Received 03.03.2026 Revised 01.06.2026 Accepted 24.06.2026 Published: 14.08.2026

Vol. 22, No. 4
2026

Scientific Reports of the National University of Life and Environmental Sciences of Ukraine

Journal homepage: https://scireports.com.ua/en e-ISSN 2223-1609

UDC 612.85:599.742.71:534.836 DOI: 10.31548/dopovidi/4.2026.127

Biophysical aspects of anthropogenic noise impact on the auditory system of *Felis catus* in various ecological niches

Olena Martynova*

PhD in Technical Sciences, Associate Professor
Odesa State Agrarian University
65012, 13 Panteleimonivska Str., Odesa, Ukraine
https://orcid.org/0000-0001-7324-2543

Abstract. Anthropogenic noise is considered an important physical factor of the urban environment that may modify behavioural, neurophysiological and sensory responses in the domestic cat *Felis catus*. The aim of this study was to conduct a meta-analytical synthesis of scientific evidence on the effects of household, traffic, clinical and other anthropogenic noise on the auditory system of *Felis catus* in different ecological niches. The study used systematic literature searching, comparative analysis of experimental and clinical studies, qualitative meta-analysis, normalisation of acoustic indicators in dB, Hz and kHz, and synthesis of data on behavioural, cardiovascular, endocrine and neurological responses. Noise sources acting in the home, veterinary clinic, shelter, hospital environment and open urban space were examined. It was found that cats, owing to their broad hearing range and their ability to respond to high-frequency and ultrasonic stimuli, may show stress responses even to sounds perceived by humans as ordinary household noise or as relatively low-intensity signals. The results of the study showed that as noise frequency increased, cats experienced stress, and the functioning of their cardiovascular system deteriorated. Additionally, noise can affect the endocrine system, as stress leads to the release of excessive amounts of hormones, which in turn affect the functioning of the entire organism. There was also a deterioration in hearing due to an increase in the frequency at which sounds were perceived, which subsequently led to the development of symptoms of deafness. Thus, sounds that humans perceive as ordinary and everyday are stressful for animals and can influence changes in their behaviour. In addition, prolonged exposure to anthropogenic noise can cause deafness in animals, leading to complete or partial hearing loss. The practical value of the study lies in the possibility of using the obtained results by veterinarians, shelter staff, cat owners and bioacoustics researchers when designing acoustically environments for *Felis catus*

Keywords: domestic cat; frequency; external ear; stress; deafness; human activity

Suggested Citation:
Martynova, O. (2026). Biophysical aspects of anthropogenic noise impact on the auditory system of *Felis catus* in various ecological niches. *Scientific Reports of the National University of Life and Environmental Sciences of Ukraine*, 22(4), 127-140. doi: 10.31548/dopovidi/4.2026.127.

**Corresponding author (Slyvka_UNU@proton.me)*

Introduction

The problem of anthropogenic noise goes beyond the traditional understanding of noise pollution as a source of discomfort for humans. For the domestic cat (*Felis catus*), noise is not merely an acoustic background but a sensory stimulus that can alter orientation, avoidance behavior, the quality of rest, and physiological balance. This issue becomes particularly significant in urban environments, where the animal is simultaneously exposed to traffic, household appliances, electronic signals, clinical noise, construction sounds, loud music, and sudden, abrupt stimuli. The practical significance of the topic stems from the fact that most of these sounds are perceived by humans as a normal part of the residential or professional environment, whereas for a cat with a wider hearing range, they may have a different intensity and biological significance. The theoretical importance of the study stems from the need to integrate a biophysical understanding of auditory perception, neurophysiological mechanisms of stress, and modern approaches to animal welfare. Underestimating the acoustic environment can lead to misinterpretation of behavioral changes, where fear, avoidance, aggression, or litter box issues are attributed solely to the animal's "temperament" rather than sensory overload. Therefore, studying the impact of anthropogenic noise on *Felis catus* is relevant both for veterinary practice and for creating a safe home, clinical, and shelter environment.

Anthropogenic noise is relevant to feline welfare because it may alter how a cat detects, interprets and avoids biologically meaningful signals. H.P. Kunc & R. Schmidt (2019), in a cross-taxon meta-analysis, Pdemonstrated that behavioural effects of anthropogenic noise are repeatedly reported across animal groups, although effect magnitude varies strongly among studies. A.C.M. Kok *et al*. (2023) extended this perspective from individual responses to community-level consequences of chronic noise, emphasising that prolonged exposure can modify interactions among organisms. L. Terray *et al*. (2025) mapped the recent evidence on airborne anthropogenic noise and identified strong taxonomic and methodological unevenness; domestic cats remain far less studied than many wildlife groups.

