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# Performance evaluation of a prototype for the defence against wolf attacks on livestock animals

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ABSTRACT
This study seeks to evaluate a prototype's effectiveness in safeguarding livestock against wolf attacks. With an increasing imperative to protect livestock from predation, the prototype's performance was systematically examined under diverse conditions. The study primarily aimed at assessing the prototype's ability to detect wolf attacks by analyzing noise variations inherent to predator assaults. Simultaneously, the prototype aimed to mitigate livestock casualties and foster coexistence between wolves and livestock. A series of controlled experiments were meticulously carried out, replicating real-world wolf encounter scenarios. The findings yield valuable insights into the prototype's practical utility and its potential to mitigate conflicts between predator populations and livestock farming. Overall, this research contributes to advancing innovative strategies for sustainable cohabitation between wildlife and agriculture.

**Section:** RESEARCH PAPER

**Keywords:** prototype effectiveness; livestock protection; wolf attacks; coexistence strategies; predator-livestock conflicts

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## 1. INTRODUCTION

Predators are experiencing a decline on a global scale [1]. However, the wolf population in Italy has exhibited growth, escalating from approximately 1500 individuals estimated in 2016 [2] to roughly 3307 individuals estimated in 2021 [3]. This surge has led to an escalation in conflicts with human activities, notably livestock farming [4]. The intricacy of this issue [5] is rooted in a confluence of contributing factors, including the absence of dependable and up-to-date data on the magnitude of this phenomenon, the prevalence of extensive livestock practices that are scarcely compatible with the presence of wolves, the prevalence of freely roaming dogs, strays, and wolf-dog hybrids [6], [7], anthropogenic elements that promote the predation process [7], and the potential for human habituation [8].

Given that the majority of documented illegal wolf kills occur in regions characterized by dense farming and substantial damage, addressing conflicts with farmers stands as a primary concern in the context of wolf conservation in Italy [9]. Various preventive measures have been implemented and widely adopted, encompassing the use of guardian dogs, electric fences, animal enclosures, and compensation strategies to mitigate financial losses. Nonetheless, each solution is not without its drawbacks, either due to functional limitations or the associated high costs of implementation.

The objective of this investigation was to assess the efficacy of a prototype designed for safeguarding sheep herds, which relies on detecting alterations in sound patterns that manifest during predator attacks on livestock. The operational concept hinges on detecting changes in the ambient sound pressure (or acoustic intensity) during instances of predation, relative to the baseline norm.

## 2. EARLY WARNING SYSTEM SET UP

The design progression of the predator defence prototype adhered to a systematic approach, commencing with a feasibility study aimed at designing attack warning systems. This path led to the procurement of essential components, which included:

- a directional microphone (Sennheiser brand mod. ME67 powered by K6 modules);
- an Arduino UNO system (electronic board proposed for the realization and acquisition of the firmware related to

Figure 1. The Sennheiser microphone model ME67.

the management of the entire predator defence prototype system);

- an Arduino GSM system (Shield V2 equipped with a switch to detect sounds and convert them into MIDI signals for activation and deactivation).

Finally, a signal processing and microphone power supply board was conceived and executed to carry out the detection of perilous situations within the herd.

### 2.1. Technical features

The prototype's development encompassed the assembly of three primary components:

- a circuitry for signal detection, peak level determination, and amplification;
- a SIM900 shield board for transmitting data via GSM to alert the occurrence of a wolf presence detection;
- an Arduino board for comprehensive system management through a microcontroller.

The core focus of the signal detection, amplification, and peak signal determination circuitry revolved around the Sennheiser microphone model ME67. This microphone capsule, shaped like a club, is well-suited for distant sound recordings and can operate effectively even in noisy environments, as depicted in Figure 1. It boasts smooth directivity, a linear and extended frequency response, and a maximum sound pressure level of 125 dB.

The ME67 microphone's signal is acquired and processed by the electrical circuit outlined in Figure 2. Consequently, a specialized printed circuit board was developed and constructed to condition the acoustic signal detected by the ME67 microphone.

