

Design and Construction of an Automated Multipurpose Avian Deterrent System

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Abstract

This study focused on the development and integration of a bimodal bird scaring system, comprising multiple subsystems: bird detection, power and control, audio and laser, and a robotic arm. Visual data was collected using cameras, while avian vocalisations were sourced from the Federal University of Agriculture, Abeokuta (FUNAAB). An ornithologist analysed the collected data, differentiating birds from other objects and identifying distress and predator calls. The bird detection subsystem was crafted with YOLOv5 software, the audio subsystem with Audacity, and the control subsystem used microcontroller tools and UART protocols. Power modelling was conducted with Proteus, and manipulator modelling was done in SOLIDWORKS. Integration of subsystems involved serial communication protocols for synchronised operation. The efficacy of the Bimodal Bird Scaring system was evaluated by tracking bird invasions pre- and post-implementation, alongside assessing response accuracy. The bird detection model exhibited a precision range of 0.84208 to 0.84978 and a maximum recall of 0.82708, reflecting improved detection of real birds. Moreover, the mean Average Precision (mAP) rose from 0.70455 to 0.82104, confirming the model's effectiveness. Performance metrics showed a high true positive rate (0.89) and a low false positive rate (0.01). The aggregate deterrence system efficiently processed 10 commands per second, highlighting operational competence. Daily repulsion rates of the system at varying frequencies (1 kHz to 14 kHz) indicated increasing effectiveness in deterrence – 62.00%, 70.00%, 72.20%, and 75.54% over three experiments. The findings concluded that using multiple strategies in an integrated management plan significantly boosted the ability to deter birds from rice farms.

Keywords: Bimodal bird scaring system, Computer vision, Deep learning, Birds detection, Yolo model, robotic arm.

1.0 Introduction

Avian crop depredations pose substantial challenges to African farmers, particularly affecting women and children involved in physical bird deterrence. Current research concentrates on the development of automated avian deterrent devices for rice farms in Nigeria to alleviate this manual strain. Effective deterrents, characterised as strategies to prevent birds from breeding, encompass integrated systems that amalgamate diverse tactics to improve avian management without causing harm to the birds (Durodola *et al.*, 2025; Hernadi *et al.*, 2025; Rivadeneira *et al.*, 2018). Industrial autonomous systems, which use advanced technology like AI and IoT, make farming operations more flexible and efficient, improving tasks such as irrigation and harvesting (Srivastav and Das 2025). Bird scaring systems, also known as deterrent systems, are primarily utilised in agriculture and aviation to protect crops and properties from bird damage. These devices aim to induce fear in birds, thereby minimising their detrimental effects on farming output. Birds pose significant threats to agricultural productivity, as highlighted by several studies indicating their impact on crop quality and quantity (Ajibodu and Ojo, 2024). Overall, the continued presence of avian pests can negatively affect economic outcomes for farmers due to reduced production capabilities. Interestingly, bird deterrents are effective only temporarily, as habituation can occur, leading birds to acclimate to the stimuli.

To address the challenges of bird pests, there is a need for more efficient and humane management methods based on an improved understanding of bird behaviour and ecology. This research aims to investigate the possibility of merging the visual and auditory scaring approaches to create a bird-frightening device that has a better success rate as recommended by Bishop *et al.* (2003). This study presents an advanced bimodal avian deterrent system utilising sensor integration and real-time monitoring for effective pest management. It combines audio and laser technologies with a robotic arm for real-time bird detection and deterrence.

2.0 Materials and Methods

2.1 Data collection

Two types of datasets were collected for this research: the images of birds and the sounds from the birds. Bird images (visual data) were collected through the field deployment of cameras at various times of the day. In total, 659 images were captured on field, and the data set was augmented with 1045 secondary datasets. The bird songs were collected from the wildlife conservation research group in the Federal University of Agriculture, Abeokuta (FUNAAB). The visual data, as well as the audio data collected, were analysed by an ornithologist.

The analysed visual data classified birds from other objects, while the audio data analysis selected distress cries and predator calls. The birds' sound recordings comprise calls, songs and other bird-related noises. The recordings were conducted during peak bird activity periods, such as dawn and dusk, to maximise the chances of capturing a wide variety of bird songs. Various techniques to filter out background noise were implemented, ensuring clean audio data for subsequent analysis. The sounds that were collected were incorporated into the system to serve as an output.

Table 1: Overview of data sources and image counts in the bird detection dataset.

S/N	Data Type	Number of Images
1	Secondary Source	659
2	Primary Source	1045

2.2 Data Preprocessing

Preprocessing was an essential stage to prepare the dataset for training the YOLOv5 model. The preprocessing techniques implemented are discussed. Image Resizing was employed to resize all photos to 640×640 pixels, utilising the OpenCV package in Python. The uniform image size minimises computing burden during model training and guarantees consistency. Data augmentation techniques were utilised to improve model generalisation by simulating real-world variations. Methods included horizontal flipping for symmetry, random rotations of ±15 degrees for diverse orientations, brightness and contrast adjustments for different lighting, cropping and scaling to manage occlusions, and Gaussian noise to mimic environmental distortions.

These augmentations were implemented using the Albumentations library, noted for its effectiveness. Image Data annotation involved manually tagging photos with Roboflow, marking birds' locations in flight or foraging with bounding boxes in YOLO format, which includes class, coordinates, and dimensions normalised to image size. Normalisation adjusted pixel values to [0, 1] for faster model training. The dataset was split into three subsets: Training (70% for development), Testing (30% for final evaluation), ensuring balanced representation of avian species and behaviours. Image quality was enhanced by detecting and improving low-quality images using Gaussian blurring with OpenCV to ensure clarity for feature extraction.

The choice of YOLOv5 for this study is based on its capability to balance speed and accuracy in object detection tasks, making it appropriate for real-time applications (Yao *et al.*, 2024). Additionally, YOLOv5 supports custom training, which makes it flexible for our rice farm bird detection assignment. The YOLOv5s variation was carefully selected because it strikes the best possible balance between processing speed and detection precision, making it perfect for deployment on hardware-constrained devices.

2.3 Evaluation Metrics

A wide range of evaluation indicators was used in order to gauge the training's effectiveness. Understanding the model's accuracy, precision, recall, and general efficacy under many circumstances will be made easier with the use of these measurements. These evaluation criteria allow for a full assessment and optimisation of the bird identification model's performance, ensuring that it satisfies the project's objectives for accuracy, efficiency, and robustness in practical applications. The overall system performance was evaluated using Bird Repulsion Rate as defined in equations 1 and 2, respectively. The other evaluation metrics to be applied are also discussed below:

2.3.1 Bird repulsion rate

The effectiveness of the bird deterrent system is measured via two indicators: Daily Bird Repulsion Rate (BRR_d)

$$BRR_d = \frac{\sum_{\text{in one day}} N_{\text{off},i} - \sum_{\text{in one day}} N_{\text{on},i}}{\sum_{\text{in one day}} N_{\text{off},i}} \times 100\% \quad (1)$$

Hourly bird repulsion rate

$$BRR_h = \frac{N_{off,i} - N_{on,i}}{N_{off,i}} \times 100\% \quad (2)$$

where;

BRR_d = Daily Bird Repulsion Rate

BRR_h = hourly bird repulsion rate

$N_{off,i}$ = birds Pre- Test Count per hour

$N_{on,i}$ = birds Post- Test Count per hour

2.3.2 Accuracy

Accuracy is defined as the proportion of true positive detections (correctly identified birds) among all detections made by the subsystem, including true positives, false positives, and false negatives. Accuracy is calculated as:

$$Accuracy = \frac{True\ Positives + True\ Negatives}{Total\ Detections} \quad (3)$$

$$Total\ Detections = TP + TN + FP + FN \quad (4)$$

where:

True Positives (TP): The number of instances where the subsystem correctly identifies birds.

