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A review of animal welfare and legislation

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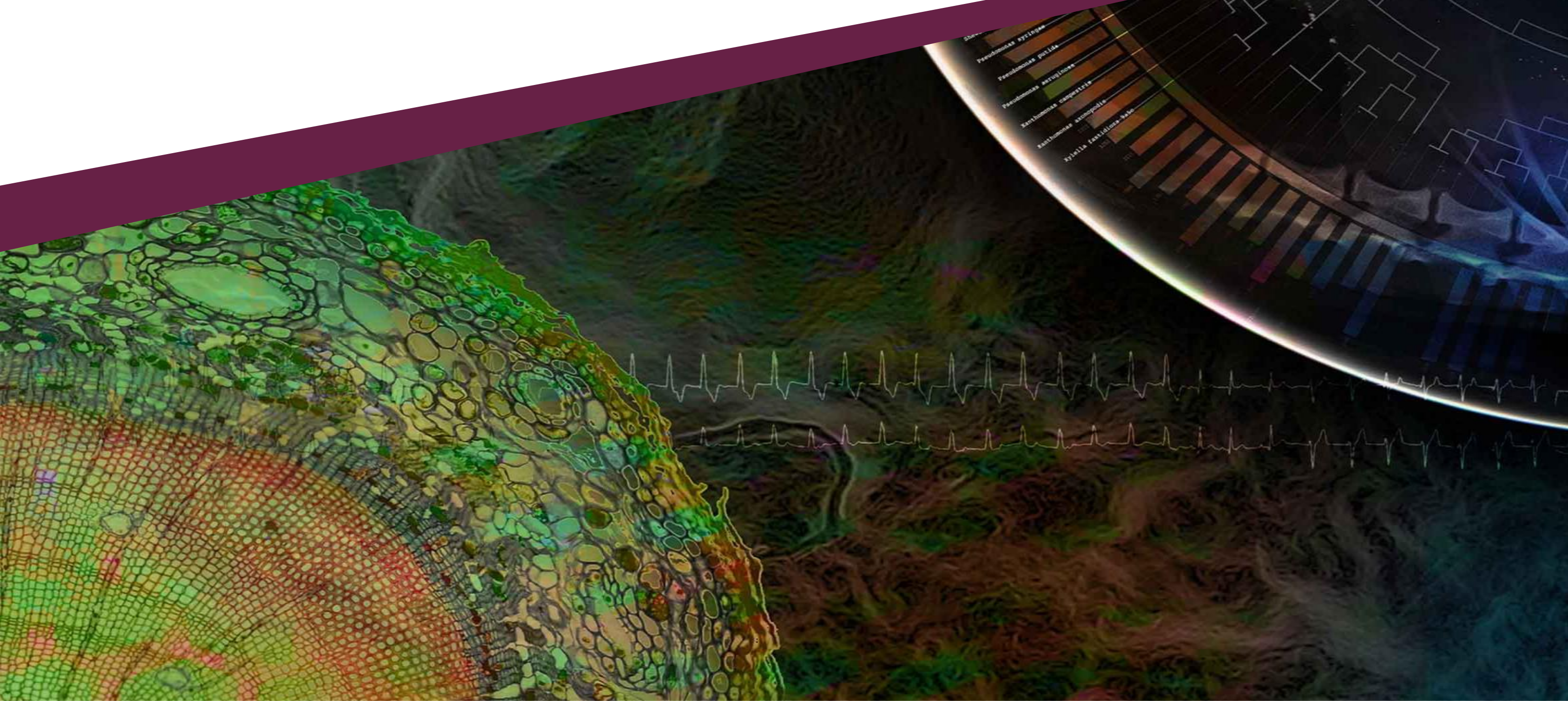

Fireworks and Animals. A review of animal welfare and legislation

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Summary

The use of fireworks is debated from an animal welfare perspective. However, a comprehensive overview of how fireworks affect the welfare of different animal species and how fireworks legislation influences animal protection is lacking. The Swedish Centre for Animal Welfare (SCAW), Swedish University of Agricultural Sciences (SLU), was therefore commissioned by the Swedish Association for the Protection of Animals (Svenska Djurskyddsföreningen) to review the current scientific literature and legislation in this area. More specifically, this report aims to compile the literature and scientific knowledge regarding the effects of fireworks on the welfare of various animal species; map the legislation on fireworks in Sweden, in selected EU member states, and at EU level; identify potential knowledge gaps and further research; and propose recommendations on the use of fireworks, considering animal welfare and legislation.

Below are the conclusions for each animal category, the identified research gaps, and suggested future research; this is followed by legislation and concludes with the authors´ recommendations on the use of fireworks.

Dogs

Firework-related noise aversion is a common problem in dogs that significantly reduces welfare. Research indicates that fireworks are the most frequent trigger of noise sensitivity. The risk of developing fear of fireworks rises with age and seems higher in females and neutered dogs, as well as in dogs acquired from shelters or as adults. Comorbidity with separation-related problems and general fearfulness is frequent. Behavioural signs of fear and stress in dogs in connection with fireworks include vigilance, trembling, hiding, escape attempts, vocalisation, and changes in appetite and elimination. Effective treatment starts with environmental management and safety planning. Behavioural modification using structured sound exposure shows promise, potentially in combination with pharmacological options and pheromones that lower arousal in order to support learning. Early-life, controlled exposure to sounds and selective breeding may reduce the risk of developing fear of fireworks.

Cats

Research on the effects of fireworks in cats is limited, but available evidence from other countries indicates that fear is very common, with negative effects on welfare. Surveys show that the majority of cats display various levels of fear and stress during fireworks, and many cats are described by their owners as very or extremely scared. Typical behaviours include hiding, trembling, escape attempts, vocalisation, and increased vigilance. Although, to our knowledge no physiological studies have

been conducted, these reactions suggest acute fear and stress responses comparable to those seen in other species. Little is known about the long-term effects of repeated noise exposure in cats, including whether such experiences lead to habituation or sensitisation. However, current evidence suggests that fear responses to fireworks may persist over time and can occur even in the absence of immediate firework exposure. Management strategies are largely based on practical advice rather than controlled evaluation, often including environmental adaptations, and using pheromone diffusers or pharmacological options.

Horses

Fear and stress in horses from fireworks and other aversive sounds are common, and have been confirmed by behavioural and physiological observations. Horses are prey animals with a highly sensitive sensory system and thus sensitive to adverse and sudden, unpredictable stimuli. Fearful reactions, such as escape attempts, can result in physical injuries, contributing to the overall negative welfare impact on horses from fireworks. Many horses express fear during fireworks by increased locomotion, i.e. running, fence or box-walking, bucking and rearing. Owners have reported that horses lose appetite, show signs of diarrhoea and increased defecation, trembling, shivering, sweating, increased vocalisation, restlessness and startle responses. Horse owners implement a variety of management strategies during firework events to align with current understanding of equine fear and stress responses. Similar to companion animals, horses may benefit from behavioural modification. In addition, pheromones and pharmacological options are also available, but scientific data on the effectiveness during fireworks are still scarce.

Farm animals

No studies are available that directly examined the effects of fireworks on livestock, but evidence from general noise and aircraft-related research provides valuable proxies for predicting responses. Exposure to sudden, intense sounds above 85–100 dB reliably triggers startle, fear, and physiological stress reactions across species, suggesting that fireworks (which often exceed 100 dB and combine both high- and low-frequency impulses) are likely to provoke similar or stronger responses. Acute high-intensity noise generally causes behavioural agitation, avoidance, startle responses, and disturbed resting patterns across livestock species, reflecting activation of physiological stress mechanisms. These changes can temporarily reduce milk let-down, growth, or reproductive efficiency, but long-term effects are currently unknown. Because fireworks share the same sudden, unpredictable, and high-intensity characteristics as e.g. industrial or aircraft noise, these findings provide a scientifically grounded basis for inferring that firework exposure constitutes a potent welfare stressor for farm animals. Management strategies are not very well studied, but environmental modifications and routine exposure to mild, predictable noise can help reduce aversive responses.

Wild animals and zoo animals

Fireworks combine intense noise and light, creating a potent source of disturbance for wildlife. Unpredictable and high-intensity stimuli can trigger strong stress- and flight responses across taxa, something that has been observed in wild birds and marine mammals. Radar and field studies show that fireworks provoke mass nocturnal flight, increased vigilance, and temporary habitat abandonment in waterfowl, with possible long-term energetic and fitness costs. Similar disruption has been reported in marine species, such as sea lions and seals, which flee or show altered communication. Evidence on terrestrial mammals is limited. In zoo animals, reactions differ by species, enclosure design and management, but agitation, vigilance and disturbed rest are common responses to fireworks or loud noise. Physiological data remain limited, though studies on wild birds demonstrate acute stress responses. Long-term welfare and population effects are largely unknown. Mitigation strategies include spatial and temporal firework restrictions, and provision of refuges in zoos.

Research gaps and future research directions

Based on the available literature, we conclude that there is a significant risk that use of fireworks causes anxiety, fear, stress, and potential suffering in both domestic and wild animals, and that preventive measures at the societal level are urgently needed. Furthermore, we list research gaps and future research directions in this area that would minimise welfare impacts as much as possible: i) Long-term, cumulative effects on animal welfare, ii) controlled behavioural and physiological studies, iii) impact of the combined effects of sound, light, and smell from fireworks on behavioural and physiological reactions, iv) effects of other aversive sound sources have been used when firework data have been missing, but research on fireworks would provide a more precise understanding, v) expand research beyond a few species, vi) assess environmental and contextual factors in relations to fireworks exposure, vii) evaluate the effectiveness of mitigation and management strategies, viii) develop standardised welfare assessment protocols to assess the impact of fireworks, iv) compare effects on animal welfare between traditional fireworks and welfare-friendly alternatives.

Legislation

The Swedish legislation on fireworks is governed by the EU legislation (Directive 2013/29/EU). Hence, it is not possible for an EU member state to ban fireworks completely or adopt stricter national rules restricting high-risk fireworks (category F4, used by professionals only), as this would breach the rules on free trade.

However, there is some flexibility which allows member states to take measures to ban or restrict the possession, use and/or sale to the general public of fireworks in categories F2 and F3 for reasons of public order or safety, health or environmental protection. In contrast to some other EU members states, such as Ireland and Romania, who only allow sales to the public of the least dangerous and non-aversive fireworks (F1), Sweden has not made full use of this flexibility. In comparison to countries like Denmark, Sweden also does not have as strict rules when fireworks can be sold and used. There is no consideration of animal welfare in neither the Swedish nor the EU legislation concerning fireworks. A proposed revision of the EU pyrotechnics directive may result in member states getting greater possibilities to restrict or ban fireworks at national level, or making EU rules overall stricter, and that animal welfare and protection become criteria for restrictions.

Recommendations

Based on the available scientific knowledge and current legislation, we recommend that, like in several other EU member states, only category F1 fireworks (e.g. sparklers, firecrackers), should be permitted for sale and use by the general public in Sweden. Other categories, with more adverse effects on animal welfare (F2 to F4), should only be used by professionals with permits/training and in an organised manner, during limited periods of time, e.g. on New Year´s Eve and Walpurgis Night. At other times of the year, permission may be granted by the municipality where the fireworks are to be used, after specific applications. When organised use of adverse fireworks is permitted, we emphasise the need to implement animal sensitive policies and activities, and, importantly, consider the time and location of the fireworks to avoid or mitigate negative welfare effects on domestic and wild animals. We also recommend early notifications systems that allow the public (i.e. animal owners) to be informed of planned fireworks well in advance and that quieter alternatives during publicly organised fireworks are encouraged. In addition, we suggest a more efficient official control of the legislation on fireworks, and that access to fireworks via online orders become more regulated. We recommend funding for applied research and extension programmes focusing on systematic monitoring of disturbance, adapted animal welfare assessments, and protective measures for domestic and wild animals. Research findings and programme measures can be integrated into legislation, guidelines, management plans and best practices. If the EU legislation on fireworks is reviewed, we recommend that Sweden advocates for greater opportunities for member states to establish stricter national rules, or that EU regulations are made stricter for all member states, and emphasises the recognition of animal welfare and protection as criteria for restrictions. However, the current EU legislation seems to allow

Swedish legislators to further regulate fireworks in Sweden, with animal welfare and protection in mind, already today.

Keywords: Fireworks, fear, stress, animal welfare, animal protection, legislation, dogs, cats, horses, farm animals, wild animals, zoo animals

Sammanfattning

Inledning

Användningen av fyrverkerier kritiseras ur ett djurvälfärdsperspektiv, men en samlad översikt över hur fyrverkerier påverkar välfärden hos olika djurarter, samt hur lagstiftningen kring fyrverkerier påverkar djurskyddet, saknas. Nationellt centrum för djurvälfärd (SCAW), Sveriges lantbruksuniversitet (SLU), har i denna rapport gjort en genomgång av den aktuella vetenskapliga litteraturen och lagstiftningen inom området, på uppdrag av Svenska Djurskyddsföreningen. Mer specifikt syftar denna rapport till att: sammanställa litteratur och vetenskaplig kunskap om hur fyrverkerier påverkar välfärden hos olika djurslag; kartlägga lagstiftningen som gäller fyrverkerier i Sverige, utvalda EU-medlemsstater och på EU-nivå; identifiera kunskapsluckor och behov av vidare forskning; samt föreslå rekommendationer för användningen av fyrverkerier med hänsyn till både djurvälfärd och lagstiftning.

Nedan följer slutsatser för respektive djurkategori, samt forskningsluckor och förslag på framtida forskning. Därefter följer en genomgång av lagstiftningen och avslutningsvis lämnar författarna rekommendationer kring användningen av fyrverkerier.

Hundar

Ljudrädsla kopplad till fyrverkerier är ett vanligt problem hos hundar och innebär betydande negativa välfärdseffekter för drabbade hundar. Studier visar att fyrverkerier är den vanligaste utlösande faktorn för ljudkänslighet. Risken att utveckla rädsla för fyrverkerier ökar med åldern och verkar vara högre hos tikar och kastrerade hundar, samt hos hundar som adopterats från djurhem eller som vuxna. Samsjuklighet med separationsrelaterade problem och generell ängslan är vanlig. Symptom på rädsla och stress vid fyrverkerianvändning omfattar vaksamhet, darrningar, att gömma sig, flyktförsök, vokalisering samt ändrad aptit och defekering/urinering. Effektiv behandling börjar med miljöanpassning och säkerhetsplanering. Beteendemodifiering med strukturerad ljudträning visar lovande resultat, särskilt i kombination med läkemedel och feromoner som dämpar stress och underlättar inlärning. Tidig, kontrollerad exponering för ljud samt selektiv avel kan minska risken för att utveckla fyrverkerirädsla.

Katter

Forskning kring fyrverkeriers påverkan på katter är begränsad, men tillgänglig data visar att rädsla är mycket vanlig, med negativ välfärd som följd. Enkäter från andra länder visar att majoriteten av katter uppvisar olika grader av rädsla och stress och många katter beskrivs av sina ägare som mycket eller extremt rädda. Vanliga beteenden inkluderar att katten gömmer sig, darrar, försöker fly, jamar eller visar ökad vaksamhet. Såvitt vi vet, så saknas fysiologiska studier på katt, men dessa reaktioner tyder på akut stress jämförbar med andra djurslag. Kunskap om långsiktiga effekter av upprepad exponering av skrämmande ljud på katter, exempelvis om sådana upplevelser leder till tillvänjning eller ökad känslighet, är bristfällig. Dock indikerar forskning på andra djurarter att rädslan kan kvarstå över tid och uppträda även utan direkt exponering för fyrverkerier. Nuvarande hanteringsstrategier baseras huvudsakligen på praktiska råd snarare än kontrollerad utvärdering och innebär ofta miljöanpassningar för katten samt användning av feromoner eller läkemedel.