The available feline evidence suggests that risk is context-dependent. N. Furgala *et al*. (2022) showed that veterinary background noise elicited fear-related responses in cats moving freely in a confined space. B. Eagan *et al*. (2021) recorded greater fear-related behaviour in shelter cats during noisier observation periods, particularly after transitions from quiet to noisy conditions. Girão *et al*. (2024) examined hospitalised cats and found that behavioural stress scores, respiratory rate and plasma cortisol generally increased as ward noise level and exposure time increased. High-frequency sound additionally has clinical relevance for a subset of cats.

The aim of the study was to conduct a analysis of scientific data on the impact of anthropogenic noise on the auditory system of *Felis catus* in order to identify patterns between the acoustic characteristics of noise, the biophysical mechanisms of auditory perception, behavioral manifestations of stress, and the risks of hearing impairment. Research objectives:

- to systematise the structural features of the auditory system in cats;
- establish the frequency and intensity of noise in the apartment;
- analyse the impact of noise on the health of cats and the functioning of the cat's auditory system.

The study focused on the auditory system and the associated behavioral and physiological responses of *Felis catus* in various ecological niches. The subject of the study was the intensity, frequency, duration, and source of anthropogenic noise, as well as cats' reactions to domestic, transportation, clinical, hospital, and shelter acoustic stimuli. Methodologically, the study was conducted as a analytic review. Sources were selected from PubMed, Scopus, Web of Science, ScienceDirect, SpringerLink, Cambridge Core, MDPI, Frontiers, and Google Scholar database for the period from 1985 to 2025. Using the following keywords: "domestic cat", "frequency", "external ear", "stress, deafness", "human activity". Inclusion criteria were the presence of data on *Felis catus* or relevant models of noise impact on animals; a description of acoustic parameters, specifically dB, Hz, kHz, or the type of sound stimulus; an assessment of behavioral, physiological, neurological, or auditory consequences; a clear description of the sample or study design; and the availability of bibliographic data. Exclusion criteria included publications lacking a scientific framework, promotional materials, texts where the author or source could not be identified, as well as reports in which noise was mentioned without any connection to hearing, stress, or animal welfare. The quality of sources was assessed based on the completeness of the sample description, the transparency of the intervention methodology, the presence of a control group or a comparative design, the accuracy of outcome measurement, and the consistency of conclusions with the data obtained.

Sources of anthropogenic noise and the biophysical characteristics of *Felis catus* hearing

In literature, acoustic stress is increasingly viewed as an interdisciplinary issue that brings together bioacoustics, ethology, ecology, neurophysiology, and veterinary medicine. C. Duarte *et al.* (2021), H. Slabbekoorn *et al.* (2018) in a comprehensive review of changes in the Anthropocene sound environment, demonstrated that anthropogenic sounds can disrupt animal communication, orientation, and behavioral responses. G. Arcangeli *et al.* (2023), J. Marlow (2025), P. Benz *et al.* (2024) in synthesising data on the neurobehavioral effects of noise in animals, concluded that prolonged or intense noise can influence anxiety, cognitive responses, activity, and stress response.

For a household cat, anthropogenic noise is a heterogeneous exposure rather than a single measurable variable. The relevant physical characteristics are sound pressure level, frequency spectrum, temporal pattern, intermittency, duration, distance from the source and acoustic properties of the room. A vacuum cleaner, extractor hood or washing machine can produce a relatively high continuous level, whereas a dropped metal object, an alarm signal or a printer notification is brief but abrupt and may contain salient high-frequency components. C. Kight & J. Swaddle (2011) argued that such distinctions determine whether sound masks meaningful cues, diverts attention or is perceived as a threat. G. Arcangeli *et al.* (2023), in a systematic review of neurobehavioural alterations from noise exposure in animals, summarised changes in anxiety-like behaviour, cognition and neuroendocrine responses, but the included evidence was predominantly experimental and cannot be directly converted into feline household risk estimates. Consequently, an exposure assessment based only on a single decibel value is insufficient for interpreting a cat's response.

The biological significance of these acoustic features is determined by the feline auditory apparatus. Sound waves enter the external auditory canal, displace the tympanic membrane and are transmitted through the ossicular chain to the cochlea. Within the cochlea, inner hair cells transform mechanical stimulation into neural signals, whereas outer hair cells contribute to cochlear amplification and frequency selectivity. Middle-ear muscle reflexes can attenuate sustained loud sound to a limited extent but are not fast enough to provide complete protection from abrupt impulse-like events. G. Strain (2017) emphasised that hearing disorders in cats have diverse congenital, inflammatory, traumatic, toxic and age-associated causes; therefore, a behavioural reaction to sound cannot be treated as evidence of noise-induced hearing loss without clinical assessment.

