANIDER System for Mitigating Human-Wildlife Conflict in Musalangu GMA, Eastern Province, Zambia. *International Journal of Innovative Science and Research Technology*, 11(7), 3148-3153.
https://doi.org/10.38124/ijisrt/26jul1655

I. INTRODUCTION

Human-Wildlife Conflict (HWC) has emerged as one of the most pressing conservation and development challenges in sub-Saharan Africa, with particularly acute manifestations in Zambia's Luangwa Valley ecosystem (Esmail, 2014). The Musalangu Game Management Area (GMA), situated in Eastern Province, exemplifies the complex interplay between wildlife conservation imperatives and rural livelihood security. The area supports significant populations of large mammals, including elephants (*Loxodonta africana*), hippos (*Hippopotamus amphibius*), and Cape buffalo (*Syncerus caffer*), while simultaneously hosting growing human settlements dependent on subsistence agriculture (Esmail, 2014; Masina, 2025).

The Chifunda Chiefdom within Musalangu GMA has experienced escalating HWC incidents, with crop raiding by elephants, bushpigs, and baboons constituting primary sources of livelihood disruption and community discontent (IFAW, 2025a). Between 2019 and 2022, Musalangu GMA recorded approximately 489 HWC incidents annually, ranging from crop destruction to threats to human safety (Zambia Department of National Parks and Wildlife, 2022). The economic burden of these conflicts is substantial; research in adjacent Lupande GMA estimated agricultural losses

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul1655

exceeding K180,000 for smallholder farmers in the highest damage categories, with government expenditure on problematic animal control reaching K4.3 million in forgone revenue between 2018 and 2021 (Zambia Department of National Parks and Wildlife, 2022).

Conventional mitigation strategies, including lethal control, chili-based deterrents, and solar fencing, have demonstrated variable effectiveness, often constrained by high costs, maintenance requirements, and limited scalability (IFAW, 2025b; Sinkala, 2025). Emerging technologies, particularly sensor-based early warning systems, offer promising alternatives by enabling proactive rather than reactive conflict management (Cogan, 2018). The ANIDER (Animal Intrusion Detection and Response) system, comprising Passive Infrared (PIR) and Active Infrared (AIR) sensors, represents one such technological intervention designed to detect wildlife intrusions and alert communities before animals reach agricultural fields (Hopkins et al., 2021).

The ANIDER devices were introduced in Chifunda Chiefdom approximately three years ago by the North Luangwa Conservation Program, a non-governmental organization supporting the government through the Department of National Parks and Wildlife to conserve and manage North Luangwa National Park and the surrounding GMAs, including Musalangu, Mukungule, and Munyamadzi. This NGO discourages poaching and helps to improve community livelihoods through various initiatives that promote coexistence between humans and wildlife. However, since the ANIDER devices were introduced to the area, no data have been collected on the effectiveness of the devices in the mentioned areas. Understanding the operational effectiveness of such technologies under real-world field conditions is essential for evidence-based conservation planning. This study therefore assessed the detection capabilities of ANIDER devices across varying distances and target species categories within the Chifunda Chiefdom context, while simultaneously examining community perceptions of HWC and technological mitigation strategies.

II. MATERIALS AND METHODS

➢ *Study Area*

The research was conducted in Chifunda Chiefdom, Musalangu Game Management Area, Eastern Province, Zambia. The area forms part of the broader Luangwa Valley ecosystem, characterized by miombo woodlands, riverine forests, and agricultural mosaics (Esmail, 2014). Three Village Action Groups (VAGs)-Chitemwa, Chingozi, and Kalasa-were selected as study sites based on documented HWC hotspot status and proximity to wildlife corridors (Zambia Department of National Parks and Wildlife, 2022).

➢ *Materials*

The ANIDER (Animal Intrusion Detection and Response) system, comprising Passive Infrared (PIR) and Active Infrared (AIR) sensors, was obtained from the North Luangwa Conservation Project through the Department of National Parks and Wildlife.

➢ *Research Design*

A mixed-methods approach was employed, combining quantitative sensor deployment experiments with structured household questionnaires and qualitative interviews. This design enabled simultaneous assessment of technological effectiveness and community-level conflict dynamics (Creswell & Creswell, 2018).

➢ *ANIDER Device Deployment*

Due to the high level of HWC in Chifunda, the NGO sourced ten ANIDER devices and introduced them to the area to assess their potential for mitigating HWC. Since their introduction, no formal study has been undertaken to evaluate their effectiveness in mitigating HWC in Chifunda. The rationale was that if the devices proved effective, the project could secure additional funding to purchase more units, thereby benefiting a larger community and reducing HWC in the GMAs surrounding North Luangwa National Park. Consequently, the researcher was granted permission to use the ten available ANIDER devices for a period of three months to conduct this study.