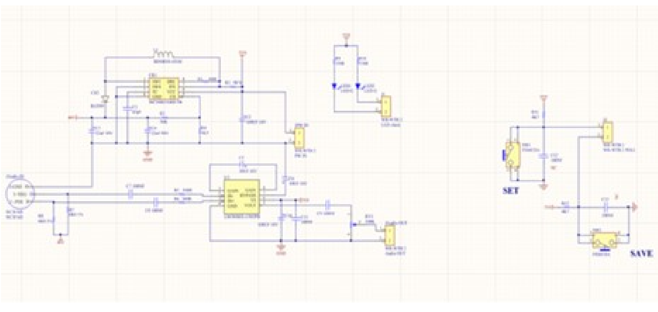

Figure 2. ME67 microphone acoustic signal processing scheme.

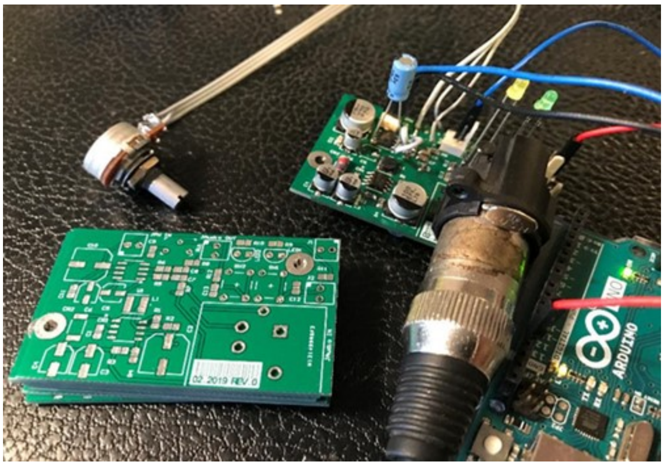

Figure 3. Printed circuit board made for processing the acoustic signal detected by the ME67 microphone.

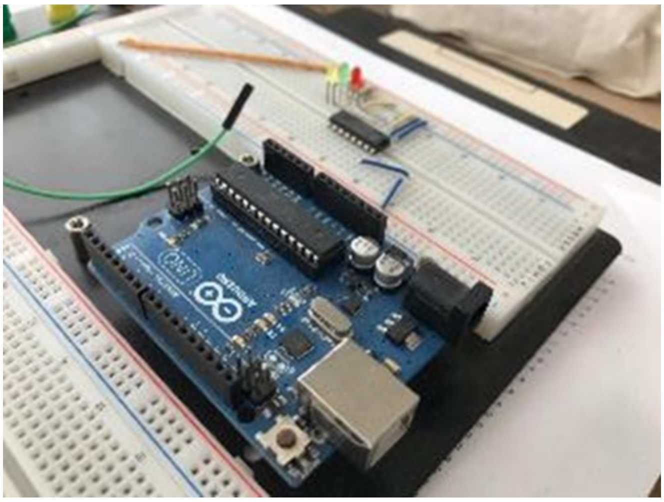

Figure 4. Arduino UNO system overview.

This circuitry integrates a female XLR connector to the ME67 through a balanced cable. By virtue of the MC34063ABD integrated circuit, this connection supplies phantom voltage (48V DC) to power the ME67. The signal, capacitively isolated by components C7 and C8, is captured by the LM386MX integrated amplifier. This amplifier undertakes the task of magnifying the acoustic signal to align with the range compatible with the Arduino UNO management system.

The output from the operational amplifier undergoes amplitude and intensity adjustments using the logarithmic potentiometer RV1. Subsequently, it is subjected to processing by a levelling diode to detect and sustain the peak value.

In essence, the detection and amplification system power the ME67 condenser microphone and inform the management system about acoustic noise detection surpassing a predefined threshold. This prompts the transmission of an alarm signal to the Arduino UNO system manager (Figure 3).

The Arduino UNO management system consists of a hardware platform comprising various electronic boards outfitted with microcontrollers (Figure 4).

