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'Pea-Rep' The Peafowl Repellence Network

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Abstract *– The frequency-based peafowl repellence network is a novel agrotronic solution designed to mitigate the destruction caused by peafowls (Pavo cristatus) to crops and harvests across the island. The proposed system utilizes specific audio frequencies, particularly within the 3.4 - 4.5 kHz range, for the repellence task, uniquely targeting peafowls compared to other pest repellent devices. Beyond acting as a repellent network, the system can also guide peafowls in a predetermined direction through a sequential switching process. This system supports local farmers cultivating crops such as rice paddy (Oryza sativa), long beans (Vigna unguiculata), corn (Zea mays), onion (Allium cepa), guava (Psidium guajava), watermelon (Citrullus lanatus), tomato (Solanum lycopersicum), and various vegetables like brinjal (Solanum melongena), okra (Abelmoschus esculentus), capsicum (Capsicum annuum), leeks (Allium ampeloprasum), and luffa (Luffa cylindrica). Implemented in farms in the North Central and Northwestern provinces, the system demonstrated an improved average accuracy of 84% in repelling peafowls, making it an effective and reliable solution for protecting crops.*

Keywords*: agrotronics (the use of electronic in agriculture), spectrum, repellence, peafowl*

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1 INTRODUCTION

Sri Lanka is home to a diverse array of ecological pests that significantly impact agriculture. Among these pests are the apple snail (*Pomacea canaliculata*), the giant African snail (*Achatina fulica*), rainbow trout (*Oncorhynchus mykiss*), marble catfish (*Clarias batrachus*), janitor fish (*Pterygoplichthys disjunctivus*), and the little brown caterpillar or armyworm (*Spodoptera spp*.) (Lowe et al., 2000). Native fauna such as the wild boar (*Sus scrofa*), crested porcupine (*Hystrix indica*), spotted deer or chital (*Axis axis*), and the long-tailed squirrel (*Funambulus sublineatus*) have also been identified as significant agricultural pests (Lowe et al., 2000). Recently, the Indian peafowl (*Pavo cristatus*) has been added to this list of detrimental species.

The term "peafowl" collectively refers to peacocks (males), peahens (females), and peachicks (juveniles). Peafowls are members of the pheasant family (*Phasianidae*), and there are three primary species globally: Indian (*Pavo cristatus*), green (*Pavo muticus*), and Congo peafowl (*Afropavo congensis*) (Clothey, 1978). Indian peafowls are the largest members of the pheasant family, known for their rapid reproduction and widespread presence across Sri Lanka's dry zones over the past few decades (Alahakoon, Jo, & Jayasena, 2016). These birds reach sexual maturity within two years and typically lay seven to eight eggs per clutch, which hatch in about a month. In the wild, peafowls have a lifespan of up to 15 years. Peafowls have been identified as an ecological pest species due to their substantial crop damage. A flock of peafowls, each ten times the size of a domestic chicken, can devastate a habitat or crop area within hours. Their invasions into farmlands and cultivations are frequent as they exploit continuous food supplies that include seeds, insects, fruits, reptiles, and small mammals.

Moreover, significant ecological changes in Sri Lanka, such as the conversion of wetlands to dry lands due to human activities, have exacerbated the problem by enabling peafowls to invade more extensive areas. The lack of natural predators has also contributed to the population explosion. In their native habitats, peafowl populations are controlled by predators such as leopards (*Panthera pardus*), jackals (*Canis aureus),* hawk-eagles (*Nisaetus cirrhatus*), mongooses (*Herpestidae*), pythons (*Python molurus*), and monitor lizards (*Varanus spp*.), which prey on eggs and young birds (Alahakoon, Jo, & Jayasena, 2016). However, human activities have reduced these predator populations, allowing peafowl numbers to grow unchecked.

Religious and cultural factors also play a role in the management challenges of peafowl populations. Peafowls are protected by law and are often considered sacred or auspicious, which inhibits farmers from taking lethal measures against them (Alahakoon, Jo, & Jayasena, 2016). Consequently, the feasible solutions to manage peafowl populations are limited to increasing mortality rates through non-lethal means or promoting emigration, the permanent movement of individuals out of a population.

As previously mentioned, the destruction of open grasslands, wetlands, and marshes in both dry and wet zones have led to a significant reduction in natural predators of peafowls. For example, jackals (*Canis aureus*), which play a crucial role in maintaining food chains and stabilizing prey populations, have experienced substantial declines over the past decades. While culling is a temporary measure, a sustainable long-term solution involves enhancing predator habitats and enforcing hunting regulations for conservation purposes (Alahakoon, Jo, & Jayasena, 2016). Although predation is a natural method for controlling prey populations, it operates more slowly than culling. It may take at least a decade to observe any significant decline in peafowl populations through natural predation alone.

Delaying either short-term or long-term actions can lead to severe crop damage and loss of ecological balance. The alarming decline in endemic biodiversity, particularly among native snakes, exacerbates this issue. Snakes help control populations of other pests, such as mice and rats, whose numbers can surge if snake populations dwindle. Additionally, the majority Buddhist population in Sri Lanka generally opposes culling, in line with Buddhist principles that emphasize non-violence (Clothey, 1978). Given this cultural context, it is imperative for authorities and environmentalists to collaborate on finding effective and rapid solutions. Failure to address the problem might compel farmers to take matters into their own hands, leading to the illegal killing of peafowls despite their cultural and religious significance.

To address these challenges, we propose a frequency-based peafowl repellence network utilizing a sequential signaling system. This innovative approach aims to repel peafowls effectively from agricultural lands, thereby protecting crops without harming the birds. The system leverages specific frequencies that deter peafowls, ensuring that they stay away from the harvest areas. This method not only aligns with ethical and cultural considerations but also provides a practical and humane solution to mitigate the agricultural damage caused by peafowls.

2 LITERATURE REVIEW ON BIRD AND CREATURE REPELLENCE METHODS

2.1 Related Works

Farmers today employ various manual fencing techniques to protect their crops, such as chain link fences, barbed wire fences, green PVC fences, and concertina coil fences. However, methods like green PVC fences are ineffective against animals like peafowls, which can easily fly over and sit on the fences. Additionally, installing physical barriers over large farmland areas is not cost-effective due to the high demand and installation costs. Traditional manual fences made of wire, plastic, or wood also fail to reliably prevent peacock intrusions.