Hästar

Rädsla och stress hos hästar till följd av fyrverkerier och andra skrämmande ljud är vanligt förekommande, vilket bekräftas av beteendeobservationer och fysiologiska förändringar. Hästar är flyktdjur med mycket känsliga sinnen, och därför särskilt mottagliga för plötsliga och oförutsägbara stimuli. Rädsla och flyktförsök kan leda till fysiska skador, vilket bidrar till den negativa påverkan på djurvälfärden. Många hästar visar ängslan och rädsla under fyrverkerier genom ökad rörelseaktivitet (t.ex. rusningar, box- eller staketvandring, bockningar, resningar). Hästägare har även rapporterat aptitförlust, diarré, darrningar, svettningar, ökad vokalisering, rastlöshet och kraftiga skrämselreaktioner. Hästägare använder hanteringsstrategier vid fyrverkerier som är i linje med befintlig kunskap om hästars stress och rädsla. I likhet med sällskapsdjur kan beteendeträning vara till nytta. Feromoner och läkemedel kan användas, men kunskap om deras effektivitet vid fyrverkerier är fortfarande begränsad.

Lantbruksdjur

Under litteratursammanställningen hittades inga studier som direkt undersökt effekterna av fyrverkerier på lantbruksdjur, men forskning om andra skrämmande ljud och buller, såsom flyg, ger användbara jämförelser. Exponering för plötsliga, intensiva ljud över 85–100 dB utlöser skräck-, flykt- och stressreaktioner hos många lantbruksdjur, vilket tyder på att fyrverkerier (som ofta överstiger 100 dB och kombinerar både hög- och lågfrekventa impulser) sannolikt ger liknande eller starkare stressreaktioner. Akut exponering för intensiva, skrämmande ljud leder ofta till oro, undvikande beteenden, skrämselreaktioner och störda vilomönster. Studier bekräftar fysiologiska stressreaktioner i dessa situationer. Stress från skrämmande ljud och buller kan tillfälligt minska mjölksläpp, samt dämpa tillväxt eller reproduktion, men långtidseffekterna är okända. Eftersom fyrverkerier har samma plötsliga, oförutsägbara och högintensiva karaktär som flyg eller industriellt buller, är det rimligt att anta att fyrverkerier kan utgöra en betydande belastning för lantbruksdjur och deras välfärd. Hanteringsstrategier är inte särskilt väl studerade, men miljöanpassningar och rutinmässig exponering för milda, förutsägbara ljud kan bidra till att minska rädsla och stress.

Vilda djur och djurparksdjur

Fyrverkerier kombinerar intensivt ljud och ljus, vilket kan innebära kraftiga störningar för vilda djur. Oförutsägbara och högintensiva stimuli kan utlösa starka stress- och flyktreaktioner hos många arter, något som påvisats hos vilda fåglar och marina däggdjur. Radar- och fältstudier visar att fyrverkerier orsakar massflykt nattetid bland sjöfågel, samt ökad vaksamhet och att habitat tillfälligt överges, vilket kan medföra långsiktiga negativa konsekvenser med avseende på energiåtgång och fysisk kondition. Liknande störningar har rapporterats hos marina arter, såsom sjölejon och sälar, som flyr eller förändrar sina kommunikationsmönster. Kunskap om landlevande däggdjur är bristfällig. I djurparker varierar reaktionerna mellan arter, inhägnadsdesign och skötsel, men oro, vaksamhet och störd vila är vanligt förekommande. Fysiologiska data har varit svår att finna, men studier på vilda fåglar visar på akuta stressreaktioner. De långsiktiga effekterna på individuella djurs välfärd och populationer är till stor del okända. Strategier som kan motverka de negativa effekterna av fyrverkerier inkluderar tids- och områdesbegränsningar samt tillgång till skyddade utrymmen i djurparker.

Forskningsluckor och framtida forskning

Baserat på tillgänglig litteratur drar vi slutsatsen att det finns en signifikant risk att användningen av fyrverkerier orsakar ångest, rädsla, stress och potentiellt lidande hos både tama och vilda djur, samt att förebyggande åtgärder på samhällsnivå är nödvändiga. Vi har identifierat följande forskningsluckor och framtida forskningsinriktningar som skulle kunna minimera välfärdspåverkan i största möjliga utsträckning: i) långsiktiga, kumulativa effekter på djurvälfärden, ii) kontrollerade beteende- och fysiologiska studier, iii) påverkan av de kombinerade effekterna av ljud, ljus och lukt från fyrverkerier på beteendemässiga och fysiologiska reaktioner, iv) effekter av andra skrämmande ljudkällor har använts när data om fyrverkerier har saknats, men forskning om fyrverkerier skulle ge en mer exakt förståelse, v) utöka forskningen till fler djurslag, vi) bedöma miljömässiga och situationsberoende faktorer vid exponering för fyrverkerier, vii) utvärdera effektiviteten av behandlings- och förebyggande åtgärder), viii) utveckla standardiserade djurvälfärdsbedömningsprotokoll för att utvärdera effekten av fyrverkerier, ix) jämföra effekterna på djurvälfärd mellan traditionella fyrverkerier och djurvälfärdsvänliga alternativ.

Lagstiftning

Den svenska lagstiftningen om fyrverkerier styrs av EU-lagstiftningen (Direktiv 2013/29/EU). Därför är det inte möjligt för en EU-medlemsstat att helt förbjuda fyrverkerier eller införa striktare nationella regler som begränsar hög-riskfyrverkerier (kategori F4, endast för professionellt bruk), eftersom detta skulle strida mot EU:s frihandelsregler. Det finns dock viss flexibilitet som tillåter medlemsstater att förbjuda eller begränsa innehav, användning och/eller försäljning av fyrverkerier i kategorierna F2 och F3, av hänsyn till allmän ordning, säkerhet, hälsa eller miljöskydd. Till skillnad från vissa andra medlemsstater, såsom Irland och Rumänien, som endast tillåter försäljning till allmänheten av de minst farliga fyrverkerierna (F1), har Sverige inte utnyttjat denna möjlighet fullt ut. Jämfört med exempelvis Danmark har Sverige även mindre strikta regler för när fyrverkerier får säljas och användas. Varken Sveriges eller EU:s lagstiftning om fyrverkerier inkluderar hänsyn till djurvälfärden. En föreslagen revidering av EU:s pyroteknikdirektiv kan dock ge medlemsstaterna större möjligheter att begränsa eller förbjuda fyrverkerier nationellt, alternativt göra EU-reglerna strängare, samt möjlighet att införa djurvälfärd och djurskydd som kriterium för restriktioner.

Rekommendationer

Baserat på tillgänglig vetenskaplig kunskap och gällande lagstiftning rekommenderar vi att, i likhet med flera andra EU-länder, endast fyrverkerier i kategori F1 (t.ex. tomtebloss, små smällare) bör tillåtas för försäljning och användning av allmänheten i Sverige. Övriga kategorier (F2–F4), som är mer skrämmande för djur, bör endast användas av utbildade yrkespersoner med tillstånd, organiserat och under begränsade perioder, t.ex. nyårsafton och valborgsmässoafton. Vid ytterligare tillfällen bör tillstånd ges av den kommun där fyrverkerierna ska användas, efter ansökan i varje enskilt fall. När organiserad användning av kraftigare fyrverkerier tillåts bör djurvänliga riktlinjer och åtgärder införas, särskilt vad gäller tidpunkt och plats, för att minimera negativa välfärdseffekter på tama och vilda djur. Tidiga varnings- och informationssystem bör införas så att allmänheten, särskilt djurägare, informeras i god tid om planerade fyrverkerier, och tystare alternativ bör uppmuntras vid offentliga evenemang. Vidare bör den officiella tillsynen av fyrverkerilagstiftningen stärkas, och tillgången till fyrverkerier via nätförsäljning regleras striktare. Vi rekommenderar också ökad finansiering av tillämpad forskning och informationsinsatser med fokus på systematisk övervakning av störningar, välfärdsbedömningar och skyddsåtgärder för både tama och vilda djur. Resultaten från sådan forskning kan integreras i lagstiftning, riktlinjer, förvaltningsplaner och bästa praxis. I det fall EU-lagstiftningen om fyrverkerier revideras bör Sverige verka för att medlemsstaterna ska få större möjligheter att införa strängare nationella regler eller att EU:s bestämmelser generellt skärps, samt att djurskydd och djurskydd erkänns som kriterium för restriktioner. Dock förefaller redan nuvarande EU-lagstiftning medge att svenska lagstiftare kan reglera användningen av fyrverkerier ytterligare, med hänsyn till djurvälfärden.

Nyckelord: Fyrverkerier, rädsla, stress, djurvälfärd, djurskydd, lagstiftning, hund, katt, häst, lantbruksdjur, vilda djur, djurparksdjur

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1. Introduction

1.1 Background and aim

Fireworks combine sudden, high-intensity, unpredictable noises with bright flashes and smell. Hence, fireworks elicit multi-sensory stimuli that can trigger fear reactions and stress in animals. Fear behaviours from fireworks and other aversive sound stimuli have been documented in several animal species (Riva et al., 2022; Shamoun-Baranes et al., 2011; van Herwijnen et al., 2024).

Animal owners report that their animals suffer from fireworks by showing fear, anxiety, panic, stress, escape attempts and get physical injuries (Dale et al., 2010; Gahagan & Wismer, 2016; Gronqvist et al., 2016). Also, veterinary staff observe that animals experience stress when exposed to fireworks, e.g. during New Year's celebrations, a time when especially many companion animal owners seek help (Levine & Mills, 2008; Riemer, 2020; Sheppard & Mills, 2003). Horses, farm and wild animals may also be negatively affected by fireworks (Bateman et al., 2023; Hoekstra et al., 2024, Olczak et al., 2023; Pedreros et al., 2016).

To mitigate the negative effects on their animals, several companion animal owners seek advice from different professional groups, e.g. animal behaviourists, veterinarians, animal trainers or pet store employees (Dale et al., 2010; Gates et al., 2019; Herwijnen et al., 2024). These procedures, in themselves, may cause stress for the pet owners and may be costly. The negative impact on animal welfare is a major reason why the use of fireworks is debated and questioned, and there are growing calls to ban or restrict the use of fireworks. For example, in New Zealand, a majority of pet owners were supportive to a ban on private sale of fireworks (83-84% in Gates et al., 2019 and Dale et al., 2010).

Several scientific publications have addressed the impact of fireworks on animal welfare, particularly in dogs. However, there is a lack of a comprehensive overview of how fireworks affect the welfare of different animal species and how firework legislation influences animal protection, both in Sweden and at the EU level. To address this lack of overview, and disseminate the scientific knowledge and legislation in this area, the Swedish Centre for Animal Welfare (SCAW), Swedish University of Agricultural Sciences (SLU), has prepared this report on behalf of the Swedish Association for the Protection of Animals (Svenska Djurskyddsföreningen). The report is authored by experts in animal welfare, behaviour and health, and legislation at SLU. The preparation of the report is funded by the Swedish Association for the Protection of Animals.

This report aims to:

- compile literature and scientific knowledge on the effects of fireworks on the welfare of various animal species,
- map the legislation on fireworks in Sweden, in selected EU member states, and at EU level,
- identify potential research gaps and future research directions,
- propose recommendations on the use of fireworks, considering animal welfare and legislation.

Based on the available scientific knowledge, the scope of this report will differ between different animal categories, e.g. the section on dogs is more extensive than the section on cats. We have primarily found information on noise-related effects of fireworks on animals, but describe and discuss effects on other sensory systems, e.g. vision and smell, when available. We describe the impact of other aversive noises on animal welfare when data on the effects of fireworks are lacking in the literature, or to complement existing firework-related data. The compiled information is based on peer-reviewed research articles, and reports, theses, book chapters and other non-peer-reviewed sources have been used when applicable, as well as legislation and legal cases (see list of references).

1.2 Definitions of animal welfare and suffering

In this report, definitions of animal protection, animal welfare, stress and suffering are based on the definitions used by the SLU Scientific Council for Animal Welfare (2025), translated from Swedish.

The term **animal protection** refers to human actions and responsibilities - what people do, fail to do, or ought to do for animals. It includes legislation, control, etc. The term **animal welfare** is used when referring to the individual animal's experience and its ability to cope with its situation. More specifically, the definition of animal welfare adopted by the World Organisation for Animal Health (WOAH) is applied here, stating that "Animal welfare means the physical and mental state of an animal in relation to the conditions in which it lives and dies" (WOAH, 2022). **Stress** is a general term that denotes a series of standard physiological reactions, often accompanied by behavioural changes. Stress can be caused by many kinds of stimuli, and individuals may respond differently in the same situation. The extent of the stress response depends on how the individual perceives the situation and its ability to predict and control it. Stress is a natural reaction intended to protect the individual but can become a welfare problem if the individual's coping capacity is exceeded. Repeated or prolonged stress causes physiological strain, which can, among other effects, put pressure on the cardiovascular system and weaken the immune system, potentially leading to disease. Stress responses can be measured and partly understood through physiological parameters (e.g. heart rate, cortisol) and behavioural observations.

Suffering is a mental experience of physical or psychological distress of significant intensity and duration. Suffering may involve stress but does not necessarily have to. While stress responses can often be measured, an individual's subjective experience, and therefore the degree of suffering, is more difficult to assess.

1.3 General aspects on fear and stress, and aversive stimuli in animals

Fear is a natural and adaptive emotional response to a stimulus that can inflict harm to an individual (Jones, 1987). Showing fear and being vigilant helps animals to survive. In a natural setting, a fear inducing stimulus can lead to an adaptive stress response, whereby the animal can behave to protect itself either by fleeing, hiding or defending itself. It gives the individual a sense of control in the situation and helps restore the physiological response such as increased heart rate, increased breathing and elevated levels of hormones (adrenaline/noradrenaline, cortisol). The degree of controllability and predictability an animal has in an adverse situation is crucial in determining the magnitude of the physiological and behavioural response (Fraser, 2008).

In situations where a sudden noise, light or smell is registered by an animal it heightens the animal's vigilance, and it can become even more sensitive to other stimuli in the environment. This is known as sensitisation (Chance, 2003). A new stimulus that comes close in time to the first frightened stimulus does not have do have the same modality, meaning that, for example a visual stimulus that the animal normally is not frightened by, scares the animal if it follows a sudden high sound that has already put the animal in a fearful state. If the animal can have control and also predict the situation, thus removing itself from the fearful situation, it can return to a more calm and relaxed state, but if not, then the fear reaction is prolonged, and the welfare of the animal is compromised (Jones, 1997). Besides sensitisation, animals also learn new things by associating different stimuli in their environment, just like us. Fear eliciting stimuli can be associated with an endless number of things, persons or situations, like the place where the animal was when being frightened. In the case of fireworks, one can predict that animals associate sudden loud noise with light in the sky. This can lead to the same or similar fear response to either of these events in the future.

Fireworks combine sudden, high-intensity, unpredictable noises with bright flashes and smell, i.e. the sort of multi-sensory stimuli that can trigger fear. In addition, pressure/vibration may have an impact as well. The sound, light and pressure/vibration waves may be further modified by the medium (air or water) in which the waves travel. The sound may be in form of bursting/rumbling, whistles or crackles and the sound level can be as loud as 120-150 dB. The sound frequency varies and may be of a range inaudible to the human ear (human range 20 Hz-20 kHz), but perceptible to the animal since many animals have a wider hearing range compared to humans. Inaudible sounds to humans may complicate the assessment of the animal's perception and potential stress from the sound. Almost all studies found when working with this report, focus on the effect of sound, or noise, on different species.