Arduino serves as a hardware platform for physical computing, integrating a microcontroller with I/O port-connected pins, a voltage regulator, and optionally, a USB interface for programming-related communication. This hardware is complemented by a cross-platform Integrated Development Environment (IDE), accessible on Linux, Apple,

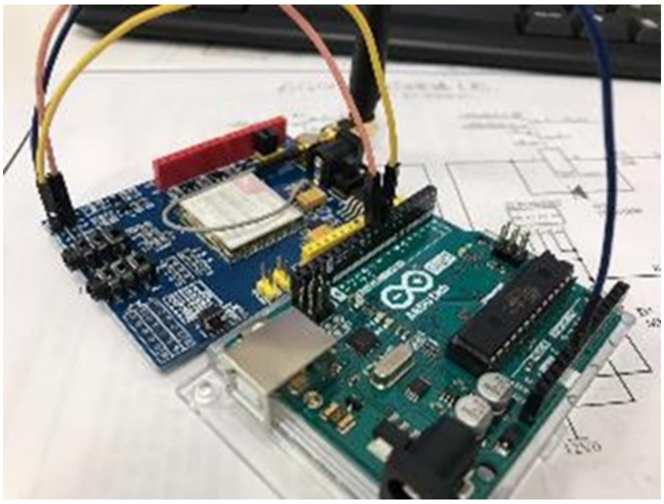

Figure 5. GSM Shield V2 SIM900 electronic board for Arduino.

and Windows systems. The IDE facilitates work with Arduino, even for less experienced individuals, due to its user-friendly and intuitive programming language, Wiring. Arduino proves versatile, suitable for both standalone interactive object development and seamless interaction with computer-resident software like Adobe, Flash, Processing, Max/MSP, Pure Data, and Super Collider.

The GSM Shield V2 GPS SIM900 Shield electronic board for Arduino (depicted in Figure 5) is adept at accommodating GSM/GPRS and GPS modules from the SIMCom family, such as SIM900 (with GSM/GPRS functionality) and SIM908 (with GSM/GPRS and GPS capabilities). These modules are efficiently controlled through a serial interface and a UART for connection management. This enables functionalities like voice calls, SMS transmission, and internet connectivity. Updated libraries facilitate software development, offering extensive configuration options for module utilization and the creation of voice, data, or web-based applications. High-level functions can be invoked with straightforward calls, permitting operations such as reading received SMS, initiating calls, and other functions akin to a standard mobile phone.

The board, compatible with Arduino 2009 and Arduino UNO, features two sockets for analogue audio flow. Utilizing a microphone and a headset equipped with a 3.5 mm jack (a standard computer headset suffices), one can engage in comprehensive voice calls. Upon receiving a call, the headset emits a ringtone, serving as an alert for incoming calls. Within the Shield, a high-capacitance capacitor is designated for the Real Time Clock (RTC) embedded within the SIM900. This ensures accurate timekeeping even when power is absent.

The entirety of the circuit operates on a 12 V DC supply voltage derived directly from the Arduino board. During power-intensive operations, like GPRS usage, the module exhibits current peaks of around 1A. Consequently, the power source must be equipped to furnish this level of current.

The Shield accommodates a connector for an external rechargeable lithium battery with a nominal voltage of 3.7 V. The necessary voltage for charging the battery is sourced directly from the Arduino board. The Shield's maximum dimensions measure 100 mm × 57 mm.

### 2.2. Development of the prototype management program

The central system responsible for overseeing and transmitting alarm signals was developed within the Arduino

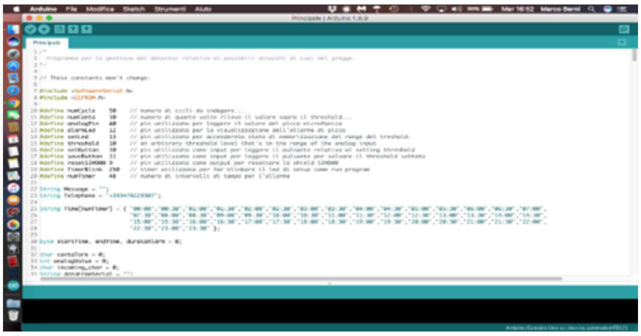

Figure 6. Source code that allows the detection of sound variation.