Other crop protection methods include the use of chemical products, but these can be expensive and may contaminate crops, particularly vegetables and grains like tomatoes and groundnuts. Therefore, there is a need for more intelligent sensing applications to protect crops (Jordania, 2011). Although extensive research has been conducted on repelling various pests using different technologies, few systems are available to specifically repel peafowls from farmland. Among the various approaches, physical repellence methods are considered less harmful to environmental and ecological balance.

2.1.1 Electric bird repelled shock track

Electric bird repelled shock tracks are designed to deliver a mild electric shock to birds that land on them, deterring them from roosting or perching on protected areas. Studies have shown that these systems can be highly effective in urban and agricultural settings. For example, Erickson et al. (2014) reported a significant reduction in bird activity around treated areas, noting that the shock was sufficient to deter birds without causing harm.

2.1.2 Bird control spikes and bird netting

Bird control spikes and netting are physical barriers that prevent birds from landing or nesting in protected areas. Spikes are typically installed on ledges, signs, and other flat surfaces, while netting can cover entire areas such as fruit trees or crop fields. According to Gorenzel and Salmon (2008), these methods are effective for many bird species, including pigeons and sparrows. However, their effectiveness can be limited in large agricultural fields due to the extensive area that needs to be covered.

2.1.3 Agri- Canon

The Agri-Canon is a propane-powered device that emits loud, sudden noises to scare away birds. Research by Avery and Decker (1994) demonstrated that such auditory deterrents can be effective in the short term, particularly for species like starlings and crows. However, birds can become habituated to the noise over time, reducing long-term effectiveness.

2.1.4 Optical and acoustic repellent methods

Studies by Blackwell et al. (2002) show that laser repellents can effectively deter birds from roosting and foraging areas by creating a visual disturbance. The effectiveness is high in low-light conditions, but birds may become habituated if exposed frequently.

Moreover, Ultrasound-based devices emit high-frequency sounds that are unpleasant to birds but inaudible to humans. These devices have been marketed as humane and non-invasive solutions for bird control. A study by Bomford and O'Brien (1990) found that ultrasound can effectively deter pigeons and other birds from specific areas. However, the range of these devices is limited, and their effectiveness can diminish if birds become accustomed to the sound. Sound-based devices that target multiple pests, including birds, typically use a combination of distress calls, predator sounds, and other noises to create an inhospitable environment for pests. Research by Khan and Gorenzel (2007) indicated that these devices can be effective across a range of species and settings. The versatility of targeting different pests is an advantage, but like other auditory repellents, habituation can reduce effectiveness over time.

2.1.5 Holographic Tape and Reflective Surfaces

Holographic tape and reflective surfaces create visual disturbances that can scare birds away. According to Shirota et al. (1983), these methods are cost-effective and easy to deploy but may have limited effectiveness in large open areas.

2.1.6 Chemical Repellents

Chemical repellents such as methyl anthranilate have been shown to deter birds from feeding on crops (Avery, 1992). These are applied directly to crops but can affect the taste and safety of the produce.

2.1.7 Predator Decoys and Models

Using decoys of predators like owls and hawks can scare birds away from certain areas. Tinarelli et al. (1999) found this method effective in the short term, but birds often learn that the decoys are not real threats, leading to reduced effectiveness over time.A comparison of the repellence schemes mentioned above is presented in Table 2.1.

Table 2.1 Comparison of Bird and Creature Repellence Methods

Method	Effectiveness	Advantages	Disadvantages
Electric Bird Repelled Shock Track	High effectiveness in urban settings and specific areas (Erickson et al., 2014)	Immediate deterrent effect, humane, does not harm birds	High installation cost, limited to specific surfaces
Bird Control Spikes and Bird Netting	Effective for preventing perching and nesting, particularly in urban environments (Gorenzel & Salmon, 2008)	Prevents birds from landing or nesting, durable	Ineffective in large agricultural fields due to extensive coverage needed
Agri-Canon	Effective in the short term for species like starlings and crows (Avery & Decker, 1994)	Immediate and effective auditory deterrent	Birds can habituate to the noise, less suitable for residential areas due to noise pollution
Ultrasound-Based Pigeon Repellent Device	Effective in deterring specific bird species without disturbing humans (Bomford & O'Brien, 1990)	Humane, non-invasive, and species-specific	Limited range, effectiveness diminishes with habituation, varies by species
Sound-Based Multiple Pest Repellent Devices	Effective in diverse pest environments, particularly in short-term applications (Khan & Gorenzel, 2007)	Versatile, targets multiple pests, immediate effect	Habituation reduces long-term effectiveness

Laser Repellents	High effectiveness in low-light conditions (Blackwell et al., 2002)	Creates visual disturbances, non-lethal, and humane	Birds may habituate if frequently exposed, less effective in bright conditions
Holographic Tape and Reflective Surfaces	Cost-effective and easy to deploy (Shirota et al., 1983)	Creates visual disturbances, inexpensive	Limited effectiveness in large open areas
Chemical Repellents	Effective in deterring birds from feeding on crops (Avery, 1992)	Targeted application, can be species-specific	Can contaminate crops, affect taste and safety of produce
Predator Decoys and Models	Effective in the short term (Tinarelli et al., 1999)	Non-lethal, easy to deploy, creates visual threat	Birds often learn decoys are not real threats, leading to reduced effectiveness over time

2.2 Theoretical Background

Frequency-based pest repelling has become a common and popular approach for controlling pests like birds and bats. Ultrasounds are often used because they are outside the human hearing range. However, peafowls (Pavo cristatus) have a hearing range that extends from 29 Hz to 7.065 kHz, as shown in Fig.6. Higher frequencies within this range, combined with high sound pressure levels (SPL-dB), can be distressing to peafowls, causing them to keep a safe distance from such sound sources (Heffner et al., 2020).