M. Martin *et al.* (2022) analysed chronic anthropogenic noise as a factor that can alter not only individual behavior but also interspecific interactions and the structure of biotic communities. R. El-Dairi *et al.* (2024) summarised the physiological and molecular responses of marine biota to noise, which is important for understanding the general principles of how an acoustic stressor affects the organism. L. Terray *et al.* (2025), in a systematic review of studies on anthropogenic airborne noise, noted the rapid increase in the number of publications but also pointed out the uneven coverage of different taxonomic groups.

In studies directly related to *Felis catus*, the focus has shifted from the general ecological effects of noise to clinical, behavioral, and sensory consequences. Cats can react to alarming sounds due to their high sensitivity, which humans may not even be aware of. All this can be seen in the animal's negative behavior, for example, scratching furniture, aggression, and excitability, urinating outside the litter box when the cat is alone at home - all of which are signals that the animal is reacting to unpleasant sounds. Among the anthropogenic noises in the apartment and yard can be the roar of the oven, trucks passing by on the road, the operation of computer equipment and electronic devices, as well as other sounds that are part of everyday life (Wright *et al.*, 2007; Pelletier, 2019; Marlow, 2025).

In a normal cat's ear, sound vibrations occur in the ear canal due to alternating compressions and rarefactions. These create vibrations in the eardrum, which are transmitted by the three bones of the middle ear (the malleus, anvil, and stirrup) to the oval window of the inner ear. In this case, the outer hair cells provide a reduction in auditory sensitivity. The brain has a mechanism for protecting itself from loud sounds - the cochlea - through the action of two muscles of the middle ear: the eardrum and the stapes muscle. These muscles contract reflexively to loud sounds and thus reduce the transmission of sound through the ossicles. However, this protective reflex is not fast enough to protect against impact sounds, such as gunshots.

Reflex contractions of the tympanic membrane and stapes muscles are protective mechanisms to reduce noise transmission to the middle ear, but do not provide protection against impact sounds such as gunshots. Noise exposure can be a temporary shift in the perception threshold, in which hearing is restored within hours or days, or a permanent shift in the threshold, which is irreversible, in which case the hearing loss is cumulative, primarily affecting the hair cells (Strain, 2017). B. Eagan *et al.* (2021), R.H. Pieniazek *et al.* (2023), studied the impact of shelter sounds on cat behavior and found that noisy periods were associated with more frequent fear-like reactions, whereas a transition to silence reduced signs of stress. N. Furgala *et al.* (2022) investigated background noise in a veterinary clinic and demonstrated that free-roaming cats exhibited more signs of fear and stress under conditions of noise exposure. M. Girão *et al.* (2024), G. Georgiou & A.D. Galatos (2025) established a link between noise levels in a hospital setting and the severity of the stress response in hospitalised cats, specifically as measured by behavioral indicators, respiratory rate, and cortisol levels. A. Tateo *et al.* (2021) described fear factors during veterinary examinations and demonstrated that the clinical context is an independent source of sensory stress. In addition, travel, changes in the home environment, and interaction with strangers or pets also have a negative impact on cats' well-being (Weller *et al.*, 2024).

The environment is filled with industries, sounds of transport, music, vibrations, which have ultrasonic frequencies that are inaccessible to human perception. However, they are well perceived by animals, especially pets, for example cats. Table 1 shows the number of decibels emitted by appliances in the apartment and by people.

Table 1. *The strength of sounds heard in an apartment, in decibels*

Instrument	Volume (dB)
TV	70-10
Vacuum cleaner	60-85
Dishwasher	55-70

Table 1. *Continued*

Instrument	Volume (dB)
Kitchen unit	80-90
Washing machine	50-75
Clock	20
Refrigerator humming	40
People	
Conversation	60
Whisper	30

Source: created by the author based on R. Heffner & H. Heffner (1985), C. Kight & G. Swaddle (2011), Your cat lives (2025)

The values in Table 1 should be interpreted as approximate source levels rather than as individual feline exposure values. They vary with appliance model, maintenance condition, operating mode, distance to the animal, door position, room size and reverberation. Whereas a food processor or vacuum cleaner produces a much higher level but usually for a shorter time. In a small reflective room, the latter can be difficult for a cat to avoid. Conversely, a short metallic impact may have a lower average level than a long appliance cycle while still provoking a pronounced startle response because of its sudden onset and spectral content.

Traffic and construction contribute a different pattern of exposure. Road traffic creates a mixture of low-frequency engine and tyre noise, intermittent peaks from acceleration, horns and braking, and vibration transmitted through windows and building structures. H.P. Kunc & R. Schmidt (2019) found considerable between-study variation in animal responses to anthropogenic noise, which supports the view that neither source category nor average level alone predicts outcome. A.C.M. Kok *et al*. (2023) further noted that chronic noise can affect organisms through repeated disruption of communication, vigilance and habitat use. For an indoor cat, traffic may be less direct than a nearby appliance, but it can become relevant when the animal has no access to an acoustically protected resting area.