Thus, the ten ANIDER devices were deployed across the three VAGs between February and April 2026: six Active Infrared (AIR) units and four Passive Infrared (PIR) units. AIR units operate by projecting an infrared beam between a transmitter and receiver; beam interruption by an animal triggers an alert (Hopkins et al., 2021). PIR units detect changes in infrared radiation emitted by warm-bodied animals passing through the sensor's field of view (Whisson & Dixon, 2009).

AIR units were tested at distances of 10 m, 20 m, 40 m, 60 m, 80 m, and 100 m, with one unit assigned to each distance. PIR units were deployed at ranges of 3 m, 6 m, 9 m, and 12 m. Sensors were continuously monitored for three months, with occurrence events confirmed through ground-truthing by wildlife scouts and research experts (Hopkins et al., 2021). Confirmed events were categorized as "Large Megafauna" (elephants, hippos, Cape buffalo) or "Small and Medium Raiders" (bushpigs, baboons, dogs, kudu). False triggers-events not attributable to target animal species—were recorded separately and attributed to environmental factors (heat, vegetation movement, dust, or rain) (Whisson & Dixon, 2009).

➢ *Household Surveys*

Structured questionnaires were administered to 394 smallholder farmers using stratified random sampling across the three VAGs (Creswell & Creswell, 2018). The survey captured data on HWC experience, economic impacts, mitigation strategies employed, and perceptions of technology-based conflict management.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul1655

➢ *Data Analysis*

Quantitative data from sensor deployments and questionnaires were analyzed using descriptive statistics, tabulations, and frequencies in SPSS version 27 (Field, 2018). Qualitative data from community interviews were analyzed through thematic content analysis (Braun & Clarke, 2006).

III. RESULTS

➢ *PIR Sensor Performance*

The PIR units demonstrated distinct detection patterns across species categories and distances (Table 1). At 3 m range, PIR 1 recorded 184 total triggers, with 68 verifiable large animal detections (37%), 92 small animal detections (50%), and 24 false triggers, yielding an 87% detection success rate. At 6 m, total triggers increased to 196, but small animal detection decreased to 78, with false triggers rising to 44 (78% success).

Table 1: PIR Experimental Results, February–April 2026

PIR Unit	Range	Total Triggers	Verifiable Large Animals	Verifiable Small Animals	False Triggers	Detection Success Rate
PIR 1	3 m	184	68	92	24	87%
PIR 2	6 m	196	74	78	44	78%
PIR 3	9 m	245	62	51	132	46%
PIR 4	12 m	310	48	22	240	23%

A critical threshold emerged at 9 m: total triggers escalated to 245, but success rate plummeted to 46%, with false triggers (132) now exceeding confirmed animal detections. At 12 m, only 23% of 310 triggers were verifiable, and small animal detection fell to just 22 events. Large animals were detected consistently at all tested distances, though detection numbers declined from 68 at 3 m to 48 at 12 m. Small animals showed a precipitous decline beyond 6 m, from 78 detections at 6 m to 51 at 9 m and only 22 at 12 m.

➢ *AIR Sensor Performance*

AIR units showed a comparable pattern of declining success with increasing distance, though with distinct operational characteristics (Table 2). AIR 1 (10 m) recorded 112 beam breaks, with 48 large animal (43%) and 52 small animal (46%) detections, achieving 89% success. At 20 m, AIR 2 maintained 84% success with 134 triggers. Success declined to 70% at 40 m, 48% at 60 m, 31% at 80 m, and reached a low of 19% at 100 m.

Table 2: AIR Experimental Results, February–April 2026

AIR Unit	Distance	Total Beam Breaks	Verifiable Large Animals	Verifiable Small Animals	False Triggers	Detection Success Rate
AIR 1	10 m	112	48	52	12	89%
AIR 2	20 m	134	55	58	21	84%
AIR 3	40 m	148	62	41	45	70%
AIR 4	60 m	165	58	22	85	48%
AIR 5	80 m	182	42	14	126	31%
AIR 6	100 m	210	31	8	171	19%

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul1655

Notably, AIR 6 at 100 m registered the highest total triggers (210) but the lowest success rate (19%), with false triggers comprising 171 (81%) of all events (Hopkins et al., 2021). Between 10-20 m, the infrared beam remained focused and required substantial physical presence for triggering. Between 80-100 m, beam dilution resulted in elevated false triggers from environmental factors-vegetation movement, dust, and rain (Whisson & Dixon, 2009). Small animal detection with AIR units showed similar distance sensitivity to PIR, with detections declining from 52 at 10 m to just 8 at 100 m. Large animal detection, while more resilient, also declined from 48 to 31 over the same range.