Peafowls are also highly sensitive to low-frequency sounds. Contrary to popular belief, when peacocks display their feathers to attract females, they also emit low-frequency sounds that are inaudible to humans. These sounds are used during mating season to communicate different messages. When peacocks are ready to mate, they fan out their iridescent tail feathers (known as trains), then rush at females while shaking these feathers to catch their attention (Watch Peacock Get Female’s Attention, 2018). This shaking produces infrasound signals, which can travel long distances and are detected by potential mates (Yorzinski et al., 2013). Theoretically and practically, a mix of low and high-frequency sounds (50 Hz to 500 Hz and 3400 Hz to 4500 Hz) within the peacock's hearing threshold can disrupt their ecological and social behaviors, such as feeding and reproduction (Jordania, 2011).

2.2.1 Advances in Frequency-Based Repellence

Research on frequency-based repellence has expanded to consider various animal species. For instance, ultrasonic devices have been successfully used to deter bats from roosting in unwanted areas (Gorresen et al., 2015). Similarly, studies on birds have shown that high-frequency sounds can prevent them from nesting and feeding in specific locations (Bomford & O'Brien, 1990). These findings support the potential effectiveness of frequency-based repellence for peafowls.

The use of frequency-based repellents aligns with the concept of using non-lethal methods for wildlife management. Non-lethal methods are preferred due to ethical considerations and legal protections for many species (Treves & Naughton-Treves, 2005). By leveraging the auditory sensitivities of peafowls, it is possible to create an environment that they find uncomfortable, thus encouraging them to move away without causing harm.

2.2.2 *Mechanisms of Auditory Deterrence*

The effectiveness of auditory deterrents depends on several factors, including sound frequency, intensity, and duration. High-frequency sounds (above 3400 Hz) can be particularly irritating to peafowls, leading to avoidance behaviors. This is shown in Fig.1 where A,B, and C represents thresholds of the individual animals. Additionally, the combination of high and low frequencies can enhance deterrence by affecting different aspects of peafowl behavior. Low frequencies (below 500 Hz) can interfere with their social communications and mating rituals, while high frequencies can disrupt their general auditory environment (Heffner et al., 2020; Yorzinski et al., 2013).

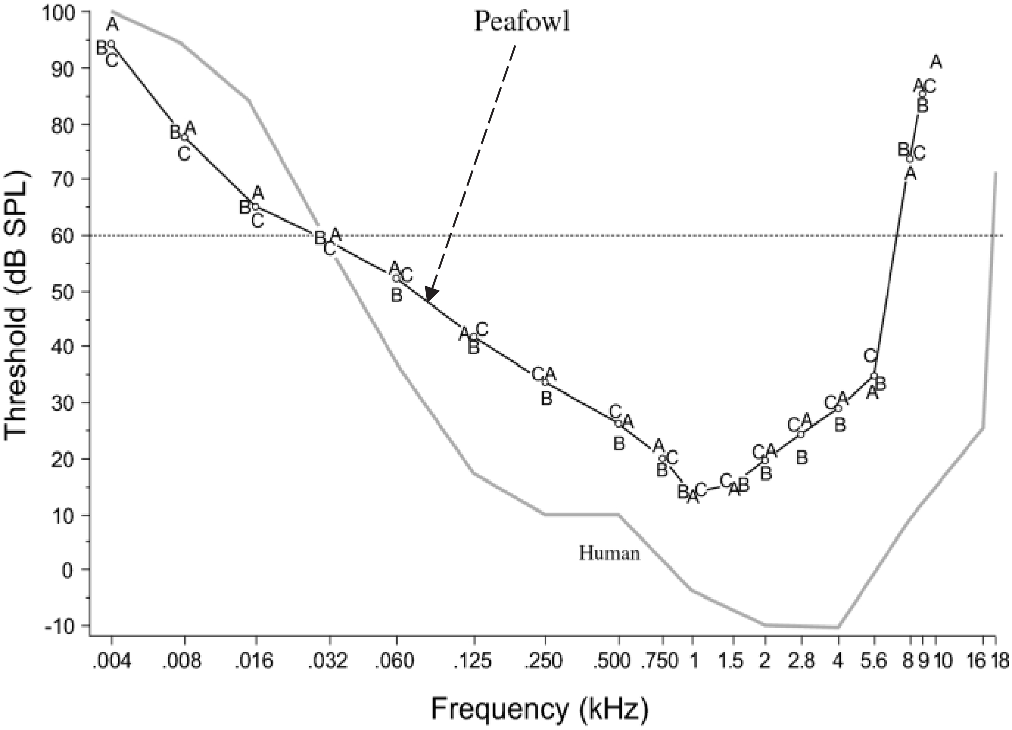

Fig.1. Sound Sensitivity variations of three peafowls with human audiogram comparison (Heffner et al, 2020)

2.3 Requirement Analysis Requirement Analysis for Effective Peafowl Repellence

To determine the most effective frequency range for repelling peafowls, a comprehensive requirement analysis was conducted. The framework of this analysis is illustrated in Fig. 2. The analysis identified that frequencies within the range of 29 Hz to 7.065 kHz are particularly harmful to peafowl hearing, making this range effective for repelling them (Heffner et al., 2020). Additionally, sounds associated with predators such as dogs or members of the jackal family can also be effective in repelling peafowls. However, these birds may become habituated to such sounds over time if they do not perceive an actual threat, reducing the long-term effectiveness of this method.

By understanding these frequency ranges and the behavioral responses of peafowls, more effective and sustainable repellence strategies can be developed. This approach ensures that the repellent system remains efficient without causing harm to the birds or disrupting the ecological balance.