Loud noises, such as fireworks, are unpredictable, sudden, uncontrollable to the animal, unpleasant and can lead to mental trauma (Grigg et al., 2021). Fear responses to sounds vary considerably between individual animals, ranging from mild fear to severe phobias that are expressed as disproportional and extreme panic reactions from which animals can take days or even weeks to recover (Riemer, 2019). Therefore, fear of fireworks dramatically reduces animal welfare. Some authors distinguish between fear and anxiety, suggesting that fear is a response to a specific, identifiable threat, whereas anxiety represents a more diffuse, anticipatory state related to the expectation of potential danger (Boissy, 1995; Steimer, 2002). In other words, fear is typically immediate and stimulus-driven, while anxiety tends to be prolonged and context-independent, often reflecting internal emotional arousal rather than direct environmental cues. In the context of fireworks and loud noises, both terms are often used interchangeably in the literature, as fireworks can elicit both an immediate fear response to loud, unpredictable stimuli and a more sustained state of anxiety in anticipation of further events.

From studies on lab-animals it has been found that the impact of sound on animal welfare is determined not only by its acoustic properties, such as intensity or loudness (dB), frequency (Hz), duration, and temporal pattern (including potential vibration), but also by species- and breed-specific hearing sensitivity, as well as the individual animal's age and physiological state at the time of exposure (Burn, 2008; Clough, 1982; Gamble, 1982; Turner et al., 2005; Voipio, 1997). Furthermore, the animal's previous experience with noise (its individual noise-exposure history) and the predictability of the acoustic stimulus influence how the sound is perceived and how strongly it affects the animal (Castelhano-Carlos & Baumans, 2009).

There are several measures that animal owners and other people responsible for animals can take to avoid or minimise the exposure to fear from fireworks, e.g.

move away from the area affected by fireworks, implement noise-mitigating strategies at home, or at the stable, etc. Behavioural treatments, such as behavioural modification, is a common treatment strategy. Pheromones and pharmacological treatments both aim to reduce fear and stress responses in animals, often in combination with behavioural modification (Dai et al., 2020; Korpivaara et al., 2017; Riva et al., 2022; Sheppard & Mills, 2003; 2008; van Herwijnen et al., 2024).

It is obvious that the perception of fear and associated stress responses from fireworks can affect animal welfare, i.e. the physical and mental state (WOAH, 2022), negatively, and even cause suffering. However, to what content fear and stress influence the welfare depends on different factors, such as previous experiences from fireworks, possibilities for the animal to control and cope with the situation, but also possible physical injuries. So far, we know more about the immediate and short-term reactions, while accumulated and long-term effects of fear and stress from fireworks are less recognised. Measurable aspects of animal welfare include behaviour, physiology, health and, although debated, production. Assessments of these aspects enable us to relate fear from fireworks with negative impacts on animal welfare.

2. Impact of fireworks on dog welfare

2.1 Introduction

Noise sensitivity in dogs is rarely attributable solely to single traumatic events (Levine & Mills, 2008). Multiple factors have been proposed as potential contributors, including traumatic experiences, insufficient habituation, stress-induced dishabituation, social transmission, and sensitisation (Levine & Mills, 2008; Sherman & Mills, 2008).

Dogs have a broader hearing capacity than humans, and are capable of detecting sounds ranging from 20 Hz to 40 kHz (Mak et al., 2022). More specifically, the hearing thresholds are around 19.5 ± 2.8 dB at 0.5 kHz, 14.5 ± 4.5 dB at 4.0 kHz, and 8.5 ± 12.8 dB at 20.0 kHz (Guérineau et al., 2024). Therefore, dogs can hear higher frequency sounds that are inaudible to humans and may be more sensitive to high frequency sounds than previously thought. The visual acuity of dogs is lower than humans, both in bright and dim light conditions (Lind et al., 2017). Furthermore, dogs have a reduced ability to perceive colours (Mowat et al., 2019) but a better night vision (Yamaue et al., 2015) compared to humans. Dogs have a superior sense of smell compared to humans, due to a larger olfactory epithelium area (18 to 150 cm^2) compared to humans (3 cm^2) (Browne et al., 2006) and the 300 million smell-sensitive receptors compared to the 125 million found in humans (Kumar, 2022). We haven´t found any studies investigating dogs' hearing capabilities in relation to fear of fireworks, but their broad hearing capacity may be a contributing factor. Although it is plausible that sight, and smell, from fireworks may contribute to a stress response in dogs, there are, to our knowledge, no studies investigating this.

2.2 Demographics

It is currently unknown what proportion of dogs are affected by fear of fireworks in Sweden because this has not yet been investigated. In a Finnish survey, 39% of the 3,284 respondents indicated that their dog has a noise sensitivity, which was the highest of all fears (e.g. higher than fear-based aggression and separation anxiety). In this study, fear of fireworks was the most common (25.8%) (Tiira et al., 2016). In a study by Blackwell et al. (2013) in the UK, about 25-49% of owners indicated that their dogs were scared of noises, and that fear of fireworks was the most common fear, with over 50% of dogs reacting on every exposure and over 80% reacting at least once. Another survey conducted in Norway showed that 23% of owners reported that their dog was scared of sounds, with 21.6% indicating that their dog showed strong or very strong signs of being fearful during fireworks (Storengen & Lingaas, 2015). It therefore seems that fear of fireworks is the most common reason for a sound sensitivity with somewhere between 25% and 80% of dogs showing fearful reactions to fireworks. The wide range is most likely due to differences in scoring and specific questions asked in the different studies. It is reasonable to expect a similar pattern in Sweden, even though this has not yet been scientifically studied.

The proportion of dogs reported by their owners as fearful of fireworks seems to increase with age (Riemer, 2019; Salonen et al., 2020), although estimations about the age of onset vary. In one study, only just over 10% of dogs under the age of 2 were reported as being fearful, which doubled between 2 and 4 years (over 20%) and kept steadily increasing as dogs aged (Salonen et al., 2020). In another study, the median age of onset of noise sensitivity was 2 years but varied from 8 weeks to 10 years of age (Tiira et al., 2016). A third study showed that 45% of fearful dogs developed the fear when they were less than 1 year of age, and the median age of onset was 1 year (Riemer, 2019). Therefore, it seems that the most common age of onset is between 1 and 2 years of age, even though fear may also develop with age. A likely explanation for the increasing fear with age is that fear responses may both sensitise and generalise as dogs get older.

In addition, neutered dogs are reported to be more fearful than non-neutered dogs, irrespective of sex (Hakanen et al., 2020a; Riemer, 2019; Souza et al., 2025; Storengen & Lingaas, 2015). Females also tend to be more likely to develop firework anxiety compared to males (Storengen & Lingaas, 2015).

2.3 Comorbidity with other behavioural and medical conditions

It is common that dogs that are fearful of noises also have other fears or phobias (so called comorbidity, i.e. the presence of one or more additional conditions or disorders that occur together with a given condition, here fear of noise). A study by Tiira et al. (2016) showed that dogs that were perceived by their owners as fearful toward strangers and new situations, 55.9% were also fearful to noises. On the other hand, dogs that were not indicated to be generally fearful, only 28.8% had reported noise sensitivity. This suggests that animals that are generally more fearful (for whatever reason) are more likely to develop fireworks anxiety. Dogs with separation anxiety were often also indicated to be fearful of noises (49.5%) and dogs with a reported noise sensitivity often also had separation anxiety (22.7%). In addition, noise-sensitive dogs are more likely to display aggressive behaviours towards unfamiliar people and other dogs, but not toward their owners (Tiira et al., 2016). Perhaps not surprisingly, dogs that are scared of fireworks are also often scared of thunder, fireworks, and gunshot noises (Tiira et al., 2016); even though this is not general for all dogs. Pain and other medical conditions may also have an effect on the severity of the anxiety experienced from noise phobias (van Herwijnen et al., 2024), since pain and other medical conditions may have an impact on the general stress level and the animals' resilience to other stressful conditions. Such eventual impact may depend on the individual's physical and mental condition, and it is difficult to draw any general conclusions.

2.4 Breeds, genetics, and personality

Several survey studies have showed a genetic predisposition of fearfulness and noted that certain breeds are overrepresented when it comes to fear of fireworks. In a Norwegian study, the Norwegian Buhund was most commonly reported to be afraid of fireworks, with 32% indicated as fearful (Storengen & Lingaas, 2015). Furthermore, the Shiba Inu (31.6 % reported as fearful) and the Irish Soft Coated Wheaten Terrier (31.2 %) and the Lagotto Romagnolo scored equally high (30.1%). Other studies have confirmed this and showed that the Lagotto Romagnolo were likely to be scared of fireworks (35% of dogs reported fearful were Lagotto Romagnolo), although mixed breeds represented 44% of dogs fearful of fireworks, and also the Finnish Lapponian dog and Wheaten Terrier scored high (>30%) (Salonen et al., 2020). In a different study, mixed breeds were reported to be most impacted by fireworks, followed by pointers and herders (Riemer, 2019). Retrievers and hounds seem to be the breeds least likely to develop a fear of fireworks (Blackwell et al., 2013; Riemer, 2019; Storengen & Lingaas, 2015). However, even though most studies identify differences between breeds, these are not consistent between studies and other factors may be more important in determining the risk of developing fear of fireworks (Blackwell et al., 2013). In Rough Collies, high genetic correlations were found between non-social fear, the curiosity/fearfulness personality dimension, and gunshot reaction, indicating a large genetic overlap between these traits (Arvelius et al., 2014).

Few studies determining the heritability of fear of fireworks have been conducted so far, although there are studies on other kinds of fear and heritability (Strandberg et al., 2025). In Poodles, the heritability of fear of noise is estimated to be between 0.09-0.16 (Handegård et al., 2021), which indicates a low to modest heritability. Genome wide significant loci for fear of sounds have been detected on regions that overlap with human neuropsychiatric loci related to glutamatergic and dopaminergic neurotransmission in the brain (Sarviaho et al., 2019). The DRD2 gene, which encodes the dopamine receptor 2, is linked to fear of noises in both the Irish Soft Coated Wheaten Terrier and the Collie (Bellamy et al., 2018). This suggests that noise sensitivity has a biological basis and overlaps with human psychiatric conditions.

2.5 Management, ownership and environmental characteristics

Several studies have also shown a link between too little exercise and increased fear of fireworks (de Souza et al., 2025; Hakanen et al., 2020a). Dogs that get too little exercise may not get the stress-reducing and mood enhancing benefits needed for stress resilience (Jongman et al., 2018; Tiira & Lohi, 2015; Zschucke et al., 2015). It seems that between 1-3 hours a day of exercise (including training, playing and walking) has a protective effect (Hakanen et al., 2020a; Tiira & Lohi, 2015).

Dogs owned by female, younger or unmarried/single dog owners are more likely to experience firework anxiety (Chin et al., 2025; de Souza et al., 2025). Also, dogs owned by inexperienced dog owners and those who did not take their dog to puppy training classes are reported to be more fearful (Hakanen et al., 2020b; Kurachi & Irimajiri, 2019). Dogs living in urban areas tend to be more fearful (Hakanen et al., 2020b), likely due to the already busy and noisy environment with a dense dog population, which may lead to additional stress that makes sensitisation to fireworks more likely.

2.6 Impact of fireworks

2.6.1 Impact on behaviour

There are a number of studies investigating the impact of fireworks on behaviour, and they range from i) owner reports (survey) studies to owner films collected during fireworks and ii) observational studies under controlled conditions.

Behaviour- Owner reports

The results presented here are based on the owners' assessment of their dogs' behaviour only, and no clinical examination or behavioural evaluations were performed. Typical reactions to fireworks, as reported by dog owners, include alertness, shaking, panting, hiding, seeking proximity to the caretaker, vocalisations, and refusal to go outside or to eat (Blackwell et al., 2013; Dale et al., 2010; Gates et al., 2019; Mann et al., 2024). Reactions are likely to vary greatly across individuals and situations and may depend on other factors. For example, female dogs (also reported to be generally fearful and neutered) expressed fear mostly by escaping, hiding, trembling, and holding a low tail, while males (also reported to be generally non-fearful and intact) often urinated or defecated and destroyed household items (Tiira et al., 2016). Age differences in the expression of fear may also be present: younger dogs defecated/urinated more, showed more freezing behaviours and less salivation compared to older dogs (Tiira et al., 2016). The clinical manifestations of fireworks anxiety in dogs are indicated in Table 1.

Table 1. Clinical manifestations of fireworks anxiety in dogs.

Category	Specific Signs/Behaviours
Vigilance and Body Posture	Trembling or Shaking
	Cowering, Crouching, or Lowered body posture
	Freezing (Cessation of movement, "Freezing to the spot")
	Vigilance or Scanning environment (Hypervigilance)
	Startle response or "Jumpy"
	Tucked tail or Tail Stiff
	Flattened ears, Ears Moving, or Ears Erect
	Tense muscles
	Inactive (Standing still, sitting, laying down), or Decreased activity
	Panic behaviour (General)
Locomotion and Escape	Pacing or Restlessness (Frantically moving back and forth)
	Running around or Locomotion
	Bolting (Abrupt escape)
	Escape behaviours (Trying to get out/Escaping confinement)
	Door orientation or Eyes focused on the door
	Hyperactivity
	Circling or Running
	Jumping or Climbing
Vocalisation	Barking, Whining, Whimpering, or Howling (Vocalising/Nervous vocalisations)
	Stress whining
Affiliative and Withdrawal	Hiding (Searching for places to hide) or Social withdrawal
	Seeking comfort or Soliciting human attention (Owner seeking/Clinginess)
Oral and Self-Soothing	Panting (Breathing heavily with open mouth)
	Salivation or Drooling (Clearly increased salivation)
	Tense muzzle
Elimination and Destruction	Inappropriate elimination (Urination/Defecation)
	Vomiting or Diarrhea
	Destructive activity (Scratching/chewing/biting floor or objects)
	Biting (Door or object)
	Fence manipulation
Other Distress Signs	Loss of appetite or Anorexia
	Self-harm or Self-trauma
	Excessive blinking
	Dilated pupils

Behaviour - Observational studies

The advantage of observational studies is that they use objective observations and can detect more subtle signs of discomfort and stress that are often missed by owners. Behaviours encoded from videos recorded during New Year's Eve and a control period of similar length when no fireworks were present showed that the ear backwards position, increased locomotor activity and panting were clear signs of fear of fireworks (Gähwiler et al., 2020). Exposure to 180 seconds of recorded fireworks in a controlled laboratory setting resulted in more alertness and attention, searching for the sound, startle responses, hiding and running away in dogs with a reported sound sensitivity compared to dogs without a sound sensitivity (Souza et al., 2018). Interestingly, typical 'stress signals' often observed in other context such as lip licking and yawning were not observed during fireworks exposure (Gähwiler et al., 2020).

2.6.2 Impact on physical injuries

A survey from New Zealand showed that 23 of 654 dogs expressing fear from fireworks were physically injured. In total, 53 of 1635 dogs and cats in the study were injured, with 21% of the injuries caused by accidental misuse, 13% by deliberate misuse and 66% by indirect results from fireworks (e.g., caused a road traffic injury by attempting to escape from fireworks) (Dale et al., 2010). Furthermore, there is a risk of ingestion of fireworks, which contain a wide range of chemical compounds and may contain other parts such as paper and metal wires that can cause injury (Gondhia et al., 2015). The clinical signs of ingestion vary depending on the presence of different chemicals and the amount. Gastrointestinal signs are commonly reported (Bates, 2022) although more severe barium poisoning can also occur (Stanley et al., 2019), but such cases are rare. Most animals will recover within 24-72 hours with appropriate care (Gahagan & Wismer, 2018).

2.6.3 Impact on physiology

Sound sensitive dogs reacted to 180 seconds of recorded fireworks in a controlled laboratory setting with exacerbated autonomic responses with changes in heart rate variability (HRV), i.e. the variation in time between consecutive heartbeats, compared to dogs not classified as sound sensitive, although cortisol concentrations were not affected by the fireworks sounds (Souza et al., 2018). However, a second laboratory study found increased cortisol levels after exposure to recorded firework sounds (Pekkin et al., 2016). Both changes in HRV as a response to sympathic nerve activation and cortisol release are indicators of stress. We have not found any other studies that have investigated the impact of fireworks on physiological parameters in dogs, although there are studies on other loud and unpleasant sounds that may be relevant. For example, cortisol concentrations increased within 40 minutes after thunderstorm exposure (Dreschel & Granger, 2005; Franzini de Souza et al., 2017).