Direct feline evidence is strongest for the behavioural consequences of noise in controlled clinical and shelter contexts rather than for everyday household appliances. This distinction matters: data from institutional settings cannot be converted into a universal household threshold, and experimental auditory trauma models should not be equated with normal domestic exposure. M. Kimura & J. Eggermont (1999) used an acute intense pure-tone model to examine response properties across auditory cortical fields in cats. These studies establish biological plausibility for noise-related neural change under controlled high-intensity conditions, but they do not demonstrate that ordinary household sound causes the same effect.

N. Aizawa & J. Eggermont (2006) addressed a developmental model by examining adult primary auditory cortical processing after noise-induced hearing loss acquired early in life. Their results linked early auditory injury with changes in temporal representations of voice-onset time and gaps in noise. The study is valuable because it separates peripheral threshold effects from cortical temporal processing; however, it involves an experimental exposure model and cannot define risk from everyday apartment noise. In practical interpretation, the most significant factors for *Felis catus* are therefore high-frequency audibility, suddenness, repeated unpredictable stimulation, proximity to the source, limited opportunity for withdrawal and pre-existing auditory vulnerability rather than the nominal decibel level alone. Cats can hear at these ultrasonic frequencies, and their health may be at risk. “Inaudible sounds” (those cannot hear) have been found to affect endocrine and cardiovascular function, sleep-wake cycles, seizure susceptibility, and behavior in laboratory animals. In particular, ultrasonic noise has been linked to audiogenic reflex seizures in cats. This syndrome develops in cats around the age of 15, and is most common in cats that are deaf or partially deaf. Protecting cats' hearing can reduce the risk of developing this syndrome.

The current evidence also supports a precautionary distinction between continuous and impulsive sound. Continuous sound may interfere with sleep, rest and detection of cues over time, whereas impulsive or high-pitched sound can induce acute avoidance and, in susceptible animals, clinically significant audiogenic responses. A practical acoustic assessment should document the source, time of occurrence, frequency character when known, perceived distance, duration, animal behaviour and access to escape. Such contextual data are more informative for veterinary or welfare decisions than an isolated statement that a room is "noisy".

Clinical, hospital, and shelter noise as a factor in physiological stress

Despite the existence of individual experimental and clinical studies, the issue of the impact of anthropogenic noise on the auditory system of *Felis catus* remains insufficiently addressed. The scientific literature includes studies on the physical characteristics of the auditory system, research on auditory-induced seizures, veterinary observations of stress, noise analysis in shelters, and general ecological reviews of anthropogenic noise pollution. This fragmentation makes it difficult to draw a comprehensive conclusion regarding which specific noise parameters are most significant for cats and through which mechanisms they may affect hearing, behavior, and viability. An additional methodological challenge is the heterogeneity of measurement units, stimulus types, animal ages, exposure environments, and response assessment criteria.

Clinical, hospital and shelter environments differ from domestic settings because animals are exposed to multiple concurrent stressors: unfamiliar odours, visual contact with conspecifics or dogs, handling, restriction of movement, altered routines and sound. Noise should therefore be interpreted as one component of a cumulative sensory load rather than as an isolated cause. Even so, institutional sound deserves separate attention because sources are numerous, recurrent and partly modifiable: doors, cages, kennel activity, cleaning equipment, staff conversation, alarms, telephones, transport trolleys and vocalisations from other animals. The acoustic objective is not absolute silence, which is unrealistic in a functioning facility, but reduction of abrupt peaks, unnecessary repetition and exposure at the animal's resting location.

The study N. Furgala *et al.* (2022) noted certain physiological and behavioral changes that confirmed the cats' negative reactions to the noise changes. In the study, cats exposed to noise changes exhibited higher heart rates and breathing rates, due to the release of hormones such as adrenaline. These results suggest that high levels of background noise induce physiological stress responses in cats, while exposure to noise during the examination and the clinical environment likely prevented the detection of treatment-related behavioral differences during the physical examination. Those working with cats in environments with high levels of background noise are advised to limit their cats' exposure to these noises to reduce fear and stress. This study suggests that noise can affect cats' responsiveness, especially in those suffering from certain disorders.

F.C. Griffin *et al.* (2021), in a randomised crossover trial, evaluated the effect of examination location on stress in cats. Although the central comparison was clinical setting rather than acoustic exposure alone, the design demonstrates that the examination environment and owner-related context can modify stress assessment. A. Tateo *et al.* (2021) analysed factors associated with fear-related behaviour during veterinary examination and similarly showed that feline stress in clinical care is multifactorial. These studies caution against attributing a behavioural response solely to sound without documenting handling technique, familiarity, waiting time, housing conditions and visual stimulation. F. Barrios *et al*. (2025) in a recent review of fear, anxiety, and stress in domestic cats, emphasised the importance of a controlled environment, low-noise handling, and spatial stability for reducing behavioral disturbances.