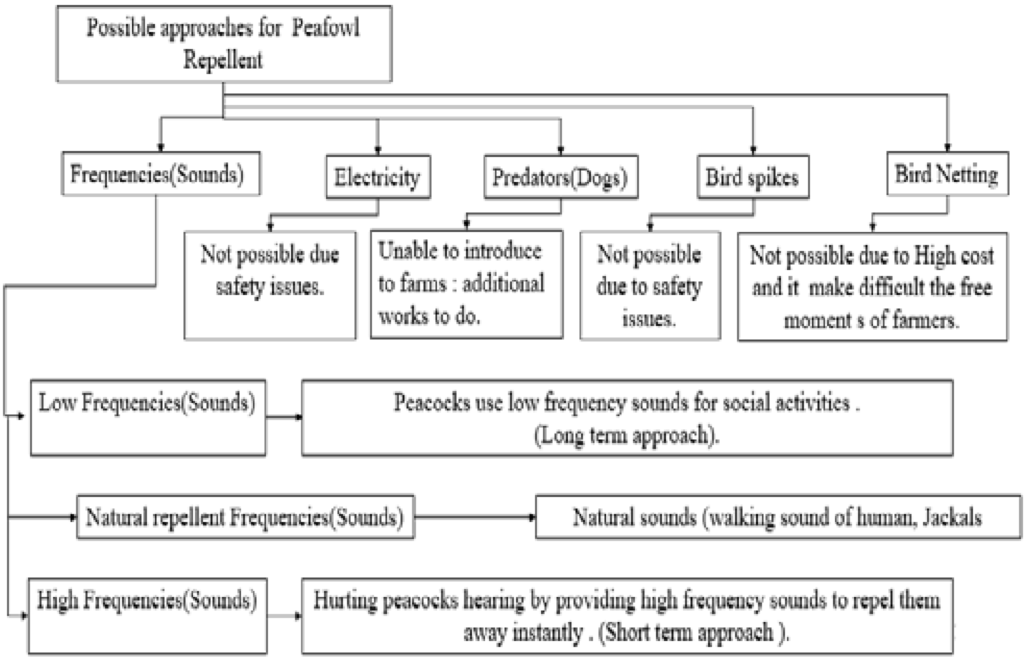

Fig.2. Requirement analysis flow diagram

Furthermore, biometric measurements of peafowls were obtained to identify the necessary body temperature and size thresholds, which are as follows:

- **Average Body Temperature**: 35 to 39 degrees Celsius
- **Length**: From bill to end of train is about 190 cm to 225 cm for males and about 60 cm to 90 cm for females
- **Height**: From bill to ground is 50 cm for males and 45 cm for females
- **Chest Height**: From ground to chest area varies from 20 cm to 40 cm, with the chest area being the hottest part of the peafowl

The proposed system was implemented in farmland areas in the North Central and Northwestern Provinces, such as *Morawewa Pankulam* and *Habarana*, *Kanthale*, as illustrated in Fig. 3.

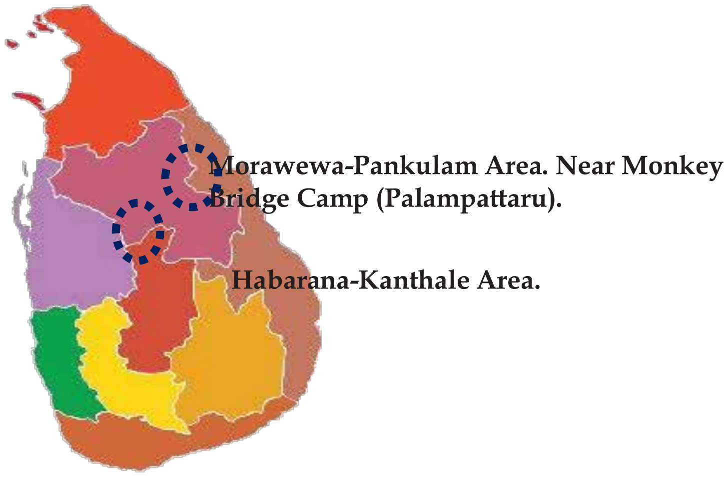

Fig. 3. Data collected areas

3 METHODOLOGY

Based on the data gathered from the requirement analysis, the proposed repellence network was installed within farmlands in the North Central and Northwestern Provinces, specifically targeting areas in *Morawewa Pankulam, Habarana*, and *Kanthale*. These locations were chosen due to high reports of peafowl activity and crop damage. The installation process began with site selection and preparation, which involved assessing each site's topography, vegetation, and existing infrastructure to ensure optimal coverage and effectiveness. The system design and layout were carefully planned, with sensor nodes strategically placed along farm boundaries and central locations to allow for seamless wave-like activation. The system operates in both automatic and manual modes. In automatic mode, the system is triggered by motion detection when a peafowl is detected, causing the sensor nodes to activate sequentially in a wave pattern from one boundary to the opposite boundary or from a central position outward. This method maximizes the effectiveness of the frequency waves, particularly on flat terrain. In manual mode, users can activate the system based on specific needs or observations, providing flexibility for farmers to respond to immediate threats.The entire system is powered by embedded solar panels with a battery backup, ensuring continuous operation during nighttime or cloudy conditions. The field layout of the proposed system, as shown in Fig.4, includes master and slave units connected within a single network, both capable of transmitting repellent sounds. The master module controls the sequential switching procedure of the nodes.Field testing was conducted in the selected farmlands to evaluate the system's performance. This involved monitoring peafowl activity and crop damage before and after the system installation. Data analysis indicated a significant reduction in peafowl intrusions and crop damage. Feedback from farmers highlighted the system's usability and impact, demonstrating its potential as an effective and environmentally friendly solution for protecting crops from peafowls. By utilizing a combination of high and low-frequency sounds and sustainable power sources, the repellence network offers a promising approach to mitigating peafowl-related crop damage.