Exposure to loud noise during an MRI examination increased cortisol and arginine vasopressin concentrations (Schroers et al., 2024). A sudden aversive sound led to an increase in heart rate as well as cortisol (Beerda et al., 1998).

2.7 Treatment and prevention

2.7.1 Awareness

In order to treat noise phobias effectively, it's important that owners recognise the signs of fear and anxiety in their dog. Research shows that many owners do not recognize subtle signs of fear (Ballantyne, 2018; Grigg et al., 2021; Mills, 2005; Mills et al., 2012), which may mean that the anxiety remains unnoticed and untreated, which would have a detrimental impact on the welfare of the dog. Second, when owners do recognise their dog's fear of fireworks, they may not be aware that there are treatment options available (Blackwell et al., 2013). International studies suggest that the percentage of owners that seeks help is relatively low (Dale et al., 2016; van Herwijnen et al., 2024). And from the ones that did, many failed to seek help from a qualified behavioural consultant or veterinarian (Blackwell et al., 2013; Riemer et al., 2019) In addition, many owners wait with seeking help until their dog's fear is unmanageable (Ballantyne, 2018), while early prevention and treatment can be an effective way to avoid escalation, We do not know to what degree these studies are relevant for Swedish conditions, since the awareness of dogs' fear of fireworks is generally high among Swedish dog owners. Nevertheless, these studies highlight the welfare risks of not recognising signs of fear and anxiety associated with fireworks.

2.7.2 Treatment and management strategies

Before any behavioural or pharmacy intervention is applied, it is important to consider how the dog's physical environment can be modified so that the impacts of the sounds are minimised, and a safe environment is maintained. This may include strategies like creating a 'safe having' or den, sound masking and changes in walking routines to avoid exposure to unexpected fireworks sounds which are more likely to occur in the evening.

Behavioural modification therapies are the cornerstone of long-term treatment for fear and anxiety (Mills, 2005; Overall, 2013; Sherman & Mills, 2008). The purpose of behavioural modification is to change the dog's emotional response to the feared stimuli through a structured learning process (Riemer, 2020; 2023). Owner survey studies suggest that behavioural modification using fireworks sound recordings is effective in reducing fear of fireworks in 55% of the cases (Riemer, 2020). However, from these surveys it is not clear how exactly the behavioural modification is applied, suggesting that the success rate could be higher if more standardised protocols were to be adopted.

The use of sedatives as a pharmacological intervention has shown to alleviate noise-associated acute anxiety and fear from fireworks in dogs (Korpivaara et al., 2017). Psychotropic medication can provide short-term relief during fireworks and play a supportive role in the treatment of fireworks anxiety, by reducing the overall anxiety and lowering the dog's anxiety threshold so that behavioural modification is more effective (Forster et al., 2020; Overall, 2013). In this sense, psychotropic interventions are not a replacement for behavioural modification but rather a complement so that the dog can be receptive to the behavioural therapy, learn new coping skills and prevents the fear from progressing (Denenberg, 2021). Similarly, dog-appeasing pheromones and supplements are also used for the alleviation of firework-induced anxiety (Riemer, 2020; Sheppard & Mills, 2003).

2.7.3 Prevention

While a limited number of studies have evaluated the effect of fireworks prevention, early results seem promising. First of all, it's important that breeding pairs are chosen carefully to prevent hereditary noise sensitivity (Bremhorst et al., 2024; Handegård et al., 2021; van Herwijnen et al., 2024). Second, the early socialisation period in puppyhood is important in preventing fear of fireworks later in life. Studies have shown that controlled gradual early-life exposure to acoustic stimuli can increase resilience to sudden noises (Alves et al., 2018; Chaloupková et al., 2018; Stolzlechner et al., 2022). This habituation process could potentially be further enhanced by pairing the sound with positive experiences such as play and treats (Bremhorst et al., 2024). Owners that indicated that they specifically trained their dog before any actual fireworks exposure reported reduced fear (Riemer, 2020) Furthermore, owners reported that early exposure to thunder made subsequent fear of fireworks less likely (Blackwell et al., 2013). These studies therefore suggest that early exposure to sounds at an intensity that is not frightening can be effective in preventing fear of fireworks.

2.8 Conclusions

Firework-related noise aversion is a common problem in dogs that significantly reduces welfare. Research indicates that fireworks are the most frequent trigger of noise sensitivity. The risk of developing fear of fireworks rises with age and seems higher in females and neutered dogs, as well as in dogs acquired from shelters or as adults. Comorbidity with separation-related problems and general fearfulness is frequent. Behavioural signs of fear and stress in dogs in connection with fireworks include vigilance, trembling, hiding, escape attempts, vocalisation, and changes in appetite and elimination. Effective treatment starts with environmental management and safety planning. Behavioural modification using structured sound exposure shows promise, potentially in combination with pharmacological options and pheromones that lower arousal in order to support learning. Early-life, controlled exposure to sounds and selective breeding may reduce the risk of developing fear of fireworks.

3. Impact of fireworks on cat welfare

3.1 Introduction

As both prey and predator animals, cats have a highly sensitive auditory system. The cat's sensitive hearing range is generally reported to span 5 Hz–32 kHz, although substantial variation exists in the literature regarding its upper and lower limits (Kruger et al., 2021; Sung, 2025). Sounds exceeding 20 kHz are classified as ultrasonic (Kruger et al., 2021), and the cat's auditory range encompasses these frequencies, enabling detection of the ultrasonic vocalisations of mice and rats. Cats possess an exceptional ability to localise even brief sounds as short as 10 milliseconds (Heffner & Heffner, 1988). Their highly mobile pinnae, capable of rotating up to 180°, act as directional amplifiers that aid in pinpointing sound sources (Calford & Pettigrew, 1984). Given this acute auditory sensitivity, fireworks, characterised by sudden, high-intensity and unpredictable noises, are likely perceived by cats as aversive and potentially threatening stimuli. In addition to intense noise, fireworks emit bright, rapidly changing flashes which may contribute to sensory overload and fear reactions in cats. Overall, cats are far better adapted to vision under low-light conditions than humans (Bradshaw et al., 2012), and their retinal sensitivity is high, while they have poor visual acuity (Beaver, 2003). Cats´ lower acuity and heightened light sensitivity suggest that the sudden, intense flashes from fireworks may appear particularly dazzling and distressing. However, an association between cats´ visual properties and fear of fireworks remains to be established. The olfactory system in cats is well developed (Chung et al., 2018), but to our knowledge, there are no studies relating the smell from fireworks with stress and fear in cats.

Compared to dogs, the effects of fireworks on cats remain poorly studied. Available evidence nonetheless indicates that most cats display behavioural signs of fear during fireworks. In a large New Zealand survey including 2,959 cats, 25.1% of owners reported their cat as extremely scared, 32.4% as very scared, and 27.1% as moderately scared (Gates et al., 2019). In another study performed in Italy, 60% of 426 cats were fearful of loud noises, gunshots, and thunderstorms, while 31.9% showed no behavioural reaction according to owners (Palestrini et al., 2022). Owner beliefs and background appear to influence reported fear levels. Owners who agreed that their behaviour could influence a cat's future reaction to fireworks tended to report less fear in their cats (van Herwijnen et al., 2024). Unlike in dogs, early-life experiences such as acquisition source or noise habituation were not associated with cats' fear responses (Dale et al., 2010; van Herwijnen et al., 2024), however, a large proportion of cat owners (45%) indicated that they did not know if their cat had undergone noise habituation as kittens (van Herwijnen et al., 2024) This suggests that other factors such as genetics or temperament may be more influential. Importantly though, Palestrini et al. (2022) found that cats older than 1 year and those adopted from rescues showed more intense behavioural reactions (hiding and vocalising) during thunderstorms. Dale et al., (2010) reported no effect of age or sex on cat fear responses to fireworks.

3.2 Impact of fireworks

3.2.1 Impact on behaviour

Behavioural responses to fireworks commonly include hiding, escape attempts, shivering or trembling, vocalisation, elimination, pacing, cowering, and increased vigilance (Dale et al., 2010; Gates et al., 2019; van Herwijnen et al., 2024). Cats may also show jumpiness, head movements, or seek visual contact with the owner (van Herwijnen et al., 2024). Perceived emotional states mirror these behaviours: 78.1% of owners considered their cat stressed, 63.5% reported the cat felt unsafe at home, and 50% described their cat as "unhappy" during fireworks periods (van Herwijnen et al., 2024). Around 30% of the cats refused to go outdoors during such periods. Notably, a higher proportion of cat owners than dog owners reported that their pet was extremely affected or had gone missing due to fireworks (8.4% of cats vs. 5.4% of dogs) (van Herwijnen et al., 2024). As cats often show subtle or passive fear signs such as hiding or withdrawal, their distress may be underestimated by owners, leading to underreporting. Additionally, because cats vocalise less than dogs, their emotional states may be harder to interpret, potentially masking the prevalence and severity of fear.

To date, no studies have specifically examined the long-term effects of repeated exposure, sensitisation, or habituation to fireworks or similar noise events in cats. Consequently, it remains unclear whether such exposures result in reduced or heightened fear responses over time. Dale et al. (2010) found no association between the degree of fear and the age of the cat, suggesting that fear responses to fireworks may not diminish with age or accumulated experience. Similarly, van Herwijnen et al. (2024) reported that 27% of cat owners indicated their cat refused to go outdoors during the fireworks period around New Year's Eve, regardless of whether fireworks were actively audible or not, implying a sustained or anticipatory fear response.

3.2.2 Impact on physical injuries

Physical injuries occasionally occur as a consequence of escape attempts. Dale et al. (2010) recorded 30 injured cats among 951 fearful cats, and Gates et al. (2019) reported 23 of 2,959 animals. Most injuries were accidental, though two cats were fatally harmed through deliberate abuse involving fireworks (Dale et al., 2010).

3.2.3 Impact on physiology

No studies have been found that directly have measured physiological responses (e.g. cortisol, heart rate, HRV, body temperature etc.) to fireworks in cats. Existing data are based entirely on owner-reported behaviour (Dale et al., 2010; Gates et al., 2019; van Herwijnen et al., 2024). This limits the ability to quantify stress magnitude or compare physiological impact to that reported in dogs and other species.

3.3 Treatment and prevention

3.3.1 Treatment and management strategies

Management strategies for fireworks-related stress in cats have largely been derived from practical guidance rather than empirical evaluation. Recommended measures include preparing a quiet, secure den with litter tray, food, and water at least two weeks in advance; providing hiding boxes; closing windows, blinds, and cat flaps before dusk; masking noise with normal-volume background sounds; and using pheromone diffusers or veterinary-prescribed anxiolytics when appropriate (Hargrave, 2015).

Reported owner practices align partly with these recommendations. Common interventions include keeping cats indoors or allowing them hiding spaces, comforting/supporting the cat, closing curtains or blinds and move the cat to a preferred location, and to smaller degree; playing music or TV and confining cats to one room (Gates et al., 2019; van Herwijnen et al., 2024), According to van Herwijnen et al. (2024), cat owners reported that allowing cats to choose where to stay during fireworks yielded the highest proportion of lasting benefits, followed closely by providing opportunities to hide and offering social reassurance through support or comfort (24–30%).

Among pharmacological and pheromone-based interventions, perceived effectiveness varied widely (van Herwijnen et al., 2024). The authors concluded that sedatives may provide temporary relief during fireworks, but long-term benefits were reported by only a small proportion of cat owners.

3.4 Conclusions

Research on the effects of fireworks in cats is limited, but available evidence from other countries indicates that fear is very common, with negative effects on welfare. Surveys show that the majority of cats display various levels of fear and stress during fireworks, and many cats are described by their owners as very or extremely scared. Typical behaviours include hiding, trembling, escape attempts, vocalisation, and increased vigilance. Although, to our knowledge no physiological studies have been conducted, these reactions suggest acute fear and stress responses comparable to those seen in other species. Little is known about the long-term effects of repeated noise exposure in cats, including whether such experiences lead to habituation or sensitisation. However, current evidence suggests that fear responses to fireworks may persist over time and can occur even in the absence of immediate firework exposure. Management strategies are largely based on practical advice rather than controlled evaluation, often including environmental adaptations, and using pheromone diffusers or pharmacological options.

4. Impact of fireworks on horse welfare

4.1 Introduction

Experimental studies and reports from horse owners have shown that exposure to fireworks and loud noises negatively affects horse welfare through measurable behavioural (Lindstedt, 2020; Riva et al., 2022,) and physiological changes (Rausk, 2020). This has also been reinforced by recent survey data from Redwings (2025), which gathered responses from 5,128 participants, where 48.9% reported firsthand experience of a horse in their care being negatively affected by fireworks. The same survey revealed that 87% of the respondents worry about the impact of fireworks on their horse(s), while only 6.7% reported not being concerned because their horses appeared unaffected.

Fireworks combine sudden, high-intensity, unpredictable noises with bright flashes and smell, the sort of multi-sensory stimuli that can trigger fear and flight in a prey species such as the horse. As prey animals, horses possess a highly sensitive auditory system that can detect high frequencies of up to ~33 kHz, well above the human range (20 kHz). Furthermore, compared to humans, horses possess a relatively poor spatial localisation of brief sounds (Cracknell & Mills, 2008; Saslow, 2002;). However, their highly mobile ears can move independently in either direction to aid in localising the sound. This sensory profile likely makes fireworks particularly distressing, as the combination of unpredictable, high-frequency noise and the inability to localise the source readily can trigger flight responses (Lindstedt, 2020). With a panoramic field of vision of almost 350°, horses can detect movement and rapid motion across a much wider area than humans (approximately 200°), though their spatial detail and visual acuity are lower than in humans (Roth & McGreevy, 2025). They see well in low light but adapt slowly to sudden brightness changes (Rørvang et al., 2020). Although not described in the scientific literature, this feature is possibly making flashes from fireworks especially startling. Horses possess a highly developed sense of smell. Research shows that unfamiliar or biologically relevant odours, such as predator scents, can heighten vigilance and physiological arousal in horses, especially when combined with loud noises (Christensen & Rundgren, 2008). Similarly, it is possible that the unfamiliar chemical and smoky odours produced by fireworks may act as additional stressors, amplifying fear responses already triggered by the sound and light, but such a connection has yet to be established.

In a large-scale New Zealand horse owner survey, in total 79.8% of 4,765 horses were described as anxious (39%) or very anxious (40%) around fireworks (Gronqvist et al., 2016). This included horses used for various purposes, including sport, trekking/leisure riding, Pony Club, and racing. In Gates et al. (2019), 38% of 817 horses were categorised by their owners as "extremely scared" and 30% as "very scared". Consequently, most owners reported to have observed different adverse behaviours exhibited by horses in response to fireworks. In the UK–US study by Riva et al. (2022), 22% reported that their horse had shown unusual or fearful behaviour during noisy events including fireworks. In an owner-based survey, 30.2% of Finnish (n = 262) and 54.7% of Swedish respondents (n = 512) reported fireworks-related anxiety in their horses around New Year's celebrations, and of those, 26.6% and 55.7%, respectively, rated the signs as severe (Lindstedt, 2020). Clearly, these studies indicate that fireworks-related fear or anxiety affects a large proportion of the horse population and therefore constitutes a major welfare concern.