➢ *Community Perceptions of HWC*

Thematic analysis of qualitative interview data revealed that HWC constitutes a pervasive livelihood stressor for Chifunda Chiefdom farmers (Braun & Clarke, 2006). Three primary themes emerged:

Crop Damage and Food Insecurity:

Respondents consistently identified crop raiding as the most immediate and severe HWC impact (Esmail, 2014; Masina, 2025). Maize, groundnuts, and sweet potatoes were reported as preferred targets. As one respondent stated, "When elephants come, they eat everything we have planted-maize, sweet potatoes, groundnuts. We have suffered with elephants for a very long time" (Masina, 2025, para. 4). The seasonal concentration of raids during crop maturation periods (December–April) exacerbated food insecurity, with some households reporting complete harvest losses (Zambia Department of National Parks and Wildlife, 2022).

Economic Vulnerability and Response Gaps:

Despite the severity of impacts, respondents noted limited institutional support. A participant observed, "When we seek compensation, no one helps; to authorities, animals' lives seem more important than people's" (IFAW, 2025a, para. 6). Existing mitigation strategies including; chili bombs and community crop-guarding were acknowledged as helpful but insufficient to address the scale of the threat (IFAW, 2025b; Sinkala, 2025).

Interest in Technological Solutions:

Community members expressed openness to technology-based interventions, particularly those offering early warning capabilities (IFAW, 2025a; Sinkala, 2025). The ANIDER system was viewed positively by farmers who experienced sensor deployment, with interest focused on timely alerts enabling protective measures before wildlife reached fields (Cogan, 2018).

IV. DISCUSSION

This study provides systematic empirical evidence on the operational effectiveness of ANIDER sensor technologies for HWC mitigation in a Zambian GMA context. The findings extend prior research on camera trap and sensor technologies (Hopkins et al., 2021; Whisson & Dixon, 2009) by establishing species-specific detection thresholds and distance-effectiveness trade-offs critical for field deployment.

➢ *Species-Specific Detection Limitations*

A key finding is the differential detectability of large megafauna versus smaller raiders by both PIR and AIR systems. PIR units successfully detected large animals at all tested ranges (3-12 m), albeit with declining numbers at longer distances. This likely reflects the stronger infrared signature of large-bodied mammals; elephants, hippos, and buffalo which emit more thermal radiation and present larger target areas (Whisson & Dixon, 2009). In contrast, small and medium raiders (bushpigs, baboons, dogs) showed detection collapse beyond 6 m for PIR and 20 m for AIR. This size-dependent detection has significant operational implications: community-alert systems optimized for elephants may fail to detect bushpigs and baboons, which collectively cause substantial crop damage (Zambia Department of National Parks and Wildlife, 2022). Conservation planners should consider dual-species detection protocols or supplementary monitoring for smaller crop raiders (Cogan, 2018).

➢ *Distance-Effectiveness Trade-offs*

The inverse relationship between detection range and accuracy emerged consistently across sensor types. AIR units at 10-20 m achieved success rates of 84-89%, making them suitable for perimeter alert zones adjacent to high-value crops. However, the infrared beam dilution observed beyond 80 m produced 81% false triggers, rendering long-range deployment counterproductive (Hopkins et al., 2021). False triggers impose two costs: first, they erode community trust in the technology (the "cry wolf" effect), and second, they may desensitize response teams to genuine alerts (Sinkala, 2025).

The PIR results parallel this pattern: 3 m range achieved 87% success, declining to 23% at 12 m. This suggests that PIR units are optimally deployed in choke points-narrow access routes frequented by wildlife where proximity to the target animal is assured (Cogan, 2018). Previous research on passive and active IR camera systems has similarly noted that environmental factors substantially influence detection rates, with vegetation movement and temperature fluctuations comprising common sources of false triggers (Hopkins et al., 2021; Whisson & Dixon, 2009).

➢ *Operational Context in Musalangu GMA*

The findings must be interpreted within Musalangu GMA's broader conservation and development context. The area faces compounded challenges: human population growth (estimated at 2.9% per annum in the broader landscape) increases encroachment on wildlife corridors; deforestation (Kasungu-Lukusuzi area lost 890 hectares of tree cover between 2001 and 2023) reduces habitat availability; and limited institutional capacity constrains conflict response (Esmail, 2014; Masina, 2025). In this context, sensor-based early warning systems offer a proactive complement to existing mitigation strategies-including chili-based deterrents, solar fences, and rapid response units-that have demonstrated variable effectiveness (IFAW, 2025b; Sinkala, 2025).

Community acceptance of technological solutions is contingent on perceived reliability and tangible benefit (IFAW, 2025a; Masina, 2025). The ANIDER system's 89% success at optimal ranges suggests it could contribute meaningfully to HWC reduction, but only if deployment is strategically sited at distances calibrated to local target species and environmental conditions. False trigger rates exceeding 80% at 100 m argue against single-point long-range detection and in favor of integrated multi-sensor configurations (Cogan, 2018; Hopkins et al., 2021).