K.A. Kerr (2026) tested music therapy in hospitalised cats and illustrated another methodological issue: altering the acoustic environment is not equivalent to removing harmful noise. Their findings did not support a simple replacement of clinical sound by music as a universal stress-reduction strategy. In practical terms, the first intervention should be removal or attenuation of avoidable sound sources; sound enrichment, if used, requires species-appropriate selection and individual monitoring. This interpretation is consistent with the 2022 ISFM/AAFP Cat Friendly Veterinary Environment Guidelines, which recommend a calm, predictable environment and attention to sensory stressors in every stage of feline care (Taylor *et al.*, 2022).

Feline audiogenic reflex seizures must be differentiated from fear-related behaviour, auditory discomfort and non-auditory neurological disorders. A cat that startles, hides or avoids a room after a noise event does not thereby meet criteria for this syndrome. Conversely, older cats or animals with suspected hearing loss and a history of recurrent sound-triggered events require veterinary neurological assessment. Environmental management should focus on identifying individual trigger sounds, avoiding unnecessary high-pitched alarms or metallic impacts near the animal and preserving a predictable retreat space. The literature does not support assigning a single frequency or decibel threshold that predicts this condition in all cats.

High-frequency environmental stimuli and auditory-induced reflex spasms

The broad behavioural hearing range reported by R. Heffner & H. Heffner (1985) provides a necessary baseline for interpreting noise-related risk. A threshold shift refers to a change in the minimum level required for sound detection; it may be temporary after intense exposure or persistent when hair-cell damage and neural changes occur. In clinical practice, however, a threshold shift in a cat cannot be inferred from hiding, vocalisation or reduced responsiveness alone. G. Strain (2017) noted that the differential diagnosis of feline hearing loss includes congenital deafness, otitis, trauma, ototoxic exposure, age-related change and central auditory disorders.

M. Lowrie *et al*. (2016) reported myoclonic events in 90 of 96 cats and clinical absences in a smaller subgroup; the study also documented that avoiding reported trigger sounds reduced events in many affected animals. These figures should not be interpreted as prevalence estimates for the general feline population because the sample consisted of referred or owner-identified cases and exposure was assessed retrospectively. Their value lies in identifying a reproducible clinical pattern: sudden, high-pitched and often repetitive sounds may provoke paroxysmal events in susceptible, commonly older cats.

In study by D. Welch (2023) a consortium of veterinary groups in the United Kingdom linked seizures in some cats to a phenomenon called "feline audiogenic reflex seizures," which are usually triggered by high-pitched sounds. The study named over a dozen common household noises that are likely to be the cause, including ringing telephones, computer printers, and even rustling aluminum foil. All seizures, according to the inclusion criteria, occurred after a noise stimulus, but in some cats, spontaneous myoclonic jerks (18/90; 20%) and acute convulsions (ACC) (8/96; 8%) were observed in rare cases without an obvious noise stimulus. All sounds that provoked these seizures were high-frequency. The sounds were capable of inducing various types of seizures without a clear sound that would predict or create a clear seizure pattern. In some cases, a repetitive sound initiated a myoclonic seizure, which, if prolonged, could progress to ACC. This phenomenon of audiogenic kindling was recorded in 86 cats. These sounds did not always cause seizures in cats and could occur without inducing seizures, sometimes in 32/96 cats (33%). Avoidance of these noises eliminated seizures in 72/96 cats (75%), although many owners reported that the nature of the sounds made it very difficult to completely eliminate seizures. All owners believed that they could reliably induce a seizure by playing one of the described trigger sounds. The loudness of the sound (amplitude) also seemed to increase the severity of seizures, regardless of the type of seizure. This was reported by 23% (22/96) of owners.

Intense noises can cause seizures in cats. For example by M. Lowrie *et al.* (2016), 82 cats responded to the crunch of foil; 79 cats to a metal spoon falling into a ceramic food bowl; 72 cats to a ringing or banging of glass; 71 cats to the crunch of paper or plastic bags; 61 cats to the tapping of a computer keyboard or mouse; 59 to the jingling of coins or keys; 38 to the hammering of nails; 24 cats to the clicking of an owner's tongue; 12 cats to the sound of foil being torn off a medicine or pill package; 8 cats to text messages; 6 cats to a digital alarm clock; 6 cats to the sound of Velcro; 4 cats to a cell phone ringing; running water was detected in 2 cats and the short, sharp cry of a small child was detected in 1 cat. No other provoking factors that could have precipitated the attack or increased the likelihood of its occurrence were reported.