Another factor that contributes to noise sensitivity is temperament, which strongly influences an individual's behavioural responses to challenging or fearful situations (Lansade et al., 2008b). Temperament refers to a set of behavioural tendencies that emerge early in life and remain relatively stable across different situations and over time (Goldsmith et al., 1987; Lansade et al., 2008a). Because of this stability, an individual's behaviour in specific contexts can be predicted to some degree. Fearfulness is regarded as one of the fundamental traits of temperament. In the context of fireworks, this implies that some horses, those with a more fearful temperament, are more likely to react strongly, displaying heightened startle or flight responses, whereas less fearful horses may react comparatively less. This may explain why some horses are consistently more fearful even to other sources of loud noises, such as gunshots, loud motorbikes or thunderstorms as reported by survey participants (Lindstedt, 2020). To our knowledge, however, no previous study has specifically investigated the role of temperament in horses' behavioural responses to fireworks/loid noises.

Building on this, individual differences in behaviour are not only shaped by temperament traits such as fearfulness, but also by the way horses cope with stress. These consistent behavioural and physiological responses to stressors are referred to as coping styles. Horses may adopt either an active (proactive) coping strategy, characterised by flight, agitation, or aggression, or a passive (reactive) strategy, involving immobility, freezing, or withdrawal (Budzyńska, 2014; Coppens et al., 2010). Over time, repeated exposure to stressful situations without adequate coping opportunities may lead to stereotypic behaviours, such as weaving or box walking, which are interpreted as attempts to regain control and reduce stress (Sarrafchi & Blokhuis, 2013). Such coping styles help explain why horses show different behavioural responses to fireworks.

4.2 Demographics

Regarding demographic and contextual factors. Riva et al. (2022) found in a UK–US based online survey of 1,836 horse owners, sex to be the only significant predictor: geldings were more frequently classified as "very anxious" compared to mares, whereas age showed no significant effect. In a Nordic survey (Finland and Sweden), owners most often first noticed signs of fireworks-related anxiety when horses were between 4 and 9 years old, and Swedish respondents who reported severe signs also perceived them as worsening with age, though statistical testing revealed no significant association between age and severity of behavioural signs (Lindstedt, 2020).

4.3 Management and environmental characteristics

Housing and management context may further influence sensitivity to fireworks. Riva et al. (2022) summarised that single-box housing has been linked to heightened reactivity to novel stimuli. Gronqvist et al. (2016) examined environmental context during fireworks and found that owner-reported anxiety levels in horses did not differ between urban and rural settings. In contrast, Lindstedt (2020) reported about a sixfold higher risk of noise anxiety in horses living in urban environments compared to those in the countryside, although this finding should be interpreted with caution as only 12 horses of total 759 horses were reported to live in urban areas.

4.4 Impact of fireworks

Prevalence estimates of fireworks- and/or noise-related anxiety in horses vary substantially across studies and countries, reflecting differences in management systems, event frequency and measurement methods.

4.4.1 Impact on behaviour

Because horses evolved as prey animals, they are naturally fearful to unknown, sudden and unpredictable stimuli. Fear is a normal and adaptive reaction to potential threats, serving to promote survival by facilitating escape from, e.g. predators (Boissy, 1995). In horses, fear often triggers an instinctive flight response that is hard-wired, i.e. deeply anchored genetically and has remained largely unaltered despite domestication. Consequently, sudden stimuli such as fireworks can provoke intense escape behaviours (Lindstedt, 2020). While such reactions are adaptive in the wild, they can pose significant safety risks in domestic settings for both horses and humans handling them. Although relatively few studies have specifically investigated horses' reactions to fireworks, the behavioural responses observed by owners closely resemble typical fear reactions reported in horses exposed to other fear-eliciting stimuli, such as novel objects or sudden auditory events (Christensen & Rundgren, 2008; Lansade et al., 2008a; von Borstel et al., 2010).

In general, most owners described their horses as anxious in response to fireworks. In New Zealand, ~39% of horses were reported as being "anxious" and 40% as "very anxious" (Gronqvist et al., 2016). In the UK, 50.3% of owners (n = 3,483) noticed a change in the horse's behaviour beyond the duration of the fireworks display itself (Redwings, 2025). Clearly, owner surveys consistently document that many horses show overt fear during fireworks as expressed in increased locomotion like running, fence or box-walking, bucking and rearing (Dai et al., 2020; Riva et al., 2022). In fact, over 80% of horses (n = 1,107) were reported by their owners to run when frightened by fireworks, sometimes leading to breaking through fences (35%) (Gronqvist et al., 2016) and escaping from the premises (Gates et al., 2019). Similar behaviours have been presented by Lindstedt (2020). Beside increased locomotion, owners often report that their horses lose appetite, show signs of diarrhoea and increased defecation, sweating, trembling, shivering, and increased vocalisation (Gates et al., 2019; Lindstedt, 2020; Riva et al., 2022,). Data from a cross-sectional survey of companion animal owners in New Zealand, including information about horses, confirm these observations in terms of reported behavioural responses to fireworks (Gates et al., 2019). Fifty-three percent of horses were observed shivering and 21% of horses vocalising. Yet the highest proportion was related to escape behaviours 72.5% (Gates et al., 2019). Other signs recognised by horse owners were restlessness (e.g. pawing, head shaking, trotting on spot, tail switching) and startle responses (horse suddenly increases the speed for a short time to get to another point of the box faster) according to Dai et al. (2020). Many of these behavioural responses correspond to medium to high stress indicators identified by Young et al. (2012), confirming that fireworks indeed often induce high levels of anxiety.

Redwings published a survey about fireworks and horses in 2025 with data collected during the previous year from 5,128 respondents. Respondents could choose several options from a list of predefined effects they had observed in their horse when stabled as compared to being kept in an outdoor paddock during fireworks exposure. The most common reaction in the stable (n=1,750) was alertness, and being nervous and unsettled (91.4%), followed by pacing/box walking (82.3%), breathing heavily/snorting (72.3%), defecating repeatedly/loose droppings/diarrhoea (61.7%), and not eating (60.9%). Not surprisingly, horses kept in outdoor enclosures (n=1,730) were observed trotting/cantering/galloping repeatably (87.9%), being alert, unsettled and nervous (85.3%), breathing heavily/snorting (65.1%), and sweating (53.1%).

4.4.2 Impact on physical injuries

Because of adverse fearful reactions during fireworks exposure, the risk of physical injury to horses is not uncommon and constitutes a significant welfare issue. In the survey study by Gronqvist et al. (2016), 26% of participants reported that their horses obtained injuries associated with fireworks. The most common injuries were lacerations (40%), strains/sprains (10%), and broken limbs (7%). Based on survey results by Riva et al. (2022), horses categorised as very anxious were more likely to sustain an injury (26%) than only slightly anxious horses (5%). Across both the Finnish and Swedish surveys, approximately 8% of horses were reported to have injured themselves in connection with noise anxiety during fireworks (Lindstedt, 2020). Most of these cases involved horses described by their owners as showing severe noise anxiety. Redwings' survey results (2025) revealed that around 26% of owners (n = 3,483) reported that their horse sustained a short-term injury due to fireworks exposure, veterinary treatment was required in 16.2%, or an existing condition was made worse (10.8%), and 5% of owners specified that the horse sustained long term-injuries. Almost 4% of horses died or had to be euthanised as a result of the incident. In around 10% of cases, a person was also injured (Redwings, 2025).

Fearful horses not only endanger themselves but also pose significant safety risks to the humans handling them. Research has shown that activities involving horses are among the most injury-prone of all animal-related pursuits, and that a large proportion of accidents occur while handling horses from the ground (Hawson et al., 2010, Thompson et al., 2015). This highlights the broader safety implications of fear and anxiety-related behaviours, both for equine welfare and for human safety.

4.4.3 Impact on physiology

As mentioned earlier, severe noise anxiety can also manifest in diarrhoea, increased defecation, shivering, and trembling (Riva et al., 2022), as well as signs resembling colic such as rolling, looking or kicking at the flank (Dai et al., 2020). Although fewer horses were reported to show colic-like symptoms when turned out compared with when stabled according to survey results from Redwings (2025). These outward signs arise from internal physiological stress reactions, mediated by the sympathetic–adrenomedullary (SAS) system and the hypothalamic–pituitary–adrenal (HPA), redirecting blood flow and muscle activity from the intestinal tract to systems needed for immediate action. (Bartolomé & Cockram, 2016; Koolhaas et al., 2011). The relative dominance of the SAS or HPA system, influenced by temperament and experience, determines whether an individual exhibits active (proactive) or passive (reactive) coping behaviour (Coppens et al., 2010). Horses with heightened HPA reactivity may show subtle behavioural signs despite strong physiological stress activation, underscoring the need to combine behavioural and physiological measures when assessing (fireworks-related) fear (König et al., 2017; Young et al., 2012).

Physiological indicators of these stress responses include changes in heart rate (HR), heart rate variability (HRV, i.e. the variation in time between consecutive heartbeats), and cortisol levels. Increased heart rate has been shown in several studies that investigated horses' reactions to fear eliciting stimuli, including noises/distracting sounds (Christensen et al., 2005; Janczarek et al., 2020; Janicka et al., 2024). A decrease in HRV reflects a transition toward sympathetic control of cardiac activity and thus increased stress (Borstel et al., 2017). For instance, HRV reduction has been observed in horses´ response to playback of predator vocalisations (Janczarek et al., 2020). Elevated cortisol levels are typically associated with acute or chronic stress responses (Borstel et al., 2017).

However, to our knowledge, studies that have directly measured physiological responses, such as heart rate or cortisol, to fireworks are lacking; most evidence comes from owner surveys, focusing on behaviour. Therefore, interpretations of physiological stress responses to fireworks have to be extrapolated from experimental studies investigating horses' reactions to other fear-eliciting situations. For example, Hole et al. (2023), investigating the effect of ear covers to damp the noise from auditory stimuli, found that the maximum and average HR was significantly higher than the resting HR. Similarly, Christensen et al. (2005) reported that horses exposed to novel white noise (10–20,000 Hz, 60 dBA) showed higher HR (62.2 ± 2.3 beats/minute) compared to a control situation (52.3 ± 2.1 beats/minute).

4.5 Treatment and prevention

4.5.1 Treatment and management strategies

Survey data from Sweden, Finland, New Zealand, UK and US indicate that a large proportion of horse owners implement a variety of management strategies during fireworks events. Such strategies, that were not necessarily the same in the various studies, include moving horses to paddocks farther away from displays, stabling or yarding, relocating the horse off-property, or confine the horse in the stable, and to a smaller degree, confining horses to a small room or pen and using closed curtains or blinds. Horse owners also used noise damping ear plugs/cover for the horse. Offering additional feed, forage, or treats to divert attention, playing music, and leaving lights on in the yard were other strategies used to mitigate the effects from fireworks. Many horse owners chose to stay with the horses to frequently check them when fireworks were anticipated, and to provide comfort or reassurance

(Gates et al., 2019; Gronqvist et al., 2016; Lindstedt, 2020; Redwings, 2025; Riva et al., 2022). Overall, many horse owners felt that their interventions were helpful, but the reported effectiveness of the different strategies varied between the studies, individuals and contexts.

Behavioural modification aims to reduce fear and anxiety by changing how horses respond to fear-eliciting stimuli such as fireworks. Behavioural modification is widely used in companion animals to treat noise anxieties (McLean & Christensen, 2017) and may also benefit horses with firework-related fear. For example, results from auditory habituation (Janicka et al., 2024) suggest that controlled exposure training may improve tolerance to unfamiliar or sudden noises. However, empirical research on different behavioural modification techniques for noise or firework anxiety in horses remains scarce compared with the extensive work on habituation to novel visual stimuli and handling (Christensen, 2013; Christensen et al., 2006; Droguett et al., 2024).

Experience from companion animals supports potential calming effects of species-appropriate pheromones in fear contexts. Overall, the few research on pheromones and in horses has mainly focused on stress associated with handling (Alves de Paula et al., 2019; Falewee et al., 2006; Gaultier et al., 2005, Tod et al., 2005). However, in a study by Dai et al. (2020) pharmacological treatments (sedatives) showed effectiveness in reducing firework-related anxiety and fear in horses.

4.6 Conclusions

Fear and stress in horses from fireworks and other aversive sounds are common, and have been confirmed by behavioural and physiological observations. Horses are prey animals with a highly sensitive sensory system and thus sensitive to adverse and sudden, unpredictable stimuli. Fearful reactions, such as escape attempts, can result in physical injuries, contributing to the overall negative welfare impact on horses from fireworks. Many horses express fear during fireworks by increased locomotion, i.e. running, fence or box-walking, bucking and rearing. Owners have reported that horses lose appetite, show signs of diarrhoea and increased defecation, trembling, shivering, sweating, increased vocalisation, restlessness and startle responses. Horse owners implement a variety of management strategies during firework events to align with current understanding of equine fear and stress responses. Similar to companion animals, horses may benefit from behavioural modification. In addition, pheromones and pharmacological options are also available, but scientific data on the effectiveness during fireworks are still scarce.

5. Impact of fireworks on farm animal welfare

5.1 Introduction

No specific studies could be found on the effects of firework on farm animals. However, a few review papers have investigated the effect of noise on farm animal welfare and stated that noise can cause behavioural activation (arousal) and sleep disorders in farm animals, indicating a physiological stress response (Brouček, 2013; Olczak et al, 2023). While fireworks are not specifically mentioned, these studies establish that unexpected or intense sounds can disturb farm animals, potentially compromising welfare. Firework noise is characteristically sudden, unpredictable, and high in peak intensity (often >100 dB), making it a likely potent stressor also for farm animals. The sharp, unpredictable high-frequency bursts are particularly disturbing to species with greater high-frequency sensitivity (like pigs and poultry), while the low-frequency booms cause physical startle and vibration that affect larger livestock.

Hearing is crucial for spatial orientation, social recognition and danger detection. The first visible reaction indicating hearing in animals is orienting attention, such as head or ear turning, toward the sound source, known as the Preyer's reflex. Classic studies by Heffner & Heffner (1983; 1990; 1999) established baseline data on frequency and loudness sensitivity in farm animals. Most species, except birds, detect higher frequencies than humans, making high-pitched tones (e.g. from electronic devices) potentially aversive.

Cattle have hearing ranges similar to humans but better high-frequency perception, though poor sound localization (Heffner & Heffner, 1983; Phillips, 2002). Pigs possess large, mobile ears whose structure and mobility vary by breed (Marcet-Rius et al., 2019; Wei et al., 2007). They detect sounds from 42 Hz to 40.5 kHz, with peak sensitivity between 250 Hz and 16 kHz (Heffner & Heffner, 1990). Chickens are most sensitive to sounds around 2.6 dB at 2 kHz and can perceive frequencies between 2 Hz and 9–12 kHz (Hill et al., 2014; Tefera, 2012). They respond less reliably below 64 Hz, suggesting infrasound is perceived differently.

No primary studies have quantified fireworks effects in farm animals while stratifying by age, sex, background, comorbidity, personality or genetics. Evidence from acute-noise analogues (e.g. aircraft overflights) suggests that disturbance responses vary across species, group size, social structure, sex, age, vegetation cover, season, terrain, and distance to the source (Gladwin et al., 1988).

5.2 Impact of aversive sound

Since, to our knowledge, there are no specific studies on the effects of fireworks on farm animals, we describe the impact of other sources of aversive sound on behaviour, physiology and production.

5.2.1 Impact of on behaviour

Cattle

In cattle, sudden and novel sounds trigger stronger behavioural reactions than continuous high noise (Arnold et al., 2007). Unexpected high intensity noise, such as low altitude jet aircraft overflights (above 110 dB), at milking parlour could provoke adverse behaviour, such as kicking or stomping (Morgan & Tromborg, 2007). The noise threshold expected to cause a behavioural response by cattle is 85 to 90 dB (Manci et al., 1988). Noises greater than threshold have provoked retreat, freezing, or strong startle response (Morgan & Tromborg, 2007). Since the sound from fireworks are sudden and of higher intensity (up to 150 dB) it is reasonable to assume that firework will cause a fear response in cattle.