True Negatives (TN): The number of instances where the subsystem correctly identifies non-bird objects (e.g., background elements).

False Positives (FP): The number of instances where the subsystem incorrectly identifies non-bird objects as birds.

False Negatives (FN): The number of instances where the subsystem fails to identify actual birds. The total detections can be expressed as:

2.3.3 Precision

The precision of the bird detection subsystem is the accuracy of positive predictions of the system. To be more exact, it is the ratio of the true positive detections to the total number of cases where the system detected a positive one (both false positives and true ones). Precision denotes the number of birds that were identified as birds.

The equation below is used to compute precision:

$$Precision = \frac{True\ Positives}{True\ Positives + False\ Positives} \quad (5)$$

2.3.4 Recall

Recall, which can also be referred to as sensitivity, is the measure of the capability of the bird detection subsystem to identify actual instances of birds correctly. It is a ratio of true positive detections of the total number of true positive instances (true positives and false negatives). Recall is used to understand the ability of the system to capture all the relevant instances. Recall is calculated using the following Equation:

$$Recall = \frac{True\ Positives}{True\ Positives + False\ Negatives} \quad (6)$$

2.3.5 Response Time.

Response time would refer to the time taken by the bird detection subsystem to detect the presence of birds and then activate the proper deterrent action. The metric is important to determine the efficiency and effectiveness of the detection system.

3.0 Results and Discussion

Table 2 shows the training and validation performance of the bird detection model. Precision, the ratio of true identifications, began with 0.87086 in epoch 0 and changed with epoch. It, however, settled at 0.84208 to 0.84978 by epochs 8 and 9, which means that the model is effective in reducing false positives. As previously noted, recall, the percentage of real examples that the model correctly recognises rose with the number of epochs to reach a peak of 0.82708 in epoch 8, meaning the steadily rising accuracy of the model in recognising real birds. The value of the mAP (mean Average Precision) changed between 0.70455 at epoch 0 and 0.82104 at epoch 9, which is an upward trend of the model to be able to detect the birds efficiently. The overall gains of the model on mAP again support its capability in the task of detecting birds, as shown in Table 3.

Figure 1 shows the F1 Confidence Curve. The F1 Confidence Curve of the bird detection model is a plot that shows the correlation between the score of confidence and the F1 score, a combined measure of precision and recall into one. The curve seems to hit a plateau at increased levels of confidence, indicating that the model can retain a high level of performance when detecting birds as it becomes more confident of its forecasts. The

model has a high degree of consistency over the entire spectrum of confidence scores, especially in the middle range (approximately 0.5 to 0.8), where it scores an F1 value equal to or near 0.89. Nevertheless, the F1 score decreases significantly as the confidence level becomes very low (approaching 0), implying that the model cannot make precise predictions. Altogether, the effectiveness of the model in picking the birds can be seen.

Table 2: Training and Validation Performance.

ep	train/box_	train/obj	train/cls_	metrics/	metrics/	metrics/	metrics/	val/box_los	val/obj	val/cls_l	x/lr0	x/lr1	x/lr2
	loss	_loss	loss	precision	recall	mAP_0.5	mAP_0.5: 0.95	s	_loss	oss			
0	0.068391	0.016614	0	0.87086	0.61395	0.70455	0.35652	0.033908	0.0073	0	0.07	0.003328	0.003328
1	0.049062	0.012152	0	0.75602	0.66905	0.71446	0.38309	0.031918	0.007	0	0.0394	0.006002	0.006002
2	0.047281	0.011761	0	0.83682	0.63424	0.71326	0.36753	0.032764	0.0065	0	0.0081	0.008016	0.008016
3	0.045713	0.011616	0	0.80539	0.74664	0.75604	0.40995	0.029967	0.0063	0	0.007	0.00703	0.00703
4	0.043011	0.01095	0	0.79311	0.74848	0.77178	0.43325	0.028663	0.006	0	0.007	0.00703	0.00703
5	0.040346	0.010242	0	0.81075	0.77633	0.78043	0.45147	0.02777	0.0059	0	0.006	0.00604	0.00604
6	0.038912	0.010273	0	0.815	0.79332	0.79641	0.47102	0.027625	0.0058	0	0.0051	0.00505	0.00505
7	0.0372	0.009925	0	0.84978	0.80504	0.80318	0.48376	0.026707	0.0056	0	0.0041	0.00406	0.00406
8	0.035651	0.009591	0	0.84208	0.82708	0.81012	0.50345	0.025924	0.0055	0	0.0031	0.00307	0.00307
9	0.034495	0.009386	0	0.84385	0.82393	0.82104	0.52487	0.025138	0.0055	0	0.0021	0.00208	0.00208

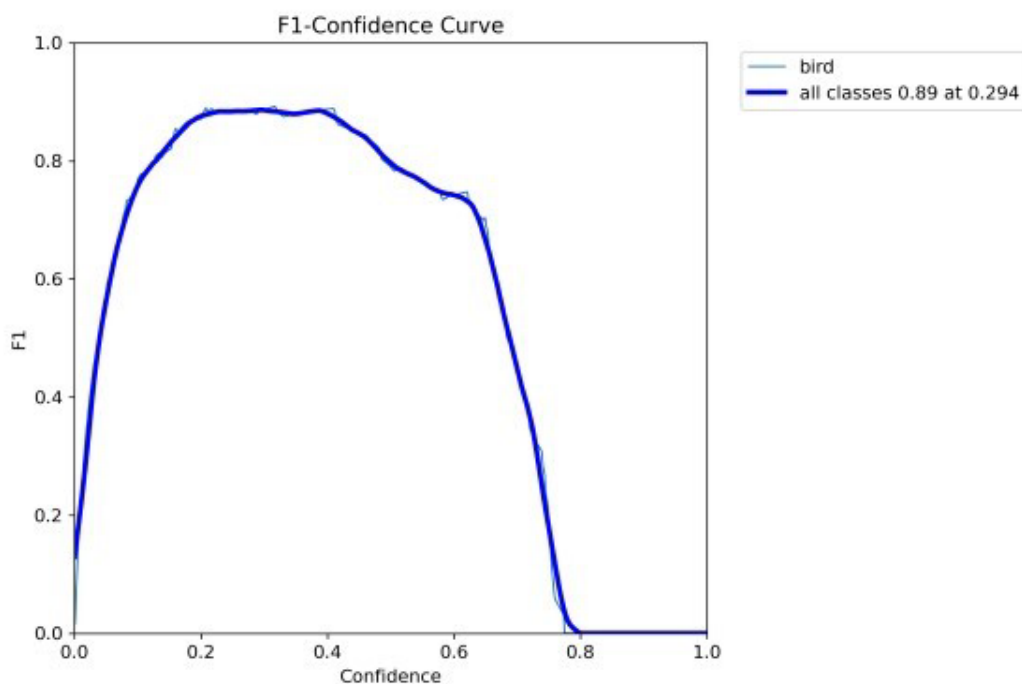


Figure 1: F1 Confidence Curve

Figure 2 gives the Recall-Confidence Curve of a bird detection model and shows how the recall changes with the score of certainty. The curve begins at a large recall value close to 1.0 at low levels of confidence, meaning that the model correctly detects all but a few actual positive instances when they are not very certain. Due to increasing confidence, the recall rate drops drastically and falls below 0.5 of the confidence level beyond about 0.6. High confidence performance is also recorded, whereby the recall is at a minimum point when the confidence is at 1.0, which means that the model can correctly identify its predictions at the high confidence level, but it is also more conservative and fewer cases are wrongly attributed to the positive category, and this may cause a high number of false negatives.