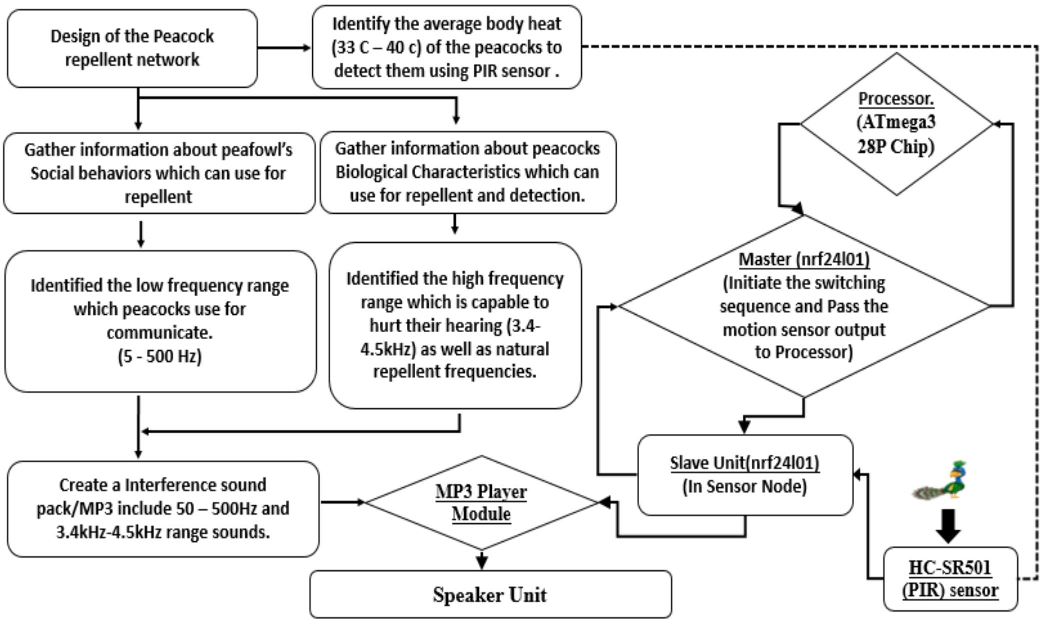

Fig.4. Proposed Methodology

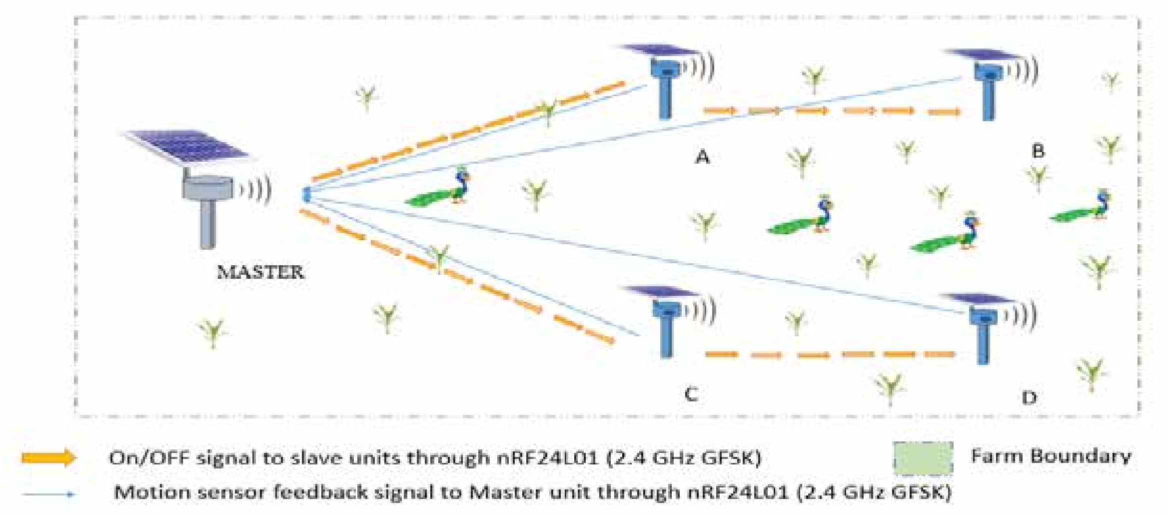

Fig. 5. Animated field layout of the network

3.1 Repellence and Deterrent

The proposed repellence system is specifically designed to detect the presence of peafowls and operate as a network to direct these birds away from cultivated areas. During field tests, the system demonstrated its effectiveness across various frequency ranges and distances. The analysis identified an effective repellence frequency range of 1.5-2.5 kHz. Additionally, frequencies in the 5 Hz to 100 Hz range were observed to be highly effective within a 5–15-meter radius from the transmitter, with power levels between 55 dB and 65 dB. These lower frequencies are particularly useful for short-range deterrence, causing immediate discomfort to peafowls and encouraging them to move away quickly. For longer-range repellence, frequencies in the 3.4-4.5 kHz range were found to be effective beyond 20 meters when transmitted at the same power levels. Based on these observations, the frequency range of 3.4-4.5 kHz was selected as the threshold repellent range, with a transmission power of 65 dB. This range provides a balance between effective deterrence and coverage area, ensuring that peafowls are repelled from larger sections of farmland without the need for excessive power consumption. The system's ability to switch between different frequency ranges and power levels allows for adaptive repellence strategies, depending on the specific conditions and requirements of each farm. The integration of motion sensors ensures that the system activates only when peafowls are detected, reducing unnecessary energy usage and minimizing disturbances to other wildlife. The sequential activation of sensor nodes in a wave-like pattern further enhances the system's efficiency, creating a dynamic barrier that guides peafowls away from crops and towards safer areas.

This combination of short-range and long-range deterrence capabilities makes the proposed repellence network a versatile and effective solution for mitigating peafowl-related crop damage. The system's reliance on sustainable power sources, such as solar panels and battery backups, ensures continuous operation and minimal environmental impact. By leveraging these technologies and adaptive strategies, the repellence network offers a promising approach to protecting farmlands from peafowls and preserving agricultural productivity.

3.2 Motion Detection

Motion detection of animals is the main input for triggering the overall system and plays a vital role in the switching sequence. In this system, motion detection is performed by the HC-SR501 IR-based motion detector. The detector operates within a 110° cone angle, as shown in Fig.6, and has the capability of detecting motion up to 7 meters. For enhanced detection, the range can be extended up to 14 meters by using dual sensor nodes placed back-to-back. The system detects motion based on the body temperature of the peafowl, ensuring precise identification. As depicted in Fig.6, the distance between two nodes should be 14 meters to maximize coverage and detection efficiency. The motion sensors can be tilted downwards by up to 25° to improve detection capabilities near the ground, where peafowls are more likely to be present. The height of the system is adjustable between 0.75 meters and 1.5 meters, depending on the type of crop being protected. The HC-SR501 IR motion detector is integral to the system's functionality. It is sensitive to infrared radiation emitted by warm objects, such as the body heat of peafowls. When a peafowl enters the detection range, the sensor activates and triggers the repellent sequence. This ensures that the system only operates when necessary, conserving energy and reducing unnecessary disturbances. The flexibility in height adjustment allows the system to be tailored to different crop types, providing effective protection without interfering with the growth and maintenance of the crops. For taller crops, the sensors can be positioned higher to maintain a clear line of sight for detection, while for shorter crops, the sensors can be lowered to ensure ground-level detection.