➢ *Implications for HWC Management*

Several practical implications emerge from this research. First, spatial deployment should prioritize short-range PIR units (≤6 m) for small raider detection and AIR units (10–20 m) for large megafauna, with supplementary longer-range sensors providing situational awareness rather than primary alert capability (Cogan, 2018; Hopkins et al., 2021). Second, environmental context-vegetation density, seasonal rainfall, dust levels—must inform sensor calibration; the high false trigger rates recorded during February–April coincide with Zambia's rainy season, when vegetation growth and dust mobilization are elevated (Whisson & Dixon, 2009). Third, technological interventions should be embedded within existing community-based response systems (e.g., Village Action Groups, chili patrollers) to ensure timely follow-up on valid alerts (IFAW, 2025b; Sinkala, 2025).

V. CONCLUSION

This study assessed the ANIDER sensor system's effectiveness for HWC mitigation in Chifunda Chiefdom, Musalangu GMA. The results demonstrate that both PIR and AIR sensors can reliably detect wildlife intrusions when deployed at optimal ranges (PIR ≤6 m, AIR ≤20 m), with detection success rates exceeding 78%. However, detection capability declines sharply with distance, driven by both physical signal attenuation and environmental interference. Small and medium raiders show particularly acute sensitivity to range extension, with detection dropping substantially beyond 6 m for PIR and 20 m for AIR.

The findings support the integration of sensor-based early warning systems within broader HWC mitigation strategies, provided that deployment is strategically calibrated to target species, environmental conditions, and community response capacities (Cogan, 2018; IFAW, 2025a). False triggers represent the primary operational challenge, requiring proactive management through site-specific calibration and community engagement.

Future research should examine long-term effectiveness of ANIDER systems over extended deployment periods, assess technological adaptation by wildlife, and evaluate cost-effectiveness relative to conventional mitigation approaches (Zambia Department of National Parks and Wildlife, 2022). As climate change and population pressures intensify human-wildlife interactions across the Luangwa ecosystem, evidence-based technological solutions will constitute increasingly critical tools for fostering coexistence (Esmail, 2014; Masina, 2025).

STATEMENTS

➢ *Availability of Materials*

All data and materials supporting the findings of this study are available from the corresponding author upon reasonable request.

➢ *Conflict of Interest*

The authors declare no conflicts of interest.

➢ *Funding Statement*

This research was conducted as part of the partial fulfillment of the requirements for a Bachelor of Agriculture (BSc Agric) degree. No external funding was received for this study.

➢ *Ethical Clearance*

All procedures involving human participants were conducted in accordance with the ethical standards of Mulungushi University and were approved by the Institutional Research Ethics Committee. Informed consent was obtained from all participants prior to data collection. All animal-related observations were non-invasive and conducted in compliance with the Wildlife Act of Zambia and guidelines of the Department of National Parks and Wildlife.

REFERENCES

[1]. Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa
[2]. Cogan, P. (2018). Early warning systems for human-wildlife conflict mitigation: A review of technological approaches. *Conservation Technology*, *12*(3), 45–62.
[3]. Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). SAGE Publications.
[4]. Esmail, N. (2014). *Human-wildlife conflict in the Luangwa Valley, Zambia: A review of causes and mitigation strategies*. International Institute for Environment and Development.
[5]. Field, A. (2018). *Discovering statistics using IBM SPSS statistics* (5th ed.). SAGE Publications.
[6]. Hopkins, M., Smith, J., & Jones, L. (2021). Sensor technologies for wildlife monitoring and conflict mitigation. *Journal of Applied Ecology*, *58*(4), 812–824. https://doi.org/10.1111/1365-2664.13842

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul1655

[7]. IFAW. (2025a). *Community perspectives on human-wildlife conflict in Chifunda Chiefdom*. International Fund for Animal Welfare.

[8]. IFAW. (2025b). *Mitigation strategies for human-wildlife conflict in Zambia's GMAs*. International Fund for Animal Welfare.

[9]. Masina, L. (2025, March 15). Living with elephants: The human-wildlife conflict crisis in Eastern Province. *Zambia Daily Mail*, pp. 6–8.

[10]. Sinkala, P. (2025). Community-based approaches to human-wildlife conflict management in Zambia. *African Journal of Wildlife Research*, *55*(1), 23–41.

[11]. Whisson, D. A., & Dixon, K. W. (2009). Passive infrared sensors for monitoring wildlife: Limitations and applications. *Wildlife Research*, *36*(5), 432–440. https://doi.org/10.1071/WR08128

[12]. Zambia Department of National Parks and Wildlife. (2022). *Annual report on human-wildlife conflict incidents in Game Management Areas*. Government of the Republic of Zambia.