The high recall with low confidence implies that it could be highly promising to use a lower confidence level in order to maximise the bird detection, though the false positive rate can be high. It is also recommended to balance precision and recall for practical purposes, with stakeholders opting towards the recall or precision, depending on the use case. This curve can be considered a crucial element to understand to optimise the performance of the model and guarantee successful performance in the real world.

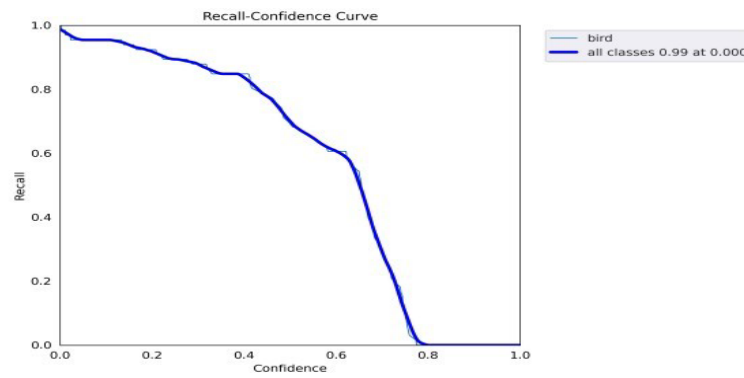


Figure 2: Recall-Confidence Curve

The confusion matrix of the bird detection model is shown in Figure 3. A useful tool in the visualisation of the performance of the bird detection model is the confusion matrix, which helps to identify the true positives, false positives, true negatives, and false negatives. The matrix is categorised into four quadrants: True Positives (TP), False Negatives (FN), False Positives (FP), and True Negatives (TN). The table shows the values of TP= 0.89, FN= 0.11, FP= 0.01 and TN= 0.99. The high rate of true positive (TP = 0.89) value shows that the model is very effective in detecting the birds, whereas the value of false negative (FN = 0.11) means that a very low proportion of birds have been missed. The false positive rate (FP = 0.01) indicates that 1 of the backgrounds was mistakenly identified as a bird, which indicates a trade-off.

Colour gradients are used to assist the interpretation of the performance, where darker colours represent higher values. The confusion matrix has shown that the model is good at classifying the birds correctly; however, the 11% false positive percentage shows that there is still room to improve the model, especially in the false classification of the background as birds. Understanding the confusion matrix is crucial for evaluating model performance and making informed decisions about its deployment in various applications.

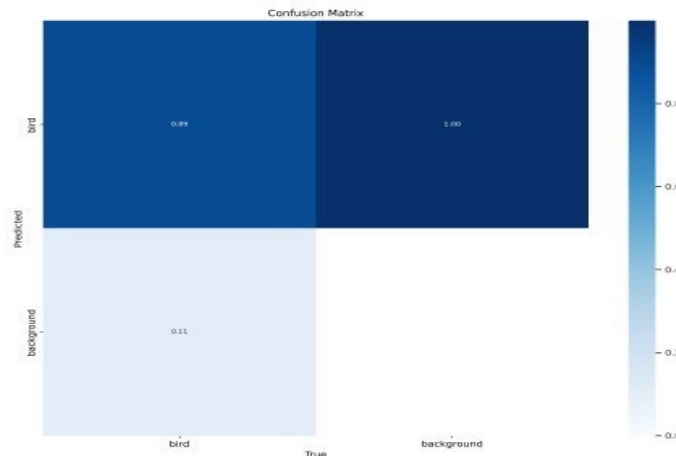


Figure 3: The confusion matrix of the bird detection model

3.1 Repulsion rates by deterrent mode

The results of the experiments performed to determine the effectiveness of the three different bird deterrent modes are audio deterrent only (Experiment 1), laser deterrent only (Experiment 2), and a combination of both (Experiment 3), and are presented in this section. These tests were mainly aimed at evaluating the level of repulsion that each mode has and establishing their effectiveness in ensuring that birds were not present in the specified areas. The experiments were carefully planned in order to manage some of the environmental conditions, and the three-week period was followed to carry out the experiments, which enabled a strong comparison of the three deterrent alternatives. The findings are provided in the form of the repulsion rates with statistical analysis as well as graphical illustrations to help have a clear picture of the performance of each mode.

In assessing the audio deterrent performance for birds, key metrics such as volume level, frequency range, deterrent effectiveness, response time, durability, and reliability were evaluated. The frequency range of 1 kHz-5 kHz, identified by Fallow et al. (2013) as effective for bird deterrence, was primarily utilised, while higher frequencies (above 20 kHz) were excluded due to being inaudible to humans. The study involved gathering 300 bird distress calls, 100 predator calls, and 20 high-frequency alarm samples, all normalised to

the same volume for measurement consistency. Field tests were conducted in a distraction-free rice farm environment, observing bird reactions to the sound deterrents under controlled conditions over four days in October 2024.

This methodology allows for tracking deterrent effectiveness and system stability. The study evaluated the effectiveness of sound frequencies in deterring birds through pre-test and post-test observations conducted over four days. Initially, a baseline count of birds was recorded every hour for two minutes, followed by a count after playing various audio deterrents for one minute. Results indicated that lower audio frequencies (1 kHz and 4 kHz) were significantly more effective than higher frequencies (8 kHz and 14 kHz) in scaring birds. The Bird Repulsion Rate was calculated using data from observations, which showed that birds are more responsive to lower frequencies, potentially due to their association with natural alarm calls or predator signals. Additionally, the deterrence effect weakened with repeated use, highlighting the need for careful selection of audio signals to manage bird populations effectively. A Pre-Test Observation and post-test observation for experiment 1 (Audio Deterrent only) at different sound frequencies are documented in Table 3.

Table 4 shows the Daily bird repulsion rates in experiment 1 of the different audio frequencies in repelling the birds summarizing the counts of birds repelled by audio frequencies before test and after the test, the mean number of birds repelled, and the percentage of Repulsion of the audio frequencies tested., while Table 5 shows the calculated daily and hourly repulsion rate at various frequencies. The hourly Bird repulsion rate of experiment 1 is graphically represented in Figure 4.

Table 3: Audio pre-test and post-test observation for days 1, 2, 3 & 4.