Integrated Development Environment (IDE). A dedicated script (Figure 6) was crafted to handle signals during situations of alarm, such as when the herd is perturbed due to a predator attack. If such an alarm endures for the predetermined duration (for instance, 2 seconds or more), Arduino triggers the transmission of an alert message via SMS to a designated telephone number. This process is facilitated by the Arduino GSM Shield V2 GPS SIM900. Arduino offers an interface through a USB Type-B port, allowing users to configure different phone numbers for sending the danger message during setup. This can be done using a straightforward terminal management program (Figure 7). This approach within the Arduino IDE ensures efficient management and timely dissemination of alerts in response to predator-induced alarms, contributing to the efficacy of the predator defence system.

### 2.3. Development of interfacing program for prototype settings

The user interface application (Figure 7), developed for configuring device parameters, was created using ECLIPSE as the Integrated Development Environment (IDE). The code, written to ensure optimal compatibility across various operating systems, was crafted using the JAVA programming language.

This application identifies the connected device via the USB Type-B port, enabling easy and intuitive parameter programming. Within the application, users can establish the phone number to which the alarm signal should be sent, specify the message content, and set the activation time interval - designating the window during which alarm messages are


Figure 7. Application interface made to set the phone number to which to send alarm SMS messages and the operating time of the prototype.

Figure 8. Detail of the prototype highlighting the acoustic detection threshold controller (potentiometer) and LED.

dispatched. Once configured, these settings are automatically stored on the device and remain in place until modified.

Within the designated time interval, if the device detects a sound surpassing the threshold specified via hardware calibration performed on the potentiometer, an alert message is transmitted to the designated mobile phone number. This systematic approach enhances the operational efficiency and reliability of the entire predator defence system.

### 2.4. LED operation and alarm threshold calibration of the prototype

On one side of the device, an XLR microphone connection is situated, facilitating the attachment of the Sennheiser model ME67 microphone. This microphone captures sound within the designated monitoring area.

At the upper section of the device, two LEDs are positioned: a green LED and an orange LED (Figure 8). The green LED, when blinking, indicates the ongoing operation of the device. The orange LED, when lit, signifies the detection of an acoustic signal surpassing the pre-set threshold. This aspect is particularly crucial during the installation phase, aiding users in fine-tuning the alarm threshold. Additionally, a knob coloured in yellow and black is present, enabling the adjustment of microphone sensitivity. This comprehensive setup streamlines the process of sound detection, threshold configuration, and real-time status assessment within the monitored environment, enhancing the device's functionality and usability.

## 3. TEST PHASE

Two prototypes were subjected to installation and testing within a farm environment. The first prototype was positioned in proximity to the barn, while the second prototype found its location near the night animal pen. The selection of these installation sites was driven by the overarching requirements of the system: the microphone necessitated a sheltered spot, shielded from adverse weather conditions (as depicted in Figure 9), and the prototype was situated in the vicinity of an electrical outlet. Moreover, the chosen installation sites must be within the coverage of the phone network to ensure the reception of alert messages.

After placing the microphone in its designated spot, it was connected to the prototype, which, in turn, received power from an electrical outlet. Following this, the prototype underwent configuration. This configuration process necessitates a computer, an internet connection, and the requisite cable for establishing a connection between the computer and the prototype. These installations and the subsequent configuration mark crucial steps in ensuring the prototypes' functionality and integration into the monitoring system.

Figure 9. Installation of the microphone with clamps under the eaves of the barn to remain sheltered from the weather.

The process begins by installing the program on the computer using the provided download link and an internet connection. Upon successful installation, the prototype must be connected to the computer via a USB port using the appropriate cable. Once the program is opened, the configuration process can commence.

During configuration, users input their cell phone number for receiving communications, specify the desired message content (e.g., "night alarm"), and establish the operational time frame (e.g., 9 p.m. to 5 a.m.). Once this information is sent to the prototype, the green LED illuminates steadily, transitioning to a blinking state upon successful acquisition of the data.