The deployment of dual sensor nodes enhances the system's detection range and reliability. By placing two sensors back-to-back, the detection area is doubled, ensuring comprehensive coverage. This configuration is particularly useful for large farmlands, where a single sensor might not be sufficient to cover the entire area. Overall, the motion detection capabilities of the HC-SR501 IR-based motion detectors, combined with the strategic placement and configuration of the sensor nodes, ensure that the repellence system is both effective and efficient in protecting crops from peafowls. The system's adaptability to different farm layouts and crop types further enhances its utility, making it a versatile solution for farmers facing challenges with peafowl intrusions.

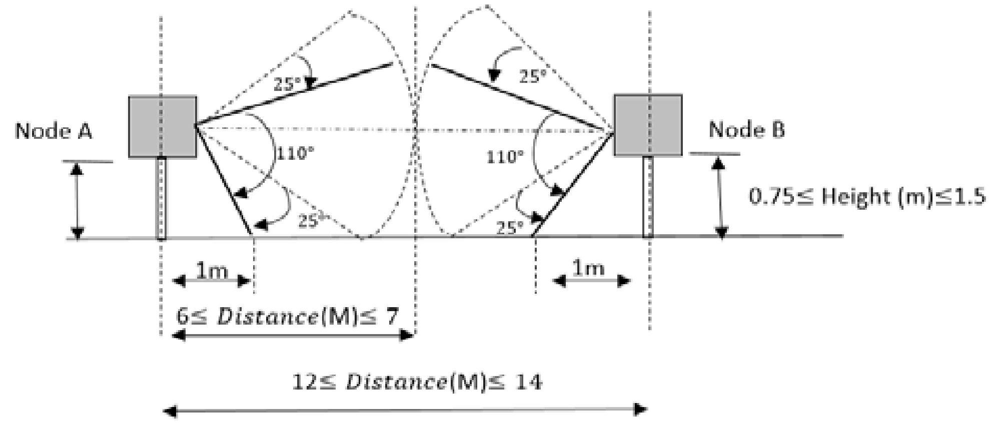

Fig. 6. Field measurements for the installation

3.3 Triggering Procedure

The entire repellence system operates in both automatic and manual modes, offering flexibility and efficiency. In automatic mode, the master unit controls the switching sequence of the slave units, which are activated sequentially rather than simultaneously to create a directional repellent effect. When a peafowl is detected by the motion sensors, the master unit sends a command to the nearest slave unit to start transmitting repellent sound frequencies for a predetermined period. This sequential activation ensures continuous deterrence as the peafowl moves through the coverage area, tailored to the layout of the farmland to optimize coverage and minimize power consumption. In manual mode, users can activate the system based on specific needs, allowing for immediate response to peafowl threats. To conserve energy, the system enters a hibernate mode during nighttime, activated by LDR-based light detectors, deactivating when peafowls are typically inactive. This design ensures that speakers are active only when necessary, reducing battery drain and enhancing overall efficiency. The customization of the triggering sequence based on farm layout an nce, making it a ver