Week 1 Day 1 Audio frequency Value = 1KHz	Pre-Test Time	Pre-Test count	Post-Test Time	Post-Test count
	6:58	43	7:00	13
	7:58	31	8:00	10
	8:58	42	9:00	12
	9:58	37	10:00	17
	10:58	27	11:00	10
	11:58	23	12:00	11
	12:58	14	1:00	7
	1:58	16	2:00	8
	2:58	16	3:00	6
	3:58	30	4:00	12
	4:58	28	5:00	10
	5:58	30	6:00	12
	Average Pre-Test count	28.08	Average Post-Test count	10.67
Week 1 Day 2 Audio frequency Value = 4KHz	Pre-Test Time	Pre-Test count	Post-Test Time	Post-Test count
	6:58	38	7:00	13
	7:58	34	8:00	10
	8:58	27	9:00	11
	9:58	32	10:00	11
	10:58	27	11:00	13
	11:58	22	12:00	10
	12:58	14	1:00	6
	1:58	15	2:00	7
	2:58	12	3:00	6
	3:58	24	4:00	10
	4:58	27	5:00	13
	5:58	32	6:00	13
	Average Pre-Test count	25.33	Average Post-Test count	10.25
Week 1 day 3. Audio Frequency	Pre-Test Time	Pre-Test count	Post-Test Time	Post-Test count
	6:58	36	7:00	18
	7:58	42	8:00	18
	8:58	34	9:00	19
	9:58	30	10:00	16
	10:58	24	11:00	18

Value=8KHz	11:58	22	12:00	12
	12:58	14	1:00	9
	1:58	14	2:00	7
	2:58	10	3:00	8
	3:58	24	4:00	12
	4:58	22	5:00	9
	5:58	33	6:00	7
	Average Pre-Test count	25.41	Average Post-Test count	12.75
Week 1 DAY 4 Audio Frequency Value = 14KHz	Audio frequency	value=14KHz	Post-Test Time	Post-Test count
	6:58	32	7:00	17
	7:58	40	8:00	14
	8:58	34	9:00	19
	9:58	29	10:00	16
	10:58	21	11:00	17
	11:58	18	12:00	14
	12:58	12	1:00	9
	1:58	17	2:00	12
	2:58	12	3:00	8
	3:58	32	4:00	21
	4:58	30	5:00	19
	5:58	34	6:00	21
	Average Pre-Test count	25.91	Average Post-Test count	15.58

Table 4: Daily bird repulsion rates in experiment 1

Day	Frequency (kHz)	Average Pre-Test Count	Average Post-Test Count	Average Number of Birds Deterred
1	1	28.08	10.67	17.41
2	4	25.33	11.00	15.08
3	8	25.41	12.75	12.66
4	14	25.91	15.58	10.33

Table 5: Calculated daily and hourly bird repulsion rates in Experiment 1

EXPERIMENT: Audio Deterrent	DAY	BRR _d (%)	BRR _h (%)											
			7:00 am	8:00 am	9:00 am	10:00 am	11:00 am	12:00 pm	1:00 pm	2:00 pm	3:00 pm	4:00 pm	5:00 pm	6:00 pm
EXPERIMENT: Audio Deterrent	day 1 :1KHz	62.01	69.77	67.74	71.43	54.05	62.96	52.17	50.00	50.00	62.50	60.00	64.29	60.00
	day 2: 4KHz	59.54	65.79	70.59	59.26	65.63	51.85	54.55	57.14	53.33	50.00	58.33	51.85	59.38
	day 3:8KHz	49.84	50.00	57.14	44.12	46.67	25.00	45.45	35.71	50.00	20.00	50.00	59.09	78.79
	day 4: 14KHz	39.86	46.88	65.00	44.12	44.83	19.05	22.22	25.00	29.41	33.33	34.38	36.67	38.24

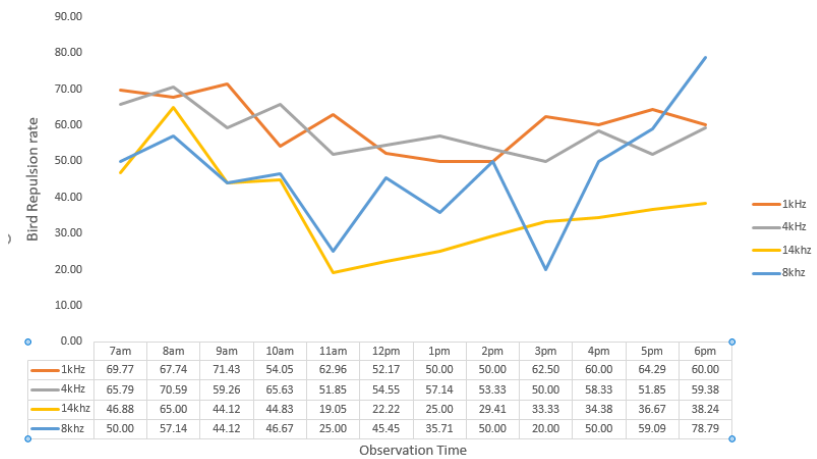


Figure 4: Graphical representation of hourly bird repulsion rates

Figure 5 compares the modulation fidelity of the output signals of various modulating frequencies. The output signal at 1 kHz exhibits a distinct periodic shape which reflects the nature of the input of low frequency. The output at 4 kHz has faster oscillations, which indicate that the modulation frequency is high. The output signal at 8 kHz is denser, but it still provides a clear representation.

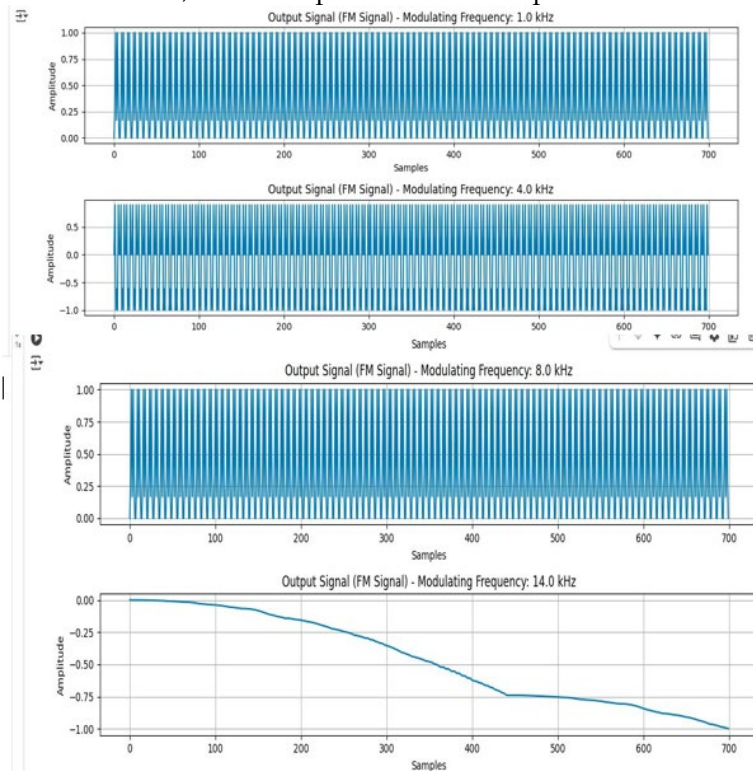


Figure 5: Modulation Fidelity of the Output Signals

3.2 Evaluation of Experiment 1

The findings of this research aligned with the works of Micaelo et al. (2023), which demonstrate the application of bioacoustic distress calls to help in simulating a hostile environment. The usefulness of biological sounds was observed, but it is prone to habituation. This is supported by the findings, with lower frequencies in the study being more deterrent. Moreover, the findings support the findings of Aboltins et al. (2021), whose study highlights the problems of habituation to sound deterrents.