Pigs

Exposure to sudden or intense sounds (85–97 dB) elicited increased locomotor activity in pigs, particularly at higher frequencies (8 kHz) and sound intensities (Talling et al., 1996). Behaviour shifted from resting to alert and aroused states, indicating activation of defence mechanisms. Responses were strongest to abrupt, high-frequency or real transport sounds, while some habituation occurred when no immediate threat followed (Talling et al., 1996). Pigs show greater aversion to intermittent and unpredictable noise than to uniform, continuous sound testing intervals and sound types between 84-86 dB (Talling et al., 1998). Their findings indicated that habituation occurred only to predictable noise. The intensity in this study was also much lower compared with the loudness elicited by fireworks.

Sheep

Sheep exposed to gunfire noise displayed clear fear-related behaviours that intensified with proximity to the sound source (Hauser et al., 2013). When heavy machine-gun salvoes were fired close to the flock, producing sound pressure levels exceeding 120 dB, similar to the intensity of fireworks, the animals showed marked fright reactions and no signs of habituation to the repeated shooting noise. Lambs exposed to noise (75–95 dB) walked longer and showed approximately 30–40% higher motor activity compared to control animals (Quaranta et al., 2002). In contrast, control lambs spent more time lying, feeding, and ruminating, indicating calmer, more routine behaviour. These results align with earlier studies reporting that lambs exposed to 95 dB noise showed elevated motor activity (Sevi et al., 2001). Such activities may hence disturb normal behaviour, reduce feed intake and rumination of importance to sheep welfare.

Goats

Studies focusing on how goats respond to sudden, high-intensity sounds (e.g. fireworks or gunfire) are to our knowledge lacking. However, available research on acoustic exposure provides some insight. Goats possess a broad hearing range, indicating high auditory sensitivity and the ability to detect a wide variety of noise types (van der Staay et al., 2011). In experimental playback studies, goats exposed to sound stimuli up to approximately 96 dB displayed behavioural arousal and changes in heart-beat parameters, followed by habituation within about three days (Johns et al., 2015). More complex or intermittent sounds (e.g. bell chimes) elicited stronger arousal and slower habituation than uniform tones, suggesting that unpredictable acoustic structures are more aversive. Goats exposed to helicopter-related acoustic (up to 110 dB) and visual stimuli showed mild alerting behaviours, raising their heads and turning their ears toward the source, but there were no significant changes in locomotion (van der Staay et al., 2011). Even during actual helicopter flyovers at low altitudes (50–75 m; peak 110 dB), goats displayed no long-term behavioural stress responses, although increased alertness was observed during over-flights (Weisenberger et al., 1996). The review of sound and livestock welfare by Olczak et al. (2023) confirms that goat-specific data on acute impulse sounds are scarce but suggest that, similar to other ruminants, goats are likely to respond more strongly to abrupt and unpredictable noises than to continuous ones of similar level.

Poultry

Among poultry, exposure to abrupt acoustic stimuli above 100 dB has been shown to trigger head-turning, startle reflexes, and a shift from resting to alert states in broilers. Similarly, 95 dB sound stimuli at 500 Hz elicited a startle response in chickens characterized by a brief latency period followed by running, immobility, jerky head movements, and drowsy behaviour (Algers et al., 1978). Crowding has also been observed in experiments where simulated aircraft flyovers (80-115 dB) whereas applied to laying hens at days 31 and 45 (Stadelman, 1958b). Importantly, their study indicated that birds were much more affected by a single simulation for 4 hours, which would be more representative of fireworks, compared to shorter, repeated exposures of the sound over several weeks. Noise exposure also induces sustained fear responses: hens exposed to 90 dB noise for 60 minutes displayed significantly longer tonic immobility durations than controls, and those exposed to truck, train, or aircraft sounds (90 dB) for 1 hour showed greater fear responses than hens kept in environments dominated by moderate 65 dB vocalisation noise

(Campo et al., 2005). In addition, mature hens (around 35 weeks old) exhibited increased feather-pecking behaviour when exposed to recorded machinery and vocalisation sounds (Bright, 2008). This indicates that poultry probably also would experience fear from fireworks.

5.2.2 Impact on physiology

Cattle

Although direct physiological data in cattle are more limited, behavioural evidence suggests a comparable stress response. In Y-maze choice tests, heifers preferentially selected quieter areas, indicating that noise is perceived as aversive and likely accompanied by physiological stress activation (Arnold et al., 2007). Moreover, Albright & Arave (1993) found that acute exposure above 110 dB during milking elevated catecholamine (e.g. adrenaline and noradrenaline) release in dairy cattle. Yearling beef heifers exposed to sudden handling noise, a mix of human shouting and metal clanging, showed increased heart rate and movement activity compared to those in silence, indicating an acute fear or stress response (Waynert et al, 1999). More broadly, noise exposure elevates dopamine, adrenaline, noradrenaline, and corticosterone, leading to oxidative stress and reduced immune function (Gesi et al., 2002; Srinivasan et al., 2016). Collectively, these findings suggest that intense or prolonged industrial noise (≥85 dB) acts as a physiological stressor in cattle, with measurable endocrine, cardiovascular, and immune effects that can compromise animal welfare and productivity (Olczak et al., 2023).

Pigs

In pigs, louder sounds (95–110 dB) induced anxiety and increased heart rate (Berner & Dietel, 1992), particularly at higher frequencies (8 kHz) (Talling et al., 1996). Moreover, acute exposure to 120 dB noise has been cited (in secondary reviews) as elevating glucocorticoid levels, though not catecholamines (Kemper et al., 1976, as cited in Venglovský et al., 2007). Longer-term experiments by Kanitz et al. (2005) indicate that repeated exposures at 90 dB (daily or triweekly) lead to both short-term and sustained endocrine changes, such as altered ACTH and cortisol dynamics, along with morphological modifications in the adrenal cortex and medulla. Similar to cattle, industrial noise (≥85 dB) may act as a physiological stressor in pigs, see Olczak et al. (2023) above, with negative impact om animal welfare.

Sheep

Sheep exposed to prolonged loud noise have been reported to exhibit reduced adrenal and pituitary weights (Arehart & Ames, 1972). In lambs exposed to 100 dB intermittent miscellaneous sounds have been associated with elevated heart rate and increased respiration, in both acclimated and naïve animals, under experimental conditions (Ames & Arehart, 1972; Manci et al., 1988) which is indicative of stress.

Goats

In goats, exposure to helicopter sounds, including real flyovers reaching 110 dB, did not induce an increase in heart rate, suggesting that brief, high-intensity noise does not necessarily trigger acute cardiovascular stress responses in this species under controlled conditions (Weisenberger et al, 1996; van der Staay et al., 2011). Exposure to playback sounds of non-uniform bell chimes (varying in amplitude and frequency, up to around 96 dB) produced transient increases in heart rate, while a uniform sinusoidal tone elicited weaker responses and faster habituation across repeated trials, suggesting that irregular, complex acoustic patterns are more physiologically stressful and potentially more aversive to goats (Johns et al., 2015).

Poultry

In poultry, exposure to loud and sustained noise activates the hypothalamic-pituitary-adrenal (HPA) axis, leading to increased secretion of corticosterone, an avian stress hormone (Cockrem, 2007; Kight & Swaddle, 2011). This activation increases metabolic rate, blood pressure, and heart rate, and during prolonged stress can impair immune function by reducing organ weights such as the spleen and lymph nodes (Ames, 1978; Morgan & Tromborg, 2007). Empirical studies show that noise exposure alters several physiological markers in poultry. Short-term exposure to 104 dB for 30 seconds caused a pronounced rise in the white blood cells (Gross, 1990), and laying hens exposed to similar noise levels showed the same response (Campo et al., 2005). Likewise, broilers exposed to 80–100 dB displayed significantly elevated plasma corticosterone, and at 100 dB also showed higher cholesterol and triglyceride concentrations (Chloupek et al., 2009). Collectively, these findings demonstrate that acute and chronic noise exposure above ~80 dB can activate stress physiology in poultry, as reflected by elevated corticosterone, alterations in white blood cells, metabolic disruption, and impaired immune function.

5.2.3 Impact on production

Although some studies cover the effects of acute noise or sudden exposure on animal production, most available research refer to chronic noise, rather than acute or sudden exposure. Hence, it is difficult to draw overall conclusions on eventual effects on production from firework exposure.

Cattle

In dairy cattle, acute exposure above 110 dB during milking elevates catecholamine release, which can inhibit milk let-down (Albright & Arave, 1997). Cows exposed to recorded jet noise for 21 days showed no significant productivity changes (Head et al., 1993). Reports from low-altitude aircraft and helicopter overflights describe temporary reductions in feed intake, growth, and milk yield, though effects vary by factors such as terrain and flight parameters (Cottereau, 1978; Manci et al., 1988).

Pigs

In pigs, simulated aircraft noise between 100–135 dB caused only minor changes in feed efficiency, weight gain, or reproductive performance (Manci et al., 1988). Nonetheless, sudden loud noises during farrowing have been linked to behavioural disturbances and an increased number of stillborn piglets (Scipioni et al., 2009).

5.3 Treatment and prevention

5.3.1 Treatment and management strategies

Management strategies to mitigate stress response to sounds like fireworks in farm animals is not very well studied. However, for livestock, physical modifications such as solid-sided chutes, sound-absorbing materials, and routine exposure to mild, predictable noise can help reduce aversive responses (Olczak et al., 2023).

5.4 Conclusions

No studies are available that directly examined the effects of fireworks on livestock, but evidence from general noise and aircraft-related research provides valuable proxies for predicting responses. Exposure to sudden, intense sounds above 85–100 dB reliably triggers startle, fear, and physiological stress reactions across species, suggesting that fireworks (which often exceed 100 dB and combine both high- and low-frequency impulses) are likely to provoke similar or stronger responses. Acute high-intensity noise generally causes behavioural agitation, avoidance, startle responses, and disturbed resting patterns across livestock species, reflecting activation of physiological stress mechanisms. These changes can temporarily reduce milk let-down, growth, or reproductive efficiency, but long-term effects are currently unknown. Because fireworks share the same sudden, unpredictable, and high-intensity characteristics as e.g. industrial or aircraft noise, these findings provide a scientifically grounded basis for inferring that firework exposure constitutes a potent welfare stressor for farm animals. Management strategies are not very well studied, but environmental modifications and routine exposure to mild, predictable noise can help reduce aversive responses.

6. Impact of fireworks on wild and zoo animal welfare

6.1 Introduction

Fireworks can cause acute stress and behavioural disruption in wild animals (Bateman et al., 2023). Unpredictable anthropogenic disturbances, such as approaching humans, aircraft, or sudden loud noises, often elicit flight and vigilance behaviours comparable to those triggered by perceived predation risk (Francis & Barber, 2013; Frid & Dill, 2002). Given the well-documented stress responses of wildlife to unpredictable acoustic stimuli (Francis & Barber, 2013; Shannon et al., 2016), fireworks represent a particularly potent form of disturbance. Although the majority of existing studies focus on birds, similar effects have been observed in mammals, amphibians, and aquatic species, suggesting that the behavioural and physiological consequences of fireworks extend broadly across taxa. Specific research on the effect of fireworks on wild terrestrial mammals has not been found, and the majority of studies related to noise focus on chronic noise pollution from e.g. traffic (hence not included in this review). Bateman et al. (2023), bring forward pollution, e.g. heavy metals, from fireworks as a potential hazard for wild animals, but this remains to be investigated.

Fireworks can pose a significant welfare concern also for zoo animals, many of which are undomesticated species housed in confined or restricted environments. The degree of disturbance likely varies not only between species but also with zoo design, enclosure structure, and management practices, which influence animals' ability to retreat or cope with stressors. While domestic species may show some habituation to human-generated noise, most zoo-housed wildlife retain strong anti-predator responses to sudden, unpredictable stimuli (Morgan & Tromborg, 2007). The majority of studies addressing noise and light disturbance in zoos have examined the effects of evening events, concerts, or visitor activities, which can alter behaviour, rest, and space use. Only a few studies have specifically focused on fireworks. However, differences in study design, species composition, and facility structure make it challenging to generalise findings or draw broad conclusions about the overall impact of fireworks on zoo animal welfare.

Individual variation in animal responses to fireworks and related disturbances in the wild appears substantial and may depend on factors such as species ecology, age, sex, diurnality, social structure and environmental context (Beaulieu & Masílková, 2024). In wild boar (*Sus scrofa*), accelerometer data revealed heterogeneous activity patterns following fireworks, where some individuals reduced activity, others remained stable or increased it, suggesting differences in coping strategies or prior experience (Beaulieu & Masílková, 2024). Sensitivity to disturbance among birds varies between species and depends on both environmental context and body size. Larger-bodied species tend to be more sensitive, whereas smaller birds are generally more tolerant and initiate flight only when threats (humans) are closer (Blumstein, 2006). Similar interindividual variability is reported in zoo animals, where behavioural reactions differ among and within species, sometimes even within social groups (Rodewald et al., 2014; Williams et al., 2023). Traits associated with increased behavioural sensitivity include being terrestrial, herbivorous/omnivorous, diurnal, and adapted to closed habitats (Queiroz & Young, 2018). However, systematic research linking demographic or intrinsic factors (age, sex, genetic traits) to firework responsiveness in wild or captive undomestic animals has not been found.

There is a wide variety of sensory characteristics among wild animal taxa, and it is outside the scope of this report to describe them. Nevertheless, observations clearly indicate the effects of adverse sound and fireworks in wild and zoo animals.

6.2 Impact of fireworks and other aversive sound

Given the relatively small numbers of scientific articles investigating the effects of fireworks on wild animals and zoo animals, in combination with the huge variety of wild species, we also focus on the impact of other sources of aversive sound.

6.2.1 Impact on behaviour

Wild animals

Wildlife generally avoids areas with frequent human disturbance (van der Kolk et al., 2021). Unrestricted and unpredictable fireworks by the public, especially during the days surrounding New Year's Eve, present a major challenge, as animals cannot habituate or anticipate such events (van der Kolk et al., 2021). Fireworks cause acute behavioural disruptions across taxa, and research has focused mainly on European and North American species, particularly water- and songbirds and marine mammals that rely on vocal communication (Shannon et al, 2016). In their review, Shannon et al. (2016) concluded that terrestrial wildlife responses to noise begin at sound levels of approximately 40 dB.

Calling bouts in Crawfish frogs (*Lithobates areolatus)* were increased due to human-generated triggers, including sounds of airplanes and automobiles (Engbrecht et al., 2015). Calling in response to noise pollution can increase exposure to predators, which may have implications on the conservation of this threatened species (Engbrecht et al., 2015).

During exposure to fireworks, certain mammals and wild birds (Weigland & McChesney, 2008), show heightened vocalisation, reflecting agitation or distress, whereas others, including South American sea lions (*Otaria flavescens*), cease vocalising entirely and flee from the area (Pedreros et al., 2016). Research on the effects of fireworks or sudden, intense noise on terrestrial mammals in the wild appears to be scarce. Only one relevant study was identified, mentioned briefly in a review focusing on methodology. Beaulieu & Masílková (2024) reported that wild boar (n = 14) exhibited diverse behavioural responses to fireworks, similar to the variation observed during hunting situations (Olejarz et al., 2024). Accelerometery indicated sudden bursts of movement or immobility depending on individual coping style and local conditions, such as distance to the fireworks, availability of cover and group composition.

In wild birds, particularly waterfowl, strong avoidance behaviour has been documented related to firework events. Weather radar studies show that birds leave roosting sites immediately after midnight, remaining displaced for at least 45 minutes (Shamoun-Baranes et al., 2011). Fireworks caused massive nocturnal flight responses, with thousands taking off simultaneously shortly after midnight and intense aerial movements, reaching peak densities around 500 metres altitude. The strongest disturbances occurred over grasslands and wetlands, key wintering habitats for waterfowl, suggesting that hundreds of thousands of birds were displaced across the Netherlands. These findings indicate that fireworks trigger widespread, high-altitude flight and large-scale disturbance in resting and feeding birds during the winter period. This may have a negative impact on the animals' welfare, not only in terms of the experience of fear, but also concerning use of energy and reduced energy intake.