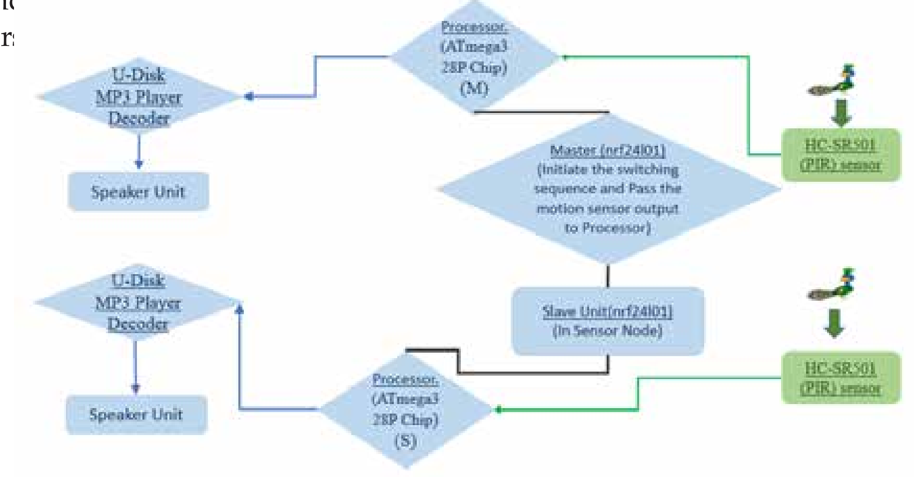

Fig. 7. Triggering Procedure

4 DESIGN AND IMPLEMENTATION

The design and implementation of this system involves several key components and considerations. The system is built around master and slave nodes, with the master node acting as the central control unit that initiates sequences, processes detection signals, and manages communication. Slave nodes are distributed throughout the farmland to detect peafowl movement and transmit data back to the master node. For detection, HC-SR501 IR sensors are used, featuring a 110° cone angle (Fig.6) and a range of up to 7 meters, which can be extended to 14 meters with dual sensor nodes. Sound emitters transmit frequency waves in the 3.4-4.5 kHz range at 65 dB to effectively repel peafowls. The power supply is ensured through embedded solar panels, with a battery backup to maintain operation during nighttime or cloudy days. The implementation steps include strategic placement of nodes around the farmland with optimized distances and angles for maximum coverage, and adjustable node heights between 0.75 m and 1.5 m based on crop type and field conditions. Initial calibration involves adjusting the detection range and sensitivity of the motion sensors, while testing different frequency ranges to identify the most effective repellent frequency. The system operates in both automatic and manual modes. In automatic mode, the system activates upon detecting motion, with the master node coordinating slave nodes to create a sequential wave of sound, directing peafowls away from the crops. In manual mode, users can activate the system as needed. Energy efficiency is maintained by operating the system only when peafowls are detected and switching to hibernate mode at night through LDR-based light detectors to conserve power. Regular monitoring and data collection help analyze the system's effectiveness, allowing for adjustments based on observed patterns and peafowl behavior. Maintenance of solar panels, sensors, and sound emitters is essential to ensure continuous and effective operation. Future enhancements may include the incorporation of advanced detection algorithms, such as machine learning, to improve accuracy and reduce false positives. Expanding coverage by adding more nodes or integrating with other wildlife management systems could help protect larger areas or manage different types of pests. By combining effective design components with a well-planned implementation strategy, the proposed system aims to provide a reliable and sustainable solution for protecting farmlands from peafowl intrusions. Figures 8.a and 8.b illustrate the proposed design of the overall system and its real-time implementation in farmland, respectively. While the master and slave nodes appear identical, their operations differ significantly. The slave nodes are equipped with sensors to detect the presence of peafowls and communicate this information to the master module. Upon receiving a detection signal, the master module commands the slave nodes to transmit frequency waves through their speakers. Although the master module can also detect peafowls and transmit sound profiles, its primary function is to initiate and manage the switching sequence of the system based on motion detection signals from both the slave nodes and itself. In addition, the proposed system is powered by a solar cell capable of providing a maximum output of 12V at 500 mA under the highest intensity of sunlight. The solar cell's output is directed to a 3500mAh (12.5-Watt hours) Li-ion battery via a 5V voltage regulator, allowing the battery to reach its full capacity within 2.5 hours. The battery's output is then applied through a voltage booster to eliminate the resonance of the radio module. This configuration ensures a reliable and sustainable power supply for the system, enabling continuous operation even during nighttime or cloudy days. Fig.15 illustrates the block diagram of the power distribution for a particular node, highlighting the integration of solar power and battery storage to maintain system functionality. By combining these efficient power management components with the strategic design and implementation detailed earlier, the proposed system aims to provide a reliable and sustainable solution for protecting farmlands from peafowl intrusions. Regular monitoring, maintenance, and potential future enhancements will ensure the system remains effective and adaptable to changing conditions and pest behaviors.

Fig. 8.a- Technical appearance of a node

Fig. 8.b-Installed physical appearance of a node

5 RESULTS AND DISCUSSION

Table 5.1 in Appendix 1 provides data on various trials conducted to determine the effectiveness and accuracy of the repellent system across different frequency ranges and power levels.

System accuracy is calculated based on the percentage of successful repellent responses at a given frequency range, distance, and power level. A successful response is recorded when the repellent system effectively deters peafowls, denoted as "Yes" under the "Repellent Response" column. The accuracy percentage increases as the response time decreases, indicating a more effective and quicker deterrence.

The number of trials can be determined by counting the rows in the table, as each row represents a single trial. Each trial involves varying the frequency range, distance, and power level to observe and record the repellent response and the corresponding response time. The system accuracy is then calculated as the percentage of trials that yielded a successful repellent response ("Yes") within a specific response time frame. Moreover, Table 5.1 includes a total of 15 trials, with various frequency ranges, power levels, and corresponding repellent responses. Out of these 15 trials, 12 trials recorded a successful repellent response ("Yes"), while the remaining 3 trials did not achieve a successful response ("No"). The successful trials occur at a frequency range of 3.4 - 4.5 kHz with power levels ranging from 42dB to 65dB. To calculate the overall accuracy, we use the formula:

$$Overall\ accuracy = \left(\frac{No.of\ successful\ trials}{Total\ no.of\ trials}\right) \times 100\% \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

By substituting the values from our analysis:

$$Overall\ accuracy = \left(\frac{12}{15}\right) \times 100\% = 80\%$$

The table demonstrates a systematic approach to testing the repellent system across different configurations. The accuracy of the system improves as the power level increases, especially within the 3.4 - 4.5 kHz frequency range. The data from these 15 trials highlight the conditions under which the repellent system is most effective, providing valuable insights for optimizing the design and deployment of the system in the field. Thus, the overall accuracy of the repellent system, based on the provided data, is approximately 80%. This indicates that the system successfully repelled peafowls in about 80% of the trials.

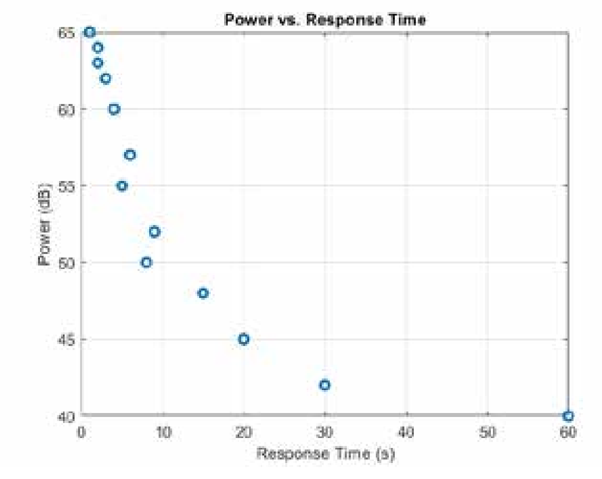

Fig.9. Response time variations with sound intensity (fixed distance 15m)

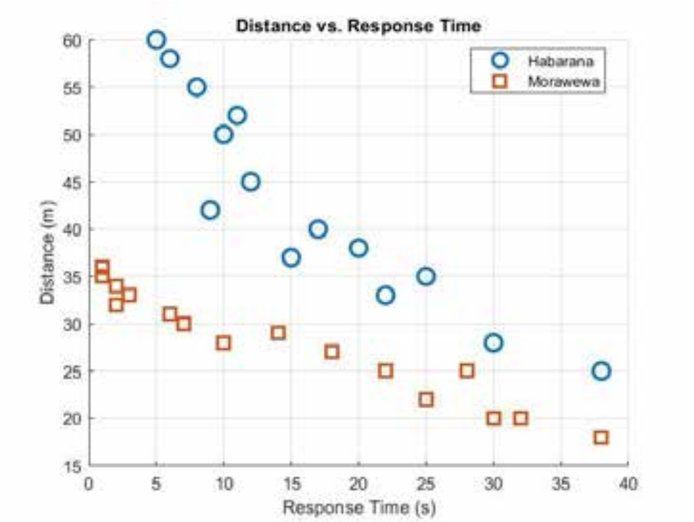

Fig.10. Response time variations with sound intensity at varying distances

5.1 Low Frequency Range measurements (5Hz - 500 Hz)

Peafowls often communicate using low-frequency sounds during various social activities, such as wing-shaking, feather displays, running, and mating rituals. The table 5.4 outlines the specific frequency ranges associated with some of these behaviors.