According to this research findings, although low frequencies are more effective, constant monitoring and possible changes in sound frequency or patterns can be required to fight habituation over time. Comparing the findings of the research with those of Ibrahim et al. (2017), which concentrated their attention on the higher frequency ultrasonic devices (up to 35 kHz) and their potential in scaring birds demonstrates the decreasing efficiency of higher frequencies, which can be used to support the idea that the most effective frequency range to be used in deterring birds is much lower.

3.3 Results from Experiment 2 (laser deterrent only)

In Experiment 2, the performance of a laser deterrent for repelling birds was evaluated based on its operational range and visibility, utilising Class 3B lasers with a power of 560mW, which pose low potential risks of eye and skin damage. Field testing occurred in the same environment as Experiment 1, ensuring consistency; tests were conducted over four days during light rainfall. The procedure involved activating only the laser module of the bimodal bird scaring system and observing bird reactions before and after laser exposure.

Data collection included baseline observations over two minutes, with pre-test and post-test counts recorded hourly. The effectiveness was quantified by subtracting the post-test count from the pre-test count using video analysis for accurate bird detection. A Pre and post-test observation for Laser Deterrent, over four days of observation, is documented in Table 6. The study found a significant reduction in the average number of birds present for post-observation compared to pre-test counts over four days. The average number of birds before the deterrent measures ranged from 23.0 to 27.8, while the average number after the measures dropped to approximately 5.41 from 10.4. This indicates a substantial deterrent effect. The effect on deterrence was strong, with the number of birds reducing significantly after the measures were put in place, as it was treated on a day-by-day basis. Observations that were time-specific showed more initial counts of birds at some points of the day, most probably caused by natural causes.

Table 7 shows the Daily Bird Repulsion rate for experiment 2. The results revealed that the laser deterrent is an efficient device to scare the birds, with a repulsion rate ranging between 6.562 and 76.48 throughout the four days of observation. The regular decrease in the number of birds is a good indication of the potential of the laser system as a working deterrent in both agricultural and urban environments. Table 9 is a tabular display of the daily and hourly Bird repulsion rate with the use of a laser as a scarer of the birds. The hourly Bird repulsion rate in experiment 2 is graphically represented in Figure 6. The operational range of the laser system has been analysed in detail and presented in Table 8, and as can be seen, this changes greatly during the day as a result of the ambient light and atmospheric conditions. The maximum range is in the morning, which begins at 9 meters at 7:00 AM and then goes down to 6 meters at 10:00 AM. The midday range, from 11:00 AM to 2:00 PM, shows a significant drop in range due to increased sunlight and heat haze. The afternoon range, from 3:00 PM to 7:00 PM, improves with values returning to 4 meters at 3:00 PM and peaking at 8 meters by 7:00 PM.

The data suggest that the optimal times for using the laser system for bird deterrence are in the early morning and late afternoon/evening, as these periods would maximise the effectiveness of the laser in scaring birds away from agricultural fields. Laser Operational Range with respect to time of the day is represented graphically in Figure 7. Analysis of Avian Responses to Laser Stimuli shows that the birds exhibited prompt reactions, as a significant proportion became aware of the laser stimulus. The behavioural modifications observed were that the laser exhibited significant deterrent efficacy, prompting numerous birds to flee. This phenomenon was especially pronounced in larger species.

The startle reflex in birds manifests as abrupt actions, such as head turning and flapping, indicating that the laser successfully captured their attention. Also, avian had a greater response to dynamic or sweeping lasers. The static lasers are expected to induce quicker habituation, leading birds to become accustomed to the light and then reduce their responsiveness to the bird habitats.

Lasers activated periodically, rather than continuously, demonstrated superior effectiveness. This methodology prevented the adaptation of birds and reduced the likelihood of habituation.

Table 6: Pre- and post-test observation for Laser Deterrent only over four days of observation

Week 2 DAY 1	Pre-Test Time	Pre-Test count	Post-Test Time	Post-Test count
	6:58	34	7:00	4
	7:58	38	8:00	7
	8:58	32	9:00	4
	9:58	27	10:00	3
	10:58	23	11:00	5
	11:58	14	12:00	6
	12:58	10	1:00	3
	1:58	7	2:00	2
	2:58	12	3:00	7
	3:58	26	4:00	8
	4:58	23	5:00	9
	5:58	30	6:00	7

	Average Pre-Test count	23	Average Post-Test count	5.41
Week 2 DAY 2	Pre-Test Time	Pre-Test count	Post-Test Time	Post-Test count
	6:58	37	7:00	4
	7:58	42	8:00	6
	8:58	32	9:00	3
	9:58	36	10:00	8
	10:58	33	11:00	10
	11:58	24	12:00	12
	12:58	19	1:00	10
	1:58	13	2:00	7
	2:58	12	3:00	8
	3:58	24	4:00	13
	4:58	27	5:00	8
	5:58	32	6:00	10
	Average Pre-Test count	27.5	Average Post-Test count	8.25
Week 2 DAY 3	6:58	37	7:00	3
	7:58	48	8:00	7
	8:58	44	9:00	10
	9:58	37	10:00	14
	10:58	31	11:00	21
	11:58	12	12:00	8
	12:58	10	1:00	6
	1:58	13	2:00	8
	2:58	12	3:00	9
	3:58	30	4:00	19
	4:58	34	5:00	12
	5:58	26	6:00	8
	Average Pre-Test Count	27.8	Average Post-Test Count	10.4
	Week 2 DAY 4	6:58	32	7:00
7:58		36	8:00	6
8:58		32	9:00	7
9:58		39	10:00	12
10:58		36	11:00	14
11:58		24	12:00	15
12:58		19	1:00	12
1:58		6	2:00	5
2:58		4	3:00	4
3:58		16	4:00	8
4:58		23	5:00	10
5:58		20	6:00	4
Average Pre-Test Count		23.91	Average Post-Test Count	8.41

Table 7: Daily bird repulsion rates in experiment 2

Day	Average Pre-Test Count	Average Post-Test Count	Average Number of Birds Deterred	bird repulsion rates (%)
1	23.00	5.41	17.59	76.48
2	27.5	8.25	24.7	70.00
3	27.81	10.41	20.5	62.56
4	23.9	8.41	15.5	64.84

Table 8: Calculated daily and hourly bird repulsion rates in experiment 2

Experiment 2: Laser Deterrent only	DA Y	BRR _d (%)	BRR _h (%)											5:00 pm	6:00 pm
			7:00 am	8:00 am	9:00 am	10:00 am	11:00 am	12:00 pm	1:00 pm	2:00 pm	3:00 pm	4:00 pm			
day 1	76.64	88.24	81.58	87.50	88.89	78.26	57.14	70.00	71.43	41.67	69.23	60.87	76.67		
day 2	70.09	89.19	85.71	90.63	77.78	69.70	50.00	47.37	46.15	33.33	45.83	70.37	68.75		
day 3	62.56	91.89	85.42	77.27	62.16	32.26	33.33	40.00	38.46	25.00	36.67	64.71	69.23		
day 4	64.80	87.50	83.33	78.13	69.23	61.11	37.50	36.84	16.67	0.00	50.00	56.52	80.00		