A pivotal step in the installation is the hardware calibration of the potentiometer (Figure 8). As the orange LED indicates acoustic noises, calibration is essential to ensure that this light deactivates in the presence of common background noises. This approach ensures that alert messages are dispatched solely in scenarios involving persistent barking of guard dogs or notable herd movements—both typically indicative of potential threats such as wolves, foxes, and stray dogs.

Adverse weather conditions, like strong wind or rain, necessitate microphone sensitivity adjustments to account for varying circumstances.

Subsequently, the time interval between abnormal noise detection and the sending of an alarm message must be configured. It is important to set a minimum duration for the acoustic stimulus to prevent frequent false alarms arising from brief, high-volume noises.

To calibrate the prototype in the field, tests were conducted at 7 different sound threshold levels (ranging from 30 to 130 dB) using pre-recorded sounds. These measurements were taken using a UNI T model UT 353 BT sound level meter under various environmental conditions, such as rain, light, and strong wind.

Once the microphone's sensitivity at different potentiometer positions is established, the appropriate operational range can be determined to ensure alarm messages are only sent for abnormal noises. To facilitate this determination, noise levels were measured in various scenarios. Initially, ambient noise levels were measured in a quiet setting, such as a barn environment with few present animals during the day when most are grazing. Stable weather conditions and low noise due to daily tasks also characterized this environment.

Obviously, in case of particularly adverse weather conditions such as days with strong wind or rain, it necessary to adjust the sensitivity of the microphone according to the contingent conditions.

Now, it is necessary to set the timelapse between abnormal noise signal detection and alarm message sending. At this scope it is important to consider a minimum duration of the acoustic stimulus for avoiding frequent false alarms determined by high sound level noises of short duration.

Additional measurements were conducted during the operational hours of the milking facilities, which should be taken into consideration if the prototype is intended to remain active during daylight hours. Milking operations typically occur during the early morning and late afternoon hours.

The prototype's calibration encompassed measurements of atmospheric noises like rain and breezes. Additionally, noise produced by barking dogs and the movement of the herd were measured. These specific noises could signify the commencement of a predatory event. Instead of treating these points as thresholds to be avoided to prevent the microphone from registering such noises, they were configured to be detected. This approach allows the system to perceive and issue alerts in the event of an attack.

The combination of testing under various conditions—ranging from atmospheric sounds to animal activities—enabled a comprehensive calibration of the prototype, ensuring its responsiveness to genuine threats while mitigating the likelihood of false alarms.

## 4. RESULTS AND DISCUSSION

The ambient noise registered by the sound level meter near the night enclosure ranged from a maximum of 52.4 dBA to a minimum of 36 dBA, with an average of 45.1 dBA. Similarly, in the quiet setting near the barn, the maximum noise reached 40.2 dBA, the minimum was 35.1 dBA, and the average measured 37.65 dBA.

Measurements were also taken during the operation of milking machinery, which predominantly occurs in the early morning and late afternoon hours. When the milking equipment was activated, the noise recorded by the sound level meter near the prototype installed in the barn reached 53.2 dBA at maximum and dropped to a minimum of 36.3 dBA, with an average reading of 44.75 dBA.

This analysis indicated that the prototype situated near the barn remained relatively unaffected by the activation of the milking machinery. Such assessments provide essential information for differentiating abnormal noises—like those of potential predators—from routine operational sounds, ensuring that the alert system responds accurately to legitimate threats. Figure 10 offers a visual representation of these noise levels.

Near the prototype positioned in close proximity to the night pen, the noise level reached a maximum of 62.3 dBA and dipped to a minimum of 56.4 dBA, with an average measurement of 59.3 dBA. This elevated value compared to the previous measurement can be attributed to the proximity of milking machinery to the prototype (Figure 11).

When the herd is in motion, the noise originates from the moving animals, their bells, and the sheep's bleating. In this scenario, the maximum perceived noise escalated to 82.6 dBA, the minimum recorded at 64.9 dBA, and the average noise level registered at 73.7 dBA. Figure 12 provides a visual representation of the noise levels captured by the sound level meter.