In addition to clinical problems or suspected problems, cats developed other seizure types: myoclonic jerks (90/96; 94%) and clinical absences or suspected absences (6/96; 6%). The majority of cats (84/96; 88%) had myoclonic jerks and clinical absences, and six (6/96; 6%) cats had the triad of absences, myoclonic jerks, and clinical absences. Six cats (6/96; 6%) had clinical absences only. Absences preceded myoclonic jerks in all six cats (6/96) with this seizure type. The first seizure observed by the owner was a clinical absence in 17% (16/96) of cats, a myoclonic seizure in 70% (67/96) of cats, and an absence in 6% (6/96). Seven (7/96; 7%) owners were unsure which type of seizure was observed first. All cats were reported to be in a normal state between seizures (Girao, 2024). Data on auditory-induced reflexive seizures indicate that high-frequency environmental sounds may have clinical significance for certain groups of cats. The greatest risk occurs when the sound is sudden, repetitive, unpredictable, and originates in close proximity to the animal.

Shift in hearing thresholds and cortical processing of auditory stimuli

Standard deviations average about 5 dB, which is typical for good clinical audiometry in normal ears. Behavioral audiograms of two cats were determined to establish the upper and lower limits of hearing for cats. The cat's hearing range for sounds at 70 dB SPL extends from 48 Hz to 85 kHz, making it one of the widest hearing ranges of any mammal. The analysis suggests that cats have evolved enhanced hearing at high frequencies without loss of hearing at low frequencies (Tsuer, 2022). It is worth noting that the impact of sound level and the number of people in the apartment is not always able to provoke new behavioral reactions and changes in the functioning of the hearing apparatus of cats. In fact, it is extremely important to take into account all sound frequencies that the animal under study can hear, and not only the sounds to which humans are sensitive. After all, the impact of noise varied between species and individuals. Therefore, it is important to pay attention to studies that are based on individual predispositions to deafness. This is done in order to improve the well-being of each animal and increase the chances of reproduction of endangered species (Green, 2021).

Another study by B. Eagan *et al.* (2021) was conducted with 98 cats. Two daily 30-minute observation sessions (morning and evening) were conducted for 98 cats from the time of admission for ten days or until the cat was collected. The cats' behavior and the presence of sound (classified by source) were recorded by instantaneous sampling at 15-second intervals. Each 30-minute observation session was classified as "quiet" or "noisy" if the one-zero score for the presence of sound was higher or lower than the median of the sessions at that time of day. To ensure that the cats had at least two full days of comparable observations, statistical analysis was limited to 70 cats (30 females, 40 males) present for two or more days of the week. The level of fear and behavior of each cat studied varied due to individual perception. Where sessions included a marked transition in the change in sound frequency, fear-related behavior was more common after the transition from silence to noise and less common after the transition from noise to silence. The results show that shelter cats vary greatly in their responses, suggesting that sound in shelters can have a significant impact on their behavior. Reducing sound levels in shelters may help improve the welfare of cats.

Mild chronic noise-induced hearing loss increased the minimum detectable frequency at voice onset and gap duration by 10 ms. N. Aizawa & J. Eggermont (2006) analysed the maximum firing frequency (FRmax) and response latency as a function of VOT (voice onset time) and gap duration and found a significant decrease in FRmax to the delayed noise spike for gap durations greater than 50 ms. This suggests that mild hearing loss acquired in early life may affect temporal signal processing in the cerebral cortex in adulthood.

The effects of noise on *Felis catus* may manifest not only through external behavior but also through changes in auditory thresholds, response latencies, and cortical processing of temporal signals (Kruger, 2023). Developmental periods are particularly vulnerable, as certain properties of the auditory cortex have not yet reached maturity. Threshold shifts may be temporary or permanent, and their consequences depend on age, frequency range, duration of exposure, and the prior state of the auditory system. In practical terms, this underscores the importance of early prevention of excessive noise exposure, rather than merely responding after behavioral symptoms appear.

Behavioral mechanisms of noise exposure

In different niches, the same level of noise can have a different effect, and some of the meaning of the sound depends on the context. In fact, practical recommendations are based not only on the measured decibels, but also on the analysis of the behavioral type of a particular creature. The behavioral effects of noise exposure are driven by three key mechanisms, which are not mutually exclusive:

- noise masks important behavioral sounds that are associated with animal communication or approaching danger.
- noise distracts animals from paying attention to important information in the environment.
- noise is perceived as a direct threat, thereby altering the animal's behavioral responses (Pocock, 2014; Kleszynski, 2024).