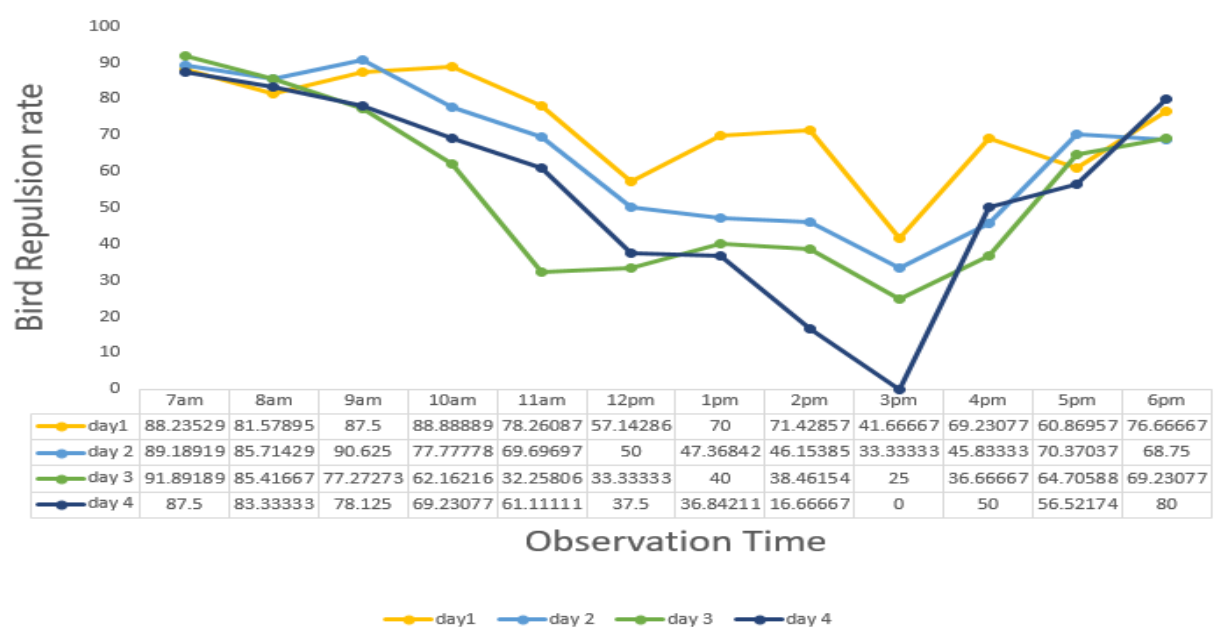


Figure 6: Graphical representation of the hourly Bird repulsion rate in experiment 2.

Table 9: Laser operational range with respect to time of day

Time of Day	Operational range (meters)
7:00	9
8:00	8
9:00	6
10:00	6
11:00	3
12:00	4
13:00	4
14:00	3
15:00	4
16:00	6
17:00	8
18:00	8
19:00	8

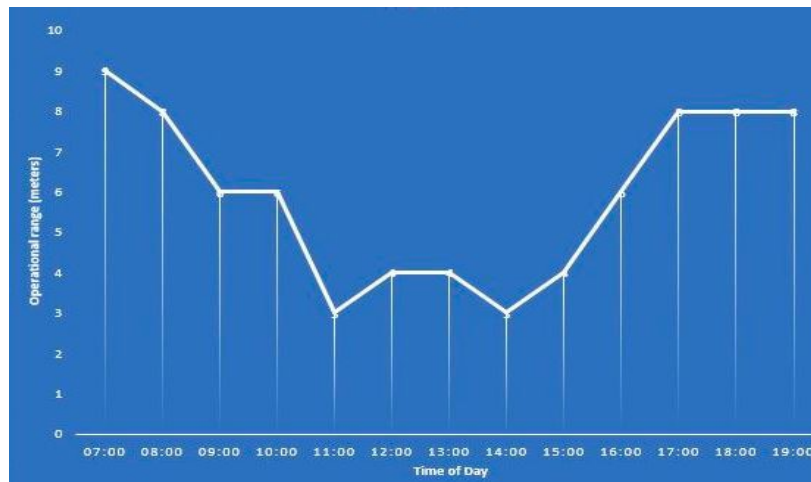


Figure 7: Laser operational range with respect to time of day

3.4 Evaluation of experiment 2

A four-day systematic observation was used in this research, where the pre- and post-test counts were noted at various hours of the day. The approach is similar to the controlled experiments of Elbers and Gonzales (2021) and Brown and Brown (2021), who employed the use of 2-choice tests to measure avoidance behaviour. The findings of the research are important as it determines the optimal limits of operation of the laser, which can be used to maximise the deterrent effects. The operation range was also investigated during Experiment 2, which confirmed that environmental factors have an impact on the performance of laser deterrents, as earlier reported by Mohamed *et al.* (2020).

The results indicated that the working range of the laser was significantly different during the day, with the most functionality experienced in the early morning and late afternoon. This fact confirms the suggestions of Brown and Brown (2021), who stated that the timing of the use of laser deterrents matters to achieve the greatest effect. The results indicate that lasers work best in the early morning. Findings reveal a high rate of birds' disappearance, where the average number of birds reduced to 8 - 10.4 during the installation of laser deterrents, compared to 23.9-28 before intervention. This aligns with findings in Brown and Brown (2021), which demonstrate that lasers can effectively disperse various bird species, particularly under low-light conditions.

The effectiveness percentage from this study (62.56% to 76.48%) corroborates the documented success rates for laser use by Blackwell *et al.* (2002) and Cepek *et al.* (2001), which reported an average of 83% and 96%, respectively, particularly with species like Canada geese, which showed marked avoidance.

3.5 Experiment 3 (laser and audio combined deterrent)

The performance of a combined Laser and Audio deterrent system for bird scaring was evaluated through various metrics, including audio frequency range, operational range, and visibility. Selected audio frequencies of 1 kHz, 4 kHz, 8 kHz, and 14 kHz, as used in experiment 1, as well as the 560 mW Class 3B lasers utilised in experiment 2, were employed. Field tests conducted in consistent environmental conditions from 6 am to 6 pm over 4 days involved observing bird responses before and after activating both the laser and audio modules.

Data collection included pre-test baseline observations every hour for two minutes and post-test counts after one minute of laser and sound activation, with results analysed using recorded video for accurate bird counting. A Pre-Test and post-test observation for experiment 3 at different sound frequencies is documented in Table 10.

Table 10. Pre-Test and post-test observation for the experiment

	Pre-Test Time	Pre-Test Count	Post-Test Time	Post-Test Count
Week 3 DAY 1 Audio frequency value=1KHz	6:58	39	7:00	4
	7:58	43	8:00	3
	8:58	38	9:00	4
	9:58	32	10:00	2
	10:58	45	11:00	3
	11:58	22	12:00	4
	12:58	14	1:00	3
	1:58	19	2:00	4
	2:58	13	3:00	2
	3:58	49	4:00	3
	4:58	40	5:00	5
	5:58	44	6:00	6