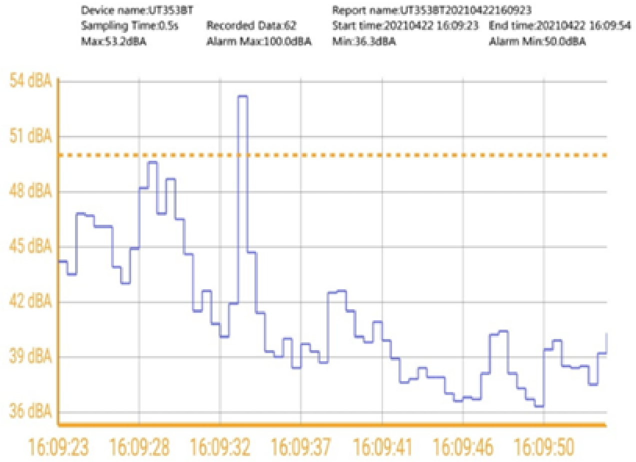


Figure 10. Graph of perceived noise with milking equipment started near the barn.

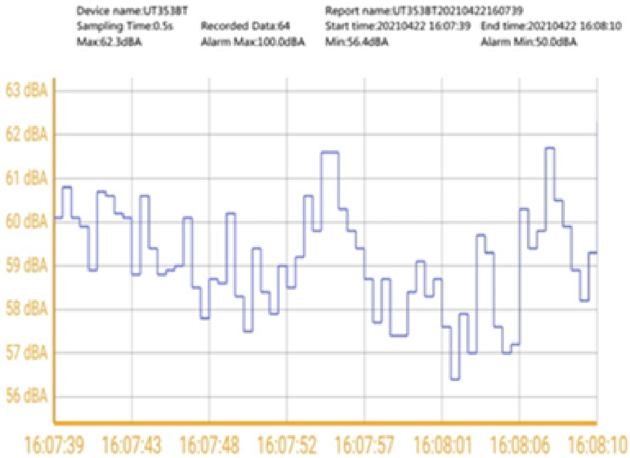


Figure 11. Graph of perceived noise with milking plant started near the night animal pen.


Figure 12. Noise produced by moving livestock.

These detailed measurements allow for a comprehensive understanding of the range of noises occurring in different operational contexts. Such knowledge is crucial for effectively distinguishing abnormal sounds, such as those associated with potential threats, and tuning the system's sensitivity parameters accordingly.

The noise emanating from barking dogs in a tranquil environmental setting, potentially due to the presence of an unfamiliar animal (like a predator), is depicted in Figure 13. In this scenario, the sound level meter recorded a maximum noise of 107.2 dBA, a minimum of 46.8 dBA, and an average measurement of 77.0 dBA.

During a predation event, both the circumstances outlined earlier (barking dogs and moving livestock) can occur simultaneously. However, inducing both situations simultaneously for measurement purposes is challenging. Nevertheless, the sound pressure values can be combined using a specialized mathematical formula.

The sound levels connected with the state of herd agitation were combined using the following formula:

$$Lp_{\mathrm{tot}} = 10 \cdot \log_{10} \sum_{i=1}^{n} 10^{\frac{Lp_i}{10}} \; , \tag{1}$$

where $Lp_i$ were sounds with different levels.

The system successfully operated by consistently transmitting signals via text messages whenever the predetermined noise threshold was exceeded. However, a limitation is encountered in configuring the acoustic intensity threshold that triggers the prototype's activation. This challenge arises due to the substantial range of noise variation (as depicted in Figure 14) in response to brief, non-continuous sound pulses over time, such as the passage of an agricultural vehicle or the barking of dogs.

For instance, in the latter scenario, the range of perceived acoustic intensity can vary from 46.8 to 107.2 dBA over a span of 30 seconds. Moreover, peak values can persist for 5-6 consecutive seconds.