Six-week-old kittens have mature hearing thresholds and cortical response latencies, but other cortical response properties, such as the duration of postactivation inhibition and the bandwidth of the frequency tuning curve, remain immature until 100-120 days of age. Spontaneous firing rate development takes even longer. Noise-induced hearing loss was found to be independent of frequency over a wide range, although in the range from 16 to 24 kHz, hearing loss was approximately 10 dB greater as measured by ABR (bioelectrical brainstem response) and up to 20 dB greater above 16 kHz as measured by multiunit cortical thresholds. This is in contrast to what is observed approximately 5 hours after noise injury; here, the loss is negligible up to 4 kHz and then increases rapidly to approximately 40 dB for frequencies above 6 kHz. Over a longer period of time after injury, the losses usually decrease somewhat, but do not extend to frequencies below 4 kHz (Aizawa & Eggermont, 2006).

Another possibility is that the noise caused only a slight hearing loss at high frequencies and that, in addition, conductive hearing loss was present. In such a case, the latency of cortical responses would be expected to be longer in the hearing-impaired animals than in the control group. Data N. Aizawa

& J. Eggermont (2006) and T. Munzel (2025) for intermediate stimuli show that the opposite was true: the latency to the conductive spike was shorter in the noise-injured group compared with the control group. Thus, it is unlikely that conductive hearing loss was present. Therefore, the increase in thresholds (from both ABR and cortical neurons) for frequencies up to 1 kHz should be characteristic of the age at which the animals were exposed.

In contrast to the number of studies that have examined the temporal effects of loud noise on the auditory nervous system down to the inferior colliculus, there have been almost no studies that have examined the effects on the activity of individual neurons in the auditory cortex. One study examined the frequency response regions of individual neurons in the primary auditory cortex (PAC) of cats before and after a transient threshold shift (TTS) induced by an intense pure tone presented half an octave below the neuron's frequency (Strain, 2017).

A domestic cat's hearing is about four times more sensitive than a human's (65 kHz in cats versus 20 kHz in humans), and cats can hear higher-frequency sounds, including ultrasound. The problem is that cats cannot identify sounds according to their territory, because their hearing is so sensitive that they pick up loud sounds when speaking in a normal voice. Noise from other cats, other animals, and strangers often frightens cats (Girao, 2024). Behavioral effects of noise are formed through masking of signals, sensory over-reaction, threat response and loss of predictability of the environment. However, the intensity of a sound can be neutral in one context and stressful in another. Therefore, the assessment of acoustic intensity may include care for a specific animal, and not the reduction of decibels. Practical approaches are directly related to the change in sharp high-frequency signals, the creation of quiet zones and the stability of the selected sound mode.

Noise can influence feline behaviour through several mechanisms that often operate simultaneously. First, it can mask meaningful signals, including vocal communication, prey-associated cues and environmental sounds used for orientation. Second, it can divert attention from feeding, resting, exploration or social contact. Third, a sudden or unfamiliar sound can be interpreted as a direct threat and trigger startle, withdrawal, freezing, hiding or defensive behaviour. C. Kight & G. Swaddle (2011) proposed these mechanisms as a general framework for animals, and the feline studies by B. Eagan *et al.* (2021) and N. Furgala *et al.* (2022) demonstrate their relevance in clinical and shelter settings.

Context modifies each mechanism. The same sound level may be tolerated when it is predictable, distant and paired with a familiar routine but provoke fear when it is sudden, close to the animal or associated with handling. Individual factors include age, previous experience, socialisation, health status, hearing ability, access to a hiding place and control over distance from the sound (Torres-Bernal *et al.*, 2025). This is why practical management should not rely on an arbitrary decibel cut-off. Instead, it should combine environmental observation with documentation of the sound source, time, duration, repetition, behavioural response and the animal's ability to move to a quieter location.

In the home, the primary measures are predictable routines and the creation of at least one protected resting zone away from televisions, loudspeakers, kitchen equipment, washing appliances and windows facing heavy traffic. A cat should not be forced to remain in the room during vacuuming, food processing, renovation or other high-level tasks. Abrupt high-pitched signals, such as electronic alarms and metallic impacts, should be minimised near older cats or animals with a history of sound-triggered events. Soft furnishings, closed doors and increased distance can reduce perceived intensity, although they do not eliminate all high-frequency components. The effectiveness of any change should be assessed through the cat's behaviour rather than assumed.

In veterinary practice, facilities can reduce acoustic burden through cat-only or visually separated waiting areas, lower alarm volume where clinically safe, soft-close doors, quieter cage hardware, control of staff conversation near wards and scheduling of noisy cleaning tasks outside feeding and rest periods. Enclosures should include an accessible hiding area and should not be positioned beside dog kennels, treatment trolleys or repeatedly opening doors when alternatives are available. The AAFP and ISFM feline nursing and veterinary environment guidelines recommend a calm, predictable sensory setting and low-stress handling as routine standards (Taylor *et al.*, 2022; Feline ear issues, n.d.).