	Average Pre-Test Count	38.16	Post-Test Count	3.58
Week 3 DAY 2, Audio frequency value=4KHz	6:58	49	7:00	4
	7:58	44	8:00	6
	8:58	42	9:00	3
	9:58	48	10:00	8
	10:58	37	11:00	7
	11:58	24	12:00	2
	12:58	12	1:00	4
	1:58	10	2:00	3
	2:58	28	3:00	5
	3:58	31	4:00	9
	4:58	32	5:00	5
	5:58	35	6:00	5
		Average Pre-Test Count	32.66	Average Post-Test Count
Week 3 DAY 3, Audio frequency value=8KHz	6:58	23	7:00	3
	7:58	18	8:00	4
	8:58	29	9:00	4
	9:58	34	10:00	8
	10:58	23	11:00	7
	11:58	12	12:00	8
	12:58	10	1:00	5
	1:58	15	2:00	6
	2:58	12	3:00	5
	3:58	33	4:00	9
	4:58	40	5:00	12
	5:58	28	6:00	6
		Average Pre-Test Count	23.08	Average Post-Test Count
Week 3 DAY 4, Audio frequency value=14KHz	6:58	30	7:00	7
	7:58	36	8:00	9
	8:58	30	9:00	4
	9:58	32	10:00	8
	10:58	36	11:00	6
	11:58	24	12:00	10
	12:58	18	1:00	6
	1:58	10	2:00	6
	2:58	19	3:00	3
	3:58	26	4:00	8
	4:58	28	5:00	5
	5:58	34	6:00	7
		Average Pre-Test Count	26.91	Average Post-Test Count

The data from the observation area shows day-to-day variations in bird population, with an average of 23 to 38 birds present across four days. The table presents pre-test and post-test counts of birds, illustrating the impact of the combined approach. The maximum rate of repulsion was recorded at the lowest audio frequency (1 kHz) when combined with the laser, and the average number of birds in both pre-test and post-test counts decreased.

The result further indicated that lower frequencies, when combined with laser (1 kHz and 4 kHz), were more efficient than higher frequencies (8 kHz and 14 kHz) in scaring away birds, perhaps because lower frequencies are more sensitive to birds. Table 11 is a summary of the Daily Bird Repulsion Rate of Experiment 3. The Table reveals that the lower the frequency, the better the effect they have when it comes to deterring birds. The data is critical in maximising deterrent measures and their prolonged efficacy in controlling the bird numbers. The joint deterrent of experiment 3 always works better when compared to the solo deterrents of experiments 1 and 2, which means that the interaction of the laser and audio prompts increases the overall effectiveness. The combined deterrent has a high bird repulsion rate of 89.20% at lower frequencies (1 kHz), which indicates that it would be best used to maximise the deterrent effect. At frequencies of 4 kHz and higher, the repulsion rate is fairly constant, but with fluctuations, especially at 14 kHz, where the repulsion rate of individual and combined systems is lower.

As demonstrated in the table, the combination of audio and laser deterrents greatly improves the performance in different frequencies. At 1kHz audio frequency, the combined deterrent registered a daily rate of 89.20 birds repulsion and in 4kHz, the daily rate of 84.44.

The repulsion rate of the birds was 72.20 per day, and the repulsion rate of the birds at 14 kHz was 75.54 per day. The data indicates that laser deterrents alone are effective, but when combined with audio deterrents, particularly at lower frequencies are beneficial. This implies that the environment which needs

deterrents needs to put a multi-faceted approach to ensure that the maximum is achieved. The slight variations in effectiveness at higher frequencies highlight the importance of context, as certain environments or situations may benefit more from one type of deterrent over the other. Table 12 is a tabular representation of the daily and hourly Bird repulsion rate when using a laser and audio combined deterrent to scare birds at different frequencies. Figure 8 is a graphical representation of the hourly Bird repulsion rate for experiment 3.

Table 11: Daily bird repulsion rates in experiment 3

Day	Audio Frequency (KHz)	Average Pre-Test Count	Average Post-Test Count	Average Number of Birds Deterred	bird repulsion rates (%)
1	1	38.16	3.58	34.58	89.20
2	4	32.66	5.08	27.58	84.44
3	8	32.08	6.41	16.67	72.20
4	14	26.91	6.58	120.33	75.54

Table 12: Calculated daily and hourly bird repulsion rate for Experiment 3.

Experiment 3: Laser and Audio Deterrent combined	DAY	BRR _d (%)	BRR _h (%)											
			7:00 am	8:00 am	9:00 am	10:00 am	11:00 am	12:00 pm	1:00 pm	2:00 pm	3:00 pm	4:00 pm	5:00 pm	6:00 pm
	day 1 : 1KHz	89.20	89.74	93.02	89.47	93.75	93.33	81.82	78.57	78.95	84.62	93.88	87.50	86.36
	day 2: 4KHz	84.44	91.84	86.36	92.86	83.33	81.08	91.67	66.67	70.00	82.14	70.97	84.38	85.71
	day 3: 8KHz	72.20	86.96	77.78	86.21	76.47	69.57	33.33	50.00	60.00	58.33	72.73	70.00	78.57
	day 4: 14KHz	75.54	76.67	75.00	86.67	75.00	83.33	58.33	66.67	40.00	84.21	69.23	82.14	79.41



Figure 8: Graphical representation of the hourly bird repulsion rate for experiment 3.

3.6 Evaluation of experiment 3 (laser and audio deterrent combined)

Recent literature has indicated that the adoption of various deterrent measures may result in enhanced performance. The study by Chen et al. (2024) showed that multi-modal intervention methods of bird control, including the use of visual as well as audio stimuli, are more effective than single interventions. This is affirmed with the results of Experiment 3, which showed that the highest rate of repelling the birds was with the combination of laser and audio deterrents and 89.20% at 1 kHz. The perceived threat to the birds is reinforced by the two deterrents, which are greater with perceived threat, and therefore the birds show a stronger reaction.

The results of Experiment 3 suggested that the lower frequencies of audio (1 kHz and 4 kHz) were more useful in frightening birds. This is in line with the research conducted by Aboltins *et al.* (2021) and Ade-Omowaye *et al.* (2024), which found that the lower frequencies were found to be especially useful in deterring birds because they were more sensitive to low frequencies. The effectiveness of audio frequencies reported in this study is also complemented by the results of Micaelo *et al.* (2023), who reported that distress calls and predator sounds in low audio frequencies were more effective in causing avoidance behaviours in birds. The experiment found immediate responses of birds to the compound deterrent, which is consistent with Elbers and Gonzales (2021) and Brown and Brown (2021), who also reported the same behavioural responses when birds were subjected to some visual stimuli.

The active character of the motion of the laser came as a good solution to avoid habituation, which is a critical aspect of this study, as Aboltins *et al.* (2021) have mentioned that habituation is a rather frequent effect of using static deterrents.

3.7 Comparison of the daily bird repulsion rate for all 3 experiments

The percentages of Bird Repulsion Rate (BRRd) have become a decisive variable of the efficiency of the bird deterrent systems in the fields. The analysis of the BRRd values in the experiments allows one to make several observations concerning the success in operations and the practical consequences of the deterrence strategies used. Table 13 and Figure 9 are a tabular and graphical comparison of the daily Bird repulsion rate in all 3 Experiments.

In Experiment 1, it is observed that the rates of repulsion decreased on days 1 to 4, which implies that the deterrent method employed was less effective. This is attributed to the different frequency of audio used. In Experiment 2, the repulsion rates were high at 76.64% on the first day and were in a fluctuating state with a high average and finally, 64.80% on the fourth day. Experiment 3 registered the highest repulsion rates on all days, starting with 89.20 on Day 1 and remaining effective with slight changes. The combined deterrent method in experiment 3 was always successful in scaring birds, although initially, there were higher rates of repellence of birds, which points to the idea that birds were more sensitive to the combined method. This reduction in effectiveness between Day 1 and Day 4 could be an indication that the birds could be desensitised to the deterrents unless the appropriate audio frequency signal is incorporated. This is especially intense in EXP. 1, in which the rate of repulsion decreased to less than 40% in the 4th Day. The images of the bimodal bird scaring system setup are provided in Figure 10.