In alternate circumstances, like driving rain or strong winds, a consistent high level of acoustic intensity is present, which remains constant over time. This unvarying noise level inhibits the instrument's capacity to discern the "additional" noise generated during a predation event.

This variability in noise patterns poses a challenge in defining a single threshold value that adequately distinguishes between genuine threats (e.g., predatory activities) and routine background noises or environmental factors. The need to strike a balance between sensitivity and specificity in setting the acoustic intensity threshold is a key consideration for ensuring accurate and reliable operation of the prototype.

## 5. CONCLUSIONS

The concept of human-wolf coadaptation stands as a pivotal element in fostering a sustainable coexistence [10]. As with any adaptation process, a period of time is necessary for the establishment of appropriate mechanisms [6]. Directed management strategies can play a vital role in enhancing harmony between productive aspects and the wolf, even through the valorisation of related ecosystem services [11].

Safeguarding livestock farms from attacks by wolves and free-ranging dogs holds significant importance not only for preserving the livelihood of livestock farmers but also for the conservation of wolf populations.

Throughout this research stage, the primary challenge encountered is accurately configuring the acoustic intensity threshold for activating the prototype. While relatively straightforward in quiet environments, this task becomes more intricate as environmental conditions change. Particularly, calibrating the threshold in scenarios involving short, non-continuous sounds like passing farm vehicles or barking dogs proves exceedingly complex. Similarly, under conditions of heavy rain or strong wind, a consistent high acoustic intensity

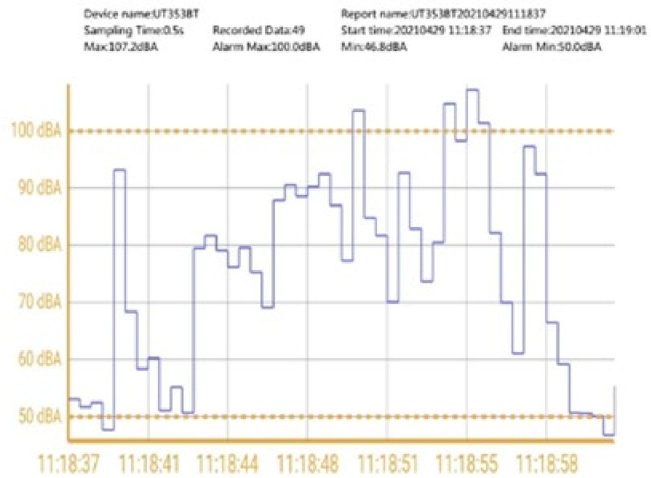


Figure 13. Noise produced by barking dogs.

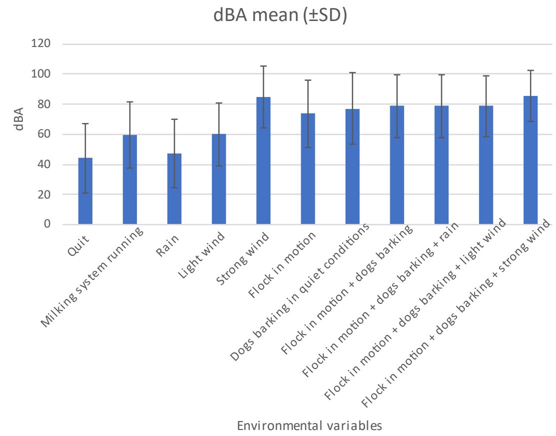


Figure 14. Intensity of noise (± SD) detected for different environmental situations.

level persists, hindering the prototype's optimal detection of the "additional" noise generated during predatory events. Determining an effective time interval between detecting abnormal noise signals and transmitting alarm messages is also intricate. Striking a balance between preventing frequent false alarms caused by brief, high-intensity sounds (e.g., slamming doors) and ensuring a swift, efficient response by farmers presents a challenge.

To mitigate false positives, future iterations of the hardware and software system should include mechanisms for filtering out sounds unrelated to the "typical" farm environment (such as wind or rain). Incorporating video recording systems can complement this by aiding in identifying noise types and facilitating prompt farmer intervention during genuine attacks.