Disturbance from fireworks increased both the distance and altitude of flight in four species of migratory wild geese in Europe (n = 347) across four species; greater white-fronted goose (*Anser albifrons*), bean goose (*Anser fabalis*), barnacle goose (*Branta leucopsis*) and pink-footed goose (*Anser brachyrhynchus*), followed by compensatory reductions in movement and increased feeding activity in subsequent days, indicating lasting behavioural effects (Kölzsch et al., 2022). Fireworks caused extensive, simultaneous take-offs of birds across the Netherlands in another study by Hoekstra et al. (2024), resulting in flight densities many times higher than on undisturbed nights. The most intense reactions occurred within 5 km of fireworks displays, though increased flight activity was still evident up to 10 km away. Birds inhabiting open areas such as agricultural land, wetlands, and waterbodies were most strongly affected, whereas those in forested or semi-open habitats showed weaker responses, likely due to sound and light buffering. In a review, Bateman et al. (2023) refer to other situations where birds have left their roosting areas during fireworks, e.g. magpies (*Pica pica*) and, with subsequent fatal collisions, Red-winged Blackbirds (*Agelaius phoeniceus*).

In an observational study by Pedreros et al. (2016), sea lions (*Otaria flavescens*) occupying a coastal rookery used for breeding, resting, and nursing were observed. Before the fireworks event, approximately 430 sea lions were present at the colony. Within seven hours after the firework display, numbers had dropped to less than half, indicating large-scale temporary abandonment. The colony gradually recovered, returning to pre-event abundance by midday the following day. Behavioural observations showed an immediate cessation of vocalisations, 287 calls recorded before the event stopped abruptly once fireworks began, along with animals becoming alert and raising their heads. Vocal activity resumed only several hours later, suggesting strong disturbance and behavioural disruption following the fireworks.

Fireworks caused clear short-term behavioural disruptions in both Cape fur seals (*Arctocephalus pusillus pusillus*) and Hartlaub's gulls (*Chroicocephalus hartlaubii*) (case study by Probert et al., 2024). During the New Year's Eve display in South Africa (Cape Town), both species showed increased vocal activity, indicating agitation and heightened alertness. The seals shifted abruptly from resting and sleeping (95% of time, mean group size = 10) to vigilant (93%, mean groups size = 9) and locomotive behaviour (7%) at the onset of fireworks, reflecting a strong disturbance response. Several individuals entered the water shortly after the explosions began and remained there until the display ended. During the recovery period, seals (mean group size = 10) showed only a partial return to rest, spending roughly 40% of the time vigilant, 30% awake but inactive, and 25% sleeping. The noise spectrum of the fireworks overlapped with the species' natural vocal frequencies, suggesting acoustic masking that could interfere with communication. Underwater recordings confirmed that firework sounds propagated into the marine environment, with levels comparable to vessel noise and concentrated below 2 kHz. Collectively, these findings demonstrate that firework displays can temporarily disrupt resting and communication behaviour in coastal marine wildlife, constituting a form of short-term behavioural harassment.

Zoo animals

Zoo species show highly variable responses depending on e.g. ecological niche, species-specific temperament, individual differences, management and enclosure design. During fireworks at a European zoo, rhinoceroses (*Ceratotherium simum*), cheetahs (*Acinonyx jubatus)* and maras (*Dolichotis patagonum*) displayed nervousness and agitation, while elephants (*Elephas maximus*) sought social contact and partial shelter but remained outdoors throughout (Rodewald et al., 2014). Lemurs (*Lemur catta*) twitched or moved in response to loud explosions but later calmed. Llamas (*Lama guanicoe)* showed cautious alertness, and giraffes (*Giraffa camelopardalis*) and bison (*Bison bison bison*) remained largely unaffected. Most animals resumed to normal behaviour soon after the fireworks ended (within 10 minutes).

More recent studies of evening "light events" (not fireworks-specific) also highlight mixed outcomes. Capybaras (*Hydrochoerus hydrochaeris*) spent more time indoors and tapirs (*Tapirus terrestris*) became more vigilant during events, while giraffes (*Giraffa camelopardalis rothschildi*) and vicuñas (*Lama vicugna*) showed little or no change (Williams et al., 2023). These findings underline large interspecific differences and suggest that control over environmental choice (access to indoor/outdoor spaces) can mitigate stress.

Several studies from other non-firework nighttime events reinforce these patterns. Among primates, macaques (*Macaca fuscata*) exposed to high noise levels showed behavioural signs of anxiety (Cronin et al, 2018). Brown spider monkeys (*Ateles hybridus*) increased vigilance and locomotion while reducing affiliative behaviours during event nights (Hunton, 2019), and spider monkeys (*Ateles geoffroyi*) near "haunted house" attractions with screaming visitors spent longer time outside, were more active and displayed startle responses (Proctor & Smurl, 2020). Drills (*Mandrillus leucophaeus*) showed increased vigilance and reduced feeding following some evening events (Williams and Clark, 2019), whereas gorillas (*Gorilla gorilla*) displayed more abnormal behaviours (regurgitation and re-ingestion) and less resting behaviour (Bastian et al., 2020; Beaulieu & Masílková, 2024).

Among non-primate species, behavioural alterations have also been observed. Fiordland penguins (*Eudyptes pachyrhynchus*) and collared peccaries (*Pecari tajacu*) exposed to music during evening events changed enclosure use, where penguins swam more, while peccaries increased time in nest boxes and stayed out of sight (Fanning et al., 2020). Alpacas (*Vicugna pacos*) were more active and spent less time resting when sound pressure levels were highest (Shamoun-Baranes et al., 2011). Tigers (*Panthera tigris sondaica*) increased resting and reduced feeding, locomotion and play during event evenings with more intense sound disturbance (Quintavalle Pastorino et al., 2017). They also showed more stretching, spraying, rubbing, flehmen, glass banging and preferred areas farther from visitors. However, responses among large carnivores are inconsistent as Asiatic lions (*Panthera leo persica*) showed no behavioural change during similar events (Quintavalle Pastorino et al., 2017).

A study of the effect of concert arrangements at zoos showed that higher noise levels influenced species differently (Harley et al, 2022). Several species, including tigers (*Pathera tigris altaica*), amur leopards (*Panthera pardus orientalis*), lynx (*Lynx lynx*), jackals (*Canis aureus*), alpacas (*Vicungna pacos*), and squirrel monkeys (*Saimiri sciureus*), showed heightened activity, vigilance, or avoidance with rising dB-levels, becoming more active, restless, or spending more time out of sight, indicative of arousal and stress. Japanese cranes (*Grus japonensis)* and vultures (*Gyps fulvus* and *G. africanus*) were less likely to rest or sleep as noise increased, reflecting reduced ability to relax and prolonged physiological activation. In contrast, porcupines (*Hystrix africaeustralis*) displayed withdrawal and reduced activity, suggesting a freezing or avoidance strategy, while ocelots (*Leopardus pardalis*) and raccoons (*Procyon lotor*) showed disrupted rest patterns and increased abnormal behaviour, implying agitation and altered circadian rhythm. Binturongs (*Arctictis binturong*) tended to rest more, and tayras (*Eira barbara*) were less likely to sleep at higher noise levels, both indicating disturbed activity-rest balance (Harley et al., 2022).

Collectively, these findings highlight that responses among zoo animals depend on species ecology, prior experience, environmental control and event characteristics (duration, volume and lighting).

6.2.2 Impact on physical injuries

Documented cases of direct physical injury to birds from fireworks are rare (Stickroth, 2015). Only in isolated incidents has the evidence been clear enough to confirm fireworks as the definite cause of death or injury. However, several case reports and online accounts suggest that such events may occur more frequently than officially recorded, particularly where intentional targeting of birds with fireworks is suspected. In confirmed cases, birds have been killed or burned by direct contact with explosive materials. The most serious risk arises from the aftereffects of panic-induced flight, which accounts for about one-third of all recorded escape events. Compared with other forms of disturbance, flocking species, particularly geese and cranes, are more prone to mass panic and chaotic flight (see also fatal collisions in Bateman et al., 2023).

6.2.3 Impact on physiology

Physiological responses to fireworks and other acute stressors in wild animals are inherently complex, as they encompass a wide diversity of taxa with distinct sensory systems, metabolic strategies, and stress-response pathways. While most animals share a broadly conserved neuroendocrine stress axis, involving rapid activation of the sympathetic-adrenal system and subsequent glucocorticoid release (e.g. Herman et al., 2016), there are important species-specific differences in how these responses are expressed and regulated. For example, mammals typically exhibit increased heart rate (HR), respiratory rate, and circulating cortisol during acute disturbance (Wingfield & Sapolsky, 2003) while birds show analogous activation of the hypothalamic-pituitary-adrenal (HPA) axis leading to elevated corticosterone (Cockrem, 2007). Fish and invertebrates display parallel endocrine or neurohormonal changes, often accompanied by altered metabolism, ventilation or ion balance (Wendelaar Bonga, 1997). These physiological reactions serve adaptive short-term functions that promote survival under threat. Yet, if repeated or prolonged, they may lead to maladaptive consequences, such as immunosuppression, oxidative stress or reproductive disruption (Romero et al., 2009; Sapolsky et al., 2000;). Because fireworks combine multiple stress-inducing stimuli (sudden sound, vibration, light and odour) they are likely to activate these pathways across diverse taxa. However, the magnitude, duration, and reversibility of the response depend strongly on species traits, environmental context and prior experience. Recognising these shared mechanisms yet distinct physiological profiles is essential for interpreting interspecific differences in stress resilience and welfare outcomes. However, a few examples are described below, indicating the risk of compromised welfare.

Wild animals

Though, physiological data are scarce, Wascher et al. (2022) investigated the effect of fireworks on heart rate and body temperature of 20 free-living greylag geese (*Anser anser*). They found that both HR and temperature were significantly higher in the first and second hour of the new year (1 January), compared with the same hour 31 December, the average during December and the average during January. Heart rate increased by 96% and body temperature increased by 3% (about 1◦C) in the first hour of the new year, suggesting that New Year's Eve celebration present a major stressor affecting individuals energy expenditure.

Noise pollution from coastal music festivals has been reported to modify the adjacent underwater soundscape and elevate stress hormone levels in Gulf toadfish (*Opsanus beta*) (Cartolano et al., 2020). During the festival, air sound levels reached 72 dBA/98 dBC, while underwater noise increased by 2–3 dB in the adjacent channel and 7–9 dB inside the fish tanks. Fish sampled during the first night of the event showed a 4–5-fold rise in plasma cortisol compared to pre-festival baselines, indicating a pronounced physiological stress response. Although preliminary, the results demonstrate that coastal above-water noise events can propagate into marine environments, potentially stressing nearby aquatic organisms, and highlight the need for further research on how such cross-boundary sound pollution affects marine life and ecosystem health.

Firework-induced flight responses in geese and other birds imply significant acute energy expenditure, potentially leading to depletion of fat reserves required for overwintering (Kölzsch et al., 2022). The sudden, intense disturbance leads to substantial energetic costs during winter, a critical period when food availability is low, potentially reducing body condition, survival, and future reproductive success in birds (Shamoun-Baranes et al., 2011). Because fireworks overlap spatially with protected wetlands and roosting areas, repeated annual exposure could result in cumulative negative effects at the population level, particularly for large-bodied migratory species. Griffon Vulture's (*Gyps fulvus*) heart rate went from 50 to 170 bpm when exposed to firework disturbance (Stickroth, 2015), illustrating the physiological sensitivity of animals to intense, unpredictable sound stimuli.

Zoo animals

No published data has been found quantifying physiological responses (e.g. glucocorticoids, heart rate, heart rate variability) in zoo-housed animals during fireworks. However, studies on comparable nocturnal events indicate stress-related behavioural patterns such as vigilance, reduced rest, abnormal behaviours without clear evidence of long-term physiological compromise (Williams et al., 2023). In great apes, event-associated abnormal behaviours such as regurgitation-reingestion in gorillas (*Gorilla gorilla*) suggest arousal responses, though faecal glucocorticoid metabolites often remain unchanged (Queiroz & Young, 2018; Williams et al., 2023).

Noise exposure related to construction work has been associated with elevated faecal glucocorticoid concentrations in emu (*Dromaius novaehollandiae*), although individual variation was present (Jakob-Hoff et al., 2019). Powell et al. (2006) found no effects of construction noise on corticoid levels in a pair of giant pandas (*Ailuropoda melanoleuca*).

6.3 Treatment and prevention

6.3.1 Treatment and management strategies

Wild animals

The unpredictability and spatial spread of public fireworks make mitigation difficult. Suggested strategies include imposing spatial and temporal restrictions, creating firework-free buffer zones around important wildlife habitats (especially wetlands and roosting sites), and replacing explosive fireworks with low-noise or light-only alternatives such as laser or drone shows (Kölzsch et al., 2022; van der Kolk et al., 2021). Predictability may facilitate partial habituation.

Zoo animals

Management recommendations emphasise identifying high-risk species and providing choice, retreat spaces and access to indoor enclosures (Rodewald et al., 2014; Williams et al., 2023). Limiting sound intensity, shielding visual stimuli, maintaining social groups and increasing staff presence for reassurance are also suggested. Evidence from other event types shows that when animals can control their exposure (e.g. move indoors, hide), behavioural responses are generally less pronounced (Williams et al., 2023). Controlled habituation or conditioning approaches may help in recurrent event contexts, though empirical validation is lacking.

6.4 Conclusions

Fireworks combine intense noise and light, creating a potent source of disturbance for wildlife. Unpredictable and high-intensity stimuli can trigger strong stress- and flight responses across taxa, something that has been observed in wild birds and marine mammals. Radar and field studies show that fireworks provoke mass nocturnal flight, increased vigilance, and temporary habitat abandonment in waterfowl, with possible long-term energetic and fitness costs. Similar disruption has been reported in marine species, such as sea lions and seals, which flee or show altered communication. Evidence on terrestrial mammals is limited. In zoo animals, reactions differ by species, enclosure design and management, but agitation, vigilance and disturbed rest are common responses to fireworks or loud noise. Physiological data remain limited, though studies on wild birds demonstrate acute stress responses. Long-term welfare and population effects are largely unknown. Mitigation strategies include spatial and temporal firework restrictions, and provision of refuges in zoos.

7. Limitations of the literature review

The literature review focused on the effects of fireworks on various welfare aspects across different animal categories, with most studies covering dogs and horses. In other animal categories, where the scientific literature on fireworks was more scarce, information from studies on other aversive sounds was included. Although fear and anxiety induced by other aversive sound sources are, to a large extent, comparable to the effects of fireworks, these other events lack fireworks' multi-triggering effects, which may reduce comparability. Specific information on the effects of fireworks on vision and smell was lacking. Most data were derived from behavioural observations, while physiological responses were reported less frequently. With some exceptions (e.g. dogs), the major studies fireworks' effects on companion animals relied on owner-reported data, which may introduce recall and reporting bias. Several studies were small, with variable firework or noise exposure and subjective outcome measures. Many studies lacked baseline or control data for the animal category studied. The effectiveness of interventions was often not systematically evaluated.

Taking these limitations of the reviewed literature into account, we find the available information very useful and are confident that it contributes significantly to the overall understanding of the effects of fireworks on animal welfare.

8. Research gaps and future research directions

Based on the available literature, we conclude that there is a significant risk that use of fireworks causes anxiety, fear, stress, and potential suffering in both domestic and wild animals, and that preventive measures at the societal level are urgently needed. Furthermore, below we list research gaps and future research directions in this area that would minimise welfare impacts as much as possible.