Table 13: Comparison of daily Bird repulsion rate in all 3 Experiments

EXP	BRRd (%) Comparison			
	DAY 1	DAY 2	DAY 3	DAY 4
EXP. 1	62.01	59.54	49.84	39.86
EXP. 2	76.64	70.09	62.56	64.80
EXP. 3	89.20	84.44	72.20	75.54

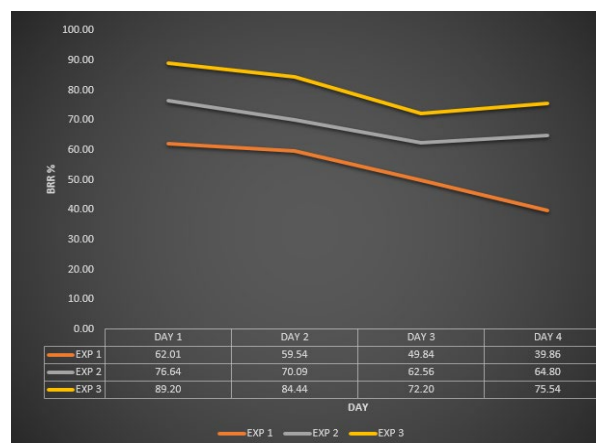


Figure 9: Graphical comparison of daily Bird repulsion rate in all 3 Experiments

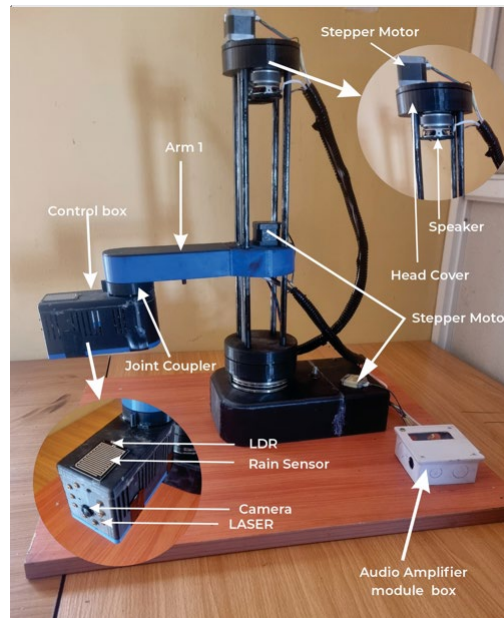


Figure 10: Automated Multipurpose Avian Deterrents System

4.0 Conclusion

The study on the Automated Multipurpose Avian Deterrent System shows significant advancements in bird pest management. By combining visual and audio deterrents, the research found that audio and laser use increased bird repulsion rates, particularly with a 1 kHz frequency, yielding a rate of 89.20%. The implementation of technologies like YOLOv5 improved bird detection and response accuracy. Behavioural insights indicated birds respond better to lower audio frequencies, suggesting adaptive strategies may be necessary to counteract habituation. Economically, this system offers farmers a viable solution to enhance crop yield and reduce losses traditionally caused by manual deterrent methods. Overall, the system marks a substantial advancement in pest management, warranting further research for adaptability across various agricultural settings.

References

1. Aboltins, A., Pikulins, D., Grizans, J., & Tjukovs, S. (2021). Piscivorous bird deterrent device based on a direct digital synthesis of acoustic signals. *Elektronika ir Elektrotechnika*, 27(6):42–48.
2. Ade-Omowaye, J., Ikubanni, P., Onu, P., & Ogunniyi, O. (2024). Advancements in Electronic Bird Repellent Technology: A Comprehensive Review of Effectiveness, Environmental Impact, and Practical Applications. In *2024 International Conference on Science, Engineering and Business for Driving Sustainable Development Goals (SEB4SDG)*, pp. 1–10. IEEE.
3. Ajibodu F. A. & Ojo B.A (2024). Development of a Solar-Powered Bird Repellant System for Increasing Rice Production in Nigeria. *American Journal of Engineering Research (AJER)* Volume-13, Issue-6, pp-134-138
4. Bishop, J., McKay, H., Parrott, D., & Allan, J. (2003). Review of international research literature regarding the effectiveness of auditory bird scaring techniques and potential alternatives. *Food and rural affairs, London*, pp. 1–53.
5. Blackwell, B. F., Bernhardt, G. E., & Dolbeer, R. A. (2002). Lasers as nonlethal avian repellents. *The Journal of Wildlife Management*, pp. 250–258.
6. Brown, R. N. & Brown, D. H. (2021). Robotic laser scarecrows: A tool for controlling bird damage in sweet corn. *Crop Protection*, 146:105652.
7. Cepek, J., Suckow, J., Croson, C., & Blackwell, B. (2001). Laser dispersal of Canada geese at Lake Galena, Pennsylvania. United States Department of Agriculture/Animal and Plant Health Inspection Service/Wildlife Services. *National Wildlife Research Centre, Summary Report, Sandusky, Ohio, USA*.
8. Chen, Y.C., Chu, J.F., Hsieh, K.W., Lin, T.H., Chang, P.Z., & Tsai, Y.C. (2024). An automatic wild bird repellent system that is based on deep-learning-based wild bird detection and integrated with a laser rotation mechanism. *Scientific Reports*, 14(1):15924.
9. Durodola F., Eludiora S., Owoeye S., Omotainse P., Oduntan O., & Alake B. (2025). Automated Bird Scaring System: A Review. *Journal of Natural Sciences Engineering and Technology*, (24), 99-111.
10. Elbers, A. R. & Gonzales, J. L. (2021). Efficacy of an automated laser for reducing wild bird visits to the free range area of a poultry farm. *Scientific Reports*, 11(1):12779.

11. Hernadi, M. F., Timur, Y. H., Manalu, R. D. P., Khairunnisa, N., & Zakaria, D. (2025). Automated Bird Deterrent System: A Review. *Journal of Electrical, Electronic, Information, and Communication Technology*, 7(1), 1-9.
12. Ibrahim, A. G., Oyedum, O. D., & Awojowogbe, O. (2017). Design Description of a Stand-Alone, Auto-Frequency Ultrasonic Brand of Weaver Bird Pest Control Device for Field Applications. *International Journal of Engineering and Manufacturing*, 7(5):1.
13. Micaelo, E. B., Lourenc,o, L. G., Gaspar, P. D., Caldeira, J. M., & Soares, V. N. (2023). Bird deterrent solutions for crop protection: approaches, challenges, and opportunities. *Agriculture*, 13(4):774.
14. Mohamed, W. M. W., Naim, M. N. M., & Abdullah, A. (2020). The Efficacy of Visual and Auditory Bird Scaring Techniques using a Drone at Paddy Fields. In *IOP Conference Series: Materials Science and Engineering*, volume 834, pp 012072. IOP Publishing.
15. Rivadeneira, P., Kross, S., Navarro-Gonzalez, N., & Jay-Russell, M. (2018). A review of bird deterrents used in agriculture. In *Proceedings of the vertebrate Pest conference* (Vol. 28, No. 28).
16. Srivastav, A. K., & Das, P. (2025). Agricultural Robotics and Autonomous Systems. In *Biotechnology and IoT in Agriculture and Food Production: Green Innovation* (pp. 201-225). Berkeley.