One potential avenue for future development involves integrating an artificial intelligence (AI) algorithm into a controller directly usable in the field. This enhancement would allow the system to be dynamically adjusted to real-time field conditions, encompassing the activation threshold and time interval.

Another avenue entails constructing a more intricate system where alerts to farmers are triggered after analysing the detected harmonic series, not solely relying on acoustic intensity. This approach could better differentiate between various environmental scenarios encountered on a farm.

Overall, addressing these challenges and incorporating advanced features promises to enhance the accuracy, effectiveness, and applicability of the prototype system, contributing to improved human-wolf coexistence and the protection of livestock farms.

## REFERENCES


[1] J. Fernández-Sepúlveda, C. A. Martín, Conservation status of the World's carnivorous mammals (order Carnivora), Mamm. Biol. 102 (2022), pp. 1-15.
DOI: 10.1007/s42991-022-00305-8

[2] M. Galaverni, R. Caniglia, E. Fabbri, P. Milanesi, E. Randi, One, no one, or one hundred thousand: how many wolves are there currently in Italy?, Mammal Res. 61 (2016), pp. 13-24.
DOI: 10.1007/s13364-015-0247-8

[3] V. La Morgia, D. D. Angelis, P. Aragno, V. Salvatori, V. Gervasi, D. De Angelis, E. Fabbri, R. Caniglia, (+4 more authors), Stima della Distribuzione e Consistenza del Lupo a scala nazionale 2020/2021, Technical Rel. carried out within the framework of the ISPRA-Ministry of Ecological Transition agreement "Attività di Monitoraggio Nazionale nell'ambito del Piano di Azione del Lupo" (2022), pp. 4–16. [In Italian].

[4] S. Lovari, A. Sforzi, C. Scala, R. Fico, Mortality parameters of the wolf in Italy: does the wolf keep himself from the door?, J. of Zoo 272(2) (2007), pp. 117–124.
DOI: 10.1111/j.1469-7998.2006.00260.x

[5] P. Ciucci, L. Boitani, Conflitto tra lupo e zootecnia in Italia: metodi di studio, stato delle conoscenze, prospettive di ricerca e conservazione, Biol. Cons. Fauna 115 (2005), pp. 26-51. [In Italian]

[6] V. Gervasi, V. Salvatori, G. Catullo, P. Ciucci, Assessing trends in wolf impact on livestock through verified claims in historical vs. recent areas of occurrence in Italy, Eur. J. of Wildl. Res. 67 (2021), 82.
DOI: 10.1007/s10344-021-01522-1

[7] P. Viola, S. Adriani, C. M. Rossi, C. Franceschini, R. Primi, M. Apollonio, A. Amici, Anthropogenic and environmental factors determining local favourable conditions for wolves during the cold season, Animals 11(7) (2021), pp. 1895.
DOI: 10.3390/ani11071895

[8] P. Viola, P. Girotti, S. Adriani, B. Ronchi, M. Zaccaroni, R. Primi, Does the wolf (Canis lupus) exhibit human habituation behaviours after rehabilitation and release into the wild? A case report from Central Italy, Animals 12(24) (2022), pp. 3495.
DOI: 10.3390/ani12243495

[9] L. Boitani, V. Salvatori, Piano di conservazione e gestione del lupo in Italia (Gennaio 2017), Action Plan in collaboration with: Ministry of the Environment and Protection of Land and Sea, ISPRA, Unione Zoologica Italiana (2017). [In Italian].

[10] N. H. Carter, J. D. C. Linnell, Co-adaptation is key to coexisting with large carnivores, Trends Ecol Evol. 31(8) (2016), pp. 575–578.
DOI: 10.1016/j.tree.2016.05.006

[11] N. Piscopo, L. Gentile, E. Scioli, V. G. Eguren, A. M. Carvajal Urueña, T. Y. García, J. P. Alberti, L. Esposito, Management models applied to the human-wolf conflict in agro-forestry-pastoral territories of two italian protected areas and one spanish game area, Animals 11(4) (2021), art. no. 1141.
DOI: 10.3390/ani11041141