Table 5.4 Low frequencies related with few peafowl activities.

Activity	Frequency (Hz).
Wing-shaking, when the male flaps his partially unfurled wings (backside facing the female)	5.4
The male vibrates his tail and train while facing toward the female at close range (1 to 1.5 m)	25–28

5.2 Walking, running and flying responses of the peafowls

Field test observations of peafowl responses under different conditions are presented in Table 5.5.

Table 5.5 Responses of peafowls in different conditions

Note*: *While low frequencies do not effectively repel peafowls, they can interfere with their social communication*

Condition	Response time to reach approx. 15m distance (s)
Normal ground feeding	120
With repellent frequency of the proposed system	4
With Low frequency	Stayed still where it was and trying to identify the sound source.

6 CONCLUSION

Peafowls have caused significant damage to harvest and cultivations in many areas of Sri Lanka over the past few years. Reports indicate that in some regions, this problem has become uncontrollable, leading to substantial financial losses for farmers. Initially endemic to dry lands with low altitudes, peafowls have now spread throughout the country, with their population steadily increasing. This research aims to mitigate the damage caused by peafowls to agricultural lands. The proposed system has a dual impact on peafowls. The direct impact involves immediately driving peafowls away from farmlands using a frequency-based repellent system. The repellent network is designed to steer peafowls in a specific direction rather than dispersing them randomly. This directional repellence is more effective in progressively moving peafowls away from farmlands. The second impact is indirect and involves using low frequency sounds similar to those peafowls use for social activities and communication. While these low frequencies may not repel peafowls directly, they can disrupt their social communication and potentially intimidate them. The proposed system is designed to operate on solar power and includes a battery backup capable of powering the system for up to three consecutive days without charging. Furthermore, the system can be adapted to repel other pests such as pigeons, rats, and wild boars, which are common in local farm areas. These enhancements are considered for future developments. Ultimately, the proposed system helps save time and resources for farmers.

In conclusion, the proposed system effectively reduces the damage caused by peafowls to farmlands by employing a frequency-based repellent mechanism. Field tests indicate that peafowls respond quickly to the repellent frequencies, significantly reducing their presence in agricultural areas. The system's ability to disrupt peafowls' social communication further enhances its effectiveness. Additionally, the solar-powered design with battery backup ensures reliable operation, making it a sustainable solution for protecting crops. Future developments could expand its applicability to other pests, thereby broadening its utility for farmers. This research offers a practical and efficient approach to mitigating wildlife-related agricultural damage in Sri Lanka.

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Appendix 1

Table 5.1 Response time variation with sound intensity-at a fixed distance of 15m

Frequency Range (kHz)	Distance (m)	Power (dB)	Repellent Response (Yes/No)	Response Time (s)
2.4 - 3.0	15	30	No	-
3.0 - 3.3	15	35	No	-
3.4 - 4.5	15	40	No	60
3.4 - 4.5	15	42	Yes	30
3.4 - 4.5	15	45	Yes	20
3.4 - 4.5	15	48	Yes	15
3.4 - 4.5	15	50	Yes	8
3.4 - 4.5	15	52	Yes	9

3.4 - 4.5	15	55	Yes	5
3.4 - 4.5	15	57	Yes	6
3.4 - 4.5	15	60	Yes	4
3.4 - 4.5	15	62	Yes	3
3.4 - 4.5	15	63	Yes	2
3.4 - 4.5	15	64	Yes	2
3.4 - 4.5	15	65	Yes	1

Table 5.2 Response time variations with sound intensity at varying distances- *Morawewa* farmlands

Frequency Range(kHz)	**Distance(m)**	**Power(dB)**	**Repellent Response (Yes/No)**	**Response Time(s)**
2.4 - 3.0	5	30	No	80
3.0 - 3.3	10	35	No	72
3.4 - 4.5	15	40	No	60
3.4 - 4.5	18	42	Yes	38
3.4 - 4.5	20	45	Yes	30
3.4 - 4.5	20	44	Yes	32
3.4 - 4.5	22	48	Yes	25
3.4 - 4.5	25	50	Yes	22
3.4 - 4.5	25	46	Yes	28
3.4 - 4.5	27	49	Yes	18
3.4 - 4.5	28	55	Yes	10
3.4 - 4.5	29	52	Yes	14
3.4 - 4.5	30	60	Yes	7
3.4 - 4.5	31	57	Yes	6
3.4 - 4.5	32	63	Yes	2
3.4 - 4.5	33	59	Yes	3
3.4 - 4.5	34	64	Yes	2
3.4 - 4.5	35	65	Yes	1
3.4 - 4.5	36	66	Yes	1

Table 5.3 Response time variations with sound intensity at varying distances- *Habarana* farmlands

Frequency Range (kHz)	**Distance (m)**	**Power (dB)**	**Repellent Response (Yes/No)**	**Response Time (s)**
2.4 - 3.0	10	30	No	83
3.0 - 3.3	18	35	No	76
3.4 - 4.5	20	40	No	55
3.4 - 4.5	25	42	Yes	38
3.4 - 4.5	35	45	Yes	25
3.4 - 4.5	38	48	Yes	20
3.4 - 4.5	40	50	Yes	17

3.4 - 4.5	45	55	Yes	12
3.4 - 4.5	50	60	Yes	10
3.4 - 4.5	55	63	Yes	8
3.4 - 4.5	60	65	Yes	5
3.4 - 4.5	28	44	Yes	30
3.4 - 4.5	33	47	Yes	22
3.4 - 4.5	37	53	Yes	15
3.4 - 4.5	42	58	Yes	9
3.4 - 4.5	52	62	Yes	11
3.4 - 4.5	58	64	Yes	6