Shelters require management at the level of zoning and daily workflow. Cat housing should be acoustically separated from dog areas where possible; cleaning, admissions, construction and volunteer activity should be planned to preserve quiet periods; and recurrent noise peaks should be logged alongside behavioural observations. The behavioural findings of B. Eagan *et al.* (2021) support particular attention to transitions from quiet to noisy conditions. Hiding spaces, visual barriers and predictable staff movement can reduce sensory load, but they are not substitutes for controlling avoidable sound at its source.

When a cat shows persistent sound avoidance, altered sleep, repeated hiding, reduced interaction, marked startle or suspected sound-triggered paroxysmal events, the appropriate response is clinical assessment rather than unstructured desensitisation. Otological examination, review of medication and neurological assessment may be necessary, especially in older cats or cats with suspected hearing impairment. Because current research does not define one safe noise threshold for all *Felis catus*, an individualised approach that combines noise reduction, environmental control and veterinary evaluation remains the most evidence-consistent strategy.

Conclusions

This analytical review considered anthropogenic noise in domestic, clinical, hospital, shelter and urban contexts in relation to the auditory system and associated responses of *Felis catus*. The reviewed evidence shows that household appliances, transport, clinical background sound, shelter activity and short high-frequency stimuli differ not only in average level but also in spectrum, abruptness, duration and predictability. These characteristics, together with the possibility of withdrawal from the source, are central to the interpretation of acoustic exposure.

The wide hearing range of domestic cats explains why acoustic components that are not prominent to humans may remain biologically relevant to the animal. Clinical and shelter studies describe associations between noisier conditions or abrupt transitions and fear-related behaviour, respiratory changes and other stress indicators. Feline audiogenic reflex seizures are a separate clinical phenomenon, primarily reported in susceptible and often older cats exposed to high-pitched household sounds. Experimental auditory studies demonstrate that intense sound can alter thresholds and cortical processing, but they do not prove that everyday domestic noise causes permanent hearing loss in healthy cats.

The principal limitation of the available literature is heterogeneity in populations, acoustic measurement, exposure duration, clinical setting and outcome assessment. A single universal permissible noise level for all cats cannot currently be derived. Further research should use calibrated spectral monitoring, repeated behavioural and physiological assessment, ABR testing and standardised reporting of environmental conditions. Until such evidence is available, reduction of avoidable peaks, provision of quiet retreat areas and individual veterinary assessment of cats with persistent sound-related reactions are justified practical measures.

Acknowledgements

None.

Funding

None.

Conflict of Interest

None.

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Біофізичні аспекти впливу антропогенного шуму на стан слухової системи *Felis catus* у різних екологічних нішах

Олена Мартинова
Кандидат технічних наук, доцент
Одеський державний аграрний університет
65012, вул. Пантелеймонівська, 13, м. Одеса, Україна
https://orcid.org/0000-0001-7324-2543

Анотація. Антропогенний шум розглядається як вагомий фізичний чинник урбанізованого середовища, що може змінювати поведінкові, нейрофізіологічні та сенсорні реакції свійського кота *Felis catus*. Метою роботи було проведення узагальнення наукових даних про вплив побутового, транспортного, клінічного та іншого антропогенного шуму на стан слухової системи *Felis catus* у різних екологічних нішах. Використано методи систематизованого пошуку літератури, порівняльного аналізу експериментальних і клінічних досліджень, якісного метааналізу, нормалізації акустичних показників у дБ, Гц і кГц. А також проведено узагальнення даних щодо поведінкових, серцево-судинних, ендокринних і неврологічних реакцій. Було досліджено джерела шумового навантаження, які діють у квартирі, ветеринарній клініці, притулку, госпітальному середовищі та відкритому урбанізованому просторі. Виявлено, що коти через широкий діапазон слухового сприйняття, зокрема здатність реагувати на високочастотні й ультразвукові стимули, можуть демонструвати стресові реакції навіть на звуки, які людиною оцінюються як побутові або неінтенсивні. Результати дослідження показали, що при підвищенні частоти шуму у котів виникав стрес, та погіршувалась робота серцево-судинної системи. Також шум здатний вплинути на роботу ендокринної системи, оскільки внаслідок стресу відбувається виділення надмірної кількості гормонів, які в свою чергу впливають на роботу всього організму. Також спостерігалося погіршення слуху через підвищення частоти сприймання звуків, що в подальшому призводило до розвитку симптомів глухоти. Встановлено, що звуки, які людина сприймає як звичайні та побутові, для тварини стресові та здатні вплинути на зміну її поведінки. Також при постійному перебуванні в антропогенному шумі у тварини розвиватиметься глухота, що призведе до повної або часткової втрати слуху. Практична цінність роботи полягає у можливості використання отриманих результатів ветеринарними лікарями, працівниками притулків, власниками котів і дослідниками біоакустики під час планування акустично безпечного середовища для *Felis catus*

Ключові слова: кіт свійський; частота; зовнішнє вухо; стрес; глухота; діяльність людини