The following research gaps and future research directions were identified:
i) Long-term, cumulative effects on animal welfare. Current research largely captures short-term behavioural reactions during fireworks events.
ii) Controlled behavioural and physiological studies, since it would provide a more complete picture of the welfare challenges and improve the design of preventive measures and targeted interventions. In particular, the gap regarding physiological data needs attention.
iii) The impact of the combined effects of sound, light, and smell of fireworks on behavioural and physiological reactions; such knowledge would improve the ability to adapt firework use and mitigate its impact on anxiety and fear.
iv) Effects of other aversive sound sources have been used when firework data have been missing. Research on fireworks would provide a more precise understanding of impact across species.
v) Expand research beyond a few species, because most existing studies focus on companion animals, leaving large knowledge gaps for wildlife, farm animals, and aquatic species.
vi) Assessing environmental and contextual factors in relations to fireworks exposure. Animals' responses likely depend on factors such as habitat type, proximity to urban areas and previous exposure. Research in varied ecological contexts would help identifying risk zones, location restrictions and optimal timing.
vii) Evaluate the effectiveness of mitigation and management strategies. There is limited empirical evidence on what helps to reduce fear and stress (e.g., indoor confinement, behavioural treatments, such as desensitisation, acoustic shielding). Controlled studies could guide policy, and help owners, farmers, and wildlife managers in implementing practical and effective measures.
viii) Develop standardised welfare assessment protocols to assess the impact of fireworks. Currently, different studies use inconsistent measures. Creating standardised methods for data collection and welfare evaluation would facilitate comparisons of study results.
iv) Compare effects on animal welfare between traditional fireworks with welfare-friendly alternatives. The relative impact from alternatives, e.g. silent fireworks,

drone light shows or laser displays, on animals remain unclear. Comparative research would inform public policy and contribute to non-harmful celebration practices.

9. Legislation

9.1 Introduction

This report focuses on legislation regulating the use of fireworks. In Sweden, we also have an Animal Welfare Act (2018:1192) that aims to protect the animals we keep from unnecessary suffering, which includes both physical and mental suffering, and a hunting law (1987:259) that states that wild animals (game) should be treated with consideration and must not be harassed (chapter 2, section 1, 2018:1192; section 5, 1987:259). Wild animals are also protected by the Environmental Code (1998:808), under which anyone who disturbs wild animals may be convicted of a species protection offence (chapter 29, section 2 b, 1998:808).

9.2 Legislation on fireworks in the European Union

All EU member states must comply with Directive 2013/29/EU of the European Parliament and of the Council of 12 June 2013 on the harmonisation of the laws of the member states, relating to the making available on the market of pyrotechnic articles, commonly referred to as the pyrotechnics directive. The purpose of the directive is to both harmonise legislation, to avoid trade barriers within the internal market, and to ensure a high level of safety for those handling pyrotechnic articles (chapter 1, article 1, p 1). It is also intended to ensure adequate environmental protection. The directive is a recast of the previously applicable Directive 2007/23/EC of 23 May 2007 on the placing on the market of pyrotechnic articles. Other legislation regulates, for example, the storage and transport of pyrotechnic articles, and the directive also does not cover manufacture for personal use within the member state (chapter 1, article 2, p g).

To ensure that the free movement of goods is not hindered, the general rule is that member states may not prohibit, restrict, or hinder the making available of pyrotechnic articles that comply with the directive (chapter 1, article 4, p 1). However, due to previously diverging national regulations, exceptions are allowed that permit prohibition and restrictions on possession, use, and/or sales to the public of certain categories of fireworks (F2 and F3, see below) for reasons related to public order or safety, health, or environmental protection (chapter 1, article 4, p 2). Therefore, the regulations may still differ between the various member states.
In the pyrotechnics directive, fireworks are defined as “a pyrotechnic article intended for entertainment purposes”, and pyrotechnic articles are categorised based on their hazard potential, type of use, purpose, or sound level (chapter 1, article 3). Fireworks are divided into the following four categories (chapter 1, article 6 p a):

- Category F1: fireworks which present a very low hazard and negligible noise level, and which are intended for use in confined areas, including fireworks which are intended for use inside domestic buildings,
- Category F2: fireworks which present a low hazard and low noise level, and which are intended for outdoor use in confined areas.
- Category F3: fireworks which present a medium hazard, which are intended for outdoor use in large open areas and whose noise level is not harmful to human health.
- Category F4: fireworks which present a high hazard, which are intended for use only by persons with specialist knowledge (commonly known as fireworks for professional use) and whose noise level is not harmful to human health.

Each category specifies a minimum age for persons to whom the fireworks may be supplied, but member states may raise the age limits for reasons of public order, safety, or health (chapter 1, article 7, p 2). The age limits may also be lowered for persons who have completed or are undergoing professional training (chapter 1, article 7, p 2).

The directive further clarifies the requirements for each category regarding for example labelling, materials, safety distances, noise levels, etc. (annex I, 5A). It also outlines the obligations of manufacturers, importers, and distributors of pyrotechnic articles. Each member state is required to take appropriate measures to prevent non-compliant products from being made available on the market, and pyrotechnic articles must carry CE marking to indicate conformity with applicable requirements (chapter 1, article 5; chapter 3, article 20). However, non-compliant products may be displayed and used for marketing purposes at fairs and exhibitions (chapter 1, article 4, p 3).

Since 1 January 2024, member states are required to collect and report injuries and fatalities caused by fireworks (articles 1–3 of Commission Implementing Decision (EU) 2023/1096 of 2 June 2023 laying down the implementing rules for Directive 2013/29/EU of the European Parliament and of the Council with regard to the regular collection and updating of data on accidents related to the use of pyrotechnic articles). But while it is emphasised that pyrotechnic articles may only be placed on the market if, when properly stored and used as intended, they do not endanger human health and safety, animal health and safety is not mentioned at all in the pyrotechnics directive. However, the European Commission has recently evaluated the pyrotechnics directive and concluded that one of the shortcomings of the legislation is the lack of animal protection (European Commission, 2025). This was also highlighted in the public consultation, and the Commission now has the task of considering a revision of the directive.

9.3 Legislation on fireworks in Sweden

In Sweden, the pyrotechnics directive is implemented through regulations issued by the Swedish Civil Contingencies Agency (MSBFS [2015:6] regulations on the provision of pyrotechnic articles and ammunition; MSBFS [2025:2] on the handling of explosive goods). The authorization to issue these regulations comes with the requirement to only allow fireworks whose main purpose is not to produce a bang, as far as possible in accordance with the rules applicable within the European Economic Area (EEA) (section 25, paragraph 2 of the Ordinance [2010:1075] on flammable and explosive goods, OFE). This means that so-called firecrackers or bangers, now require a permit from the municipality and special training to be used in Sweden, and that the sound level for fireworks in categories F1–F3 must not exceed 120 dB (A Imp) (MSBFS 2015:6, annex 1, p 5 A). Rockets launched into the air can also make noise, but if the sound is only a side effect, they are permitted.

The Act (2010:1011) on Flammable and Explosive Goods (AFE) includes a general duty of care. Anyone who handles, transfers, imports, or exports flammable or explosive goods must take the necessary measures and precautions to prevent, avoid, and limit accidents and harm to life, health, the environment, or property caused by fire or explosion of such goods, and to prevent unauthorized handling (section 6, AFE). The same law also states that it is not allowed to transfer or hand over explosive goods to someone who is not authorised to handle them (section 15, AFE). According to section 7 of the AFE, explosive goods may only be handled by someone over the age of 18, which means, for example, that fireworks may not be sold or given to minors. A person who intentionally or negligently violates the requirement regarding sales or transfers may be fined, whereas it is not punishable for a minor to handle fireworks (section 28, paragraph 2, point 1, AFE). For some pyrotechnic articles considered to pose low risk, such as sparklers and snap string fireworks, exceptions to the age limit are made (12 years), while others, considered high-risk, require a permit and/or training (AFE, MSBFS 2025:2). Since June 1, 2019, for instance, rockets with guiding sticks require both a permit and training (section 16, AFE). Applications for permits are assessed by the municipality where the fireworks will be used (section 17, AFE).

Using fireworks may also require a permit from the Police Authority. The Public Order Act (1993:1617), POA, states that pyrotechnic items may not be used without a permit from the Police Authority if the usage, due to time, location, or other circumstances, involves a risk of harm or significant inconvenience to people or property (chapter 3, section 7, POA). The law does not specify exactly what this entails, but it could apply, for instance, in crowded areas or near buildings. Generally, no permit is needed to set off fireworks on New Year's Eve, but in densely populated areas, a permit may still be required. The preparatory works to the law state: “If the use involves a risk of injury or other significant inconvenience to people or property, such as pets, the use of pyrotechnic articles should require a permit” (Government Bill 1992/93:210, p. 121). If a public fireworks display is arranged, for example a display open to the public in a public space, it may also be considered a public event and require an additional permit (chapter 2, section 4, POA).

The Public Order Act also allows municipalities to issue local regulations, which may further govern the use of fireworks (chapter 3, section 9, POA). For example, fireworks might only be permitted during certain hours on specific days, or there may be complete bans in certain areas or near stables, hospitals, or nursing homes. However, the restrictions must not be too general or too extensive in terms of, for example, the geographical area or the period during which they are to apply (Supreme administrative court 2018 ref. 75). Several municipalities have found that proposed regulations restricting the use of fireworks have been rejected by higher instances because they were considered to impose unnecessary constraints and unjustified restrictions on individual freedom (chapter 3, section 12 of the POA, Sundsvall Administrative Court of Appeal, judgment in case no. 3003-2018; Stockholm Administrative Court, judgment in cases nos. 437-23 and 18839-23; Jönköping County Administrative Board, ref. no. 213-10323-2018).

According to the Environmental Code and the Species Protection Ordinance, it is prohibited to intentionally disturb animals (chapter 8, section 1 of the Environmental Code [1998:808], sections 4 and 4a [Species Protection Ordinance 2007:845]), which also led to a ban on the use of fireworks during an event as it was considered to cause unnecessary and unreasonable disturbance to wildlife (Land and Environment Court, judgment case no. 1941-25).

Sky lanterns can be a quieter alternative to fireworks, but they too require safety measures and - in some cases - permits, especially if they involve fire or contain metal. They can be carried by the wind and ignite flammable surfaces or negatively affect animals and the environment. If more than 50 lanterns are to be released, or if the lanterns are 100 cm or taller, a permit is required from the Swedish Transport Agency (sections 1 and 8 of the Swedish Transport Agency’s regulations and general guidelines (TSFS 2013:77); chapter 2, section 9 and annex 2 of TSFS 2010:145 on air traffic rules for aviation apply). Releasing them within 10 kilometres (as the crow flies) of an airport with air traffic control services is only allowed after coordination with the relevant airport to ensure that air traffic is not disrupted (section 9, TSFS 2013:77). Lanterns may also be subject to the provisions of the Public Order Act (1993:1617) and local regulations issued under that law.

9.4 Legislation on fireworks in a selection of other member states in EU

9.4.1 Denmark

As a member of the EU, Denmark has undertaken to comply with the pyrotechnics directive. In addition to this, Denmark has chosen to severely restrict the use of fireworks by the general public in the national legislation. According to section 2 of the Danish fireworks act (Statutory order of the act on fireworks and other pyrotechnic articles, LBK nr 2 of 03/01/2019), fireworks may only be sold to private individuals in retail stores from 15 December to 31 December, and they may only be set off during the period from 27 December to 1 January. If you want to organise a private fireworks display at other time of the year, you must contact an approved professional operator (festfyrværkere) (41 § Statutory order on the import, manufacture, storage, transfer, acquisition and use of fireworks and other pyrotechnic articles BEK nr 1798 of 09/09/2021). Fireworks belonging to category F1 may be sold and used throughout the year. These include Bengal torches, sparklers, firecrackers, etc.

Special safety distances apply in certain situations, and on agricultural properties with livestock, dog kennels, or areas with animals outdoors, rockets or other fireworks may not be set off closer than 100 meters (39 § BEK nr 1798). Other examples of situations where special safety distances must be observed include the vicinity of thatched roofs, haystacks, forest areas, etc. Consideration should also be given to wind, which can double the minimum distance 43 § BEK nr 1798).

In Denmark, there are also local municipal regulations that may further regulate the use of fireworks.

9.4.2 Ireland

Ireland has been a member of the EU since 1973, and the handling of fireworks is regulated by both the EU pyrotechnics directive and national legislation. The pyrotechnics directive has been implemented through Statutory instrument No. 174/2015, and the illegal handling of fireworks is also regulated by the Criminal Justice Act (2006). Since 4 July 2010, only category F1 fireworks may be purchased and used by the general public, and these are subject to an age limit of 12 years (chapter 1 section 7 p. 3 statutory instrument no. 174/2015). Other categories may only be used in organised displays by professional operators and imported, possessed or sold professionally and with a licence.

9.4.3 Romania

In Romania, the placing on the market and safe use of pyrotechnic articles is regulated by law 126/1995 on the regime of explosives and the technical implementation norm, as subsequently amended and supplemented, decision 1102/2014. The law was revised in 2025 and the rules on fireworks were tightened. The changes meant that only category F1 fireworks may be sold to the general public and then only to persons over 16 years of age (article 7 of law no. 126/1995). Other fireworks may only be sold for professional use and used under the supervision of certified pyrotechnicians (articles 7 and 9 of law no. 126/1995). Fireworks may only be used during certain holidays and other times approved by the authorities (article 9 of law no. 126/1995). When used in the vicinity of residential buildings with up to 4 floors, a safety distance of at least 50 m must be maintained, and if the building has more than 4 floors, a distance of at least 100 m is required (article 34 of law no. 126/1995). Fireworks may not be set off on public roads, pavements or in open spaces where there are many people (article 34 of law no. 126/1995). The distance to forests must be at least 250 m for category F2 fireworks and at least 500 m for heavier fireworks (article 34 of law no. 126/1995). In connection with the review of the regulations, penalties were also tightened, and unauthorised production, possession, sale or use of high-risk fireworks (F2-F4) is punishable by 1–5 years' imprisonment (article 15 of law No. 126/1995). The sale of category F1 fireworks to persons under the age of 16 is punishable by a fine or imprisonment for 3 months to 1 year.

9.4.4 The Netherlands

In the Netherlands, the sale, production, storage and use of fireworks are mainly regulated by the Vuurwerksbesluit (the Fireworks Decree). Fireworks in categories F1 and F2 may be sold to private individuals, but with certain restrictions. While category F1 fireworks may be sold year-round and to persons over the age of 12, category F2 fireworks may only be sold from 29 to 31 December and to persons over the age of 16 (if any of these days is a Sunday, fireworks may also be sold on 28 December) (articles 2.3.2 and 2.3. 5 Vuurwerkbesluit). For category F2 fireworks, it is also not permitted to sell more than 25 kg of category F2 fireworks to the same customer, and it is prohibited to set them off at times other than between 6 p.m. on 31 December and 2 a.m. on 1 January of the following year (does not apply to professional use) (articles 2.3.3, 2.3.6 and 2.3.7 Vuurwerkbesluit). In order to obtain fireworks in other categories, a so-called pyro-pass must be presented (article 1.1.1 Vuurwerkbesluit).

As in many other countries, fireworks and the regulations governing their use are a controversial topic. Despite the short period during which the public is allowed to use category F2 fireworks, there are many incidents, which place a heavy burden on law enforcement and healthcare services. There are also many reports showing that police officers, firefighters and ambulance personnel are often attacked with fireworks. During the New Year's holiday weekend of 2022–2023, more than 1,200 people were injured by fireworks, and legal fireworks were involved in 34% of these accidents (Valkenberg and Nijman, 2023). The country also has experience of the risks associated with the manufacture of fireworks. In 2000, a major fire broke out in a warehouse at a factory, killing 23 people, injuring 950 and destroying many homes and other property (Visit Enschede, n.d.).

The Senate recently voted to tighten the regulations on fireworks in the Netherlands. On 1 July 2025, a new bill was passed which means that only category F1 fireworks, i.e. the least dangerous fireworks, will be allowed to be possessed or used by the public (Tweede Kamer, 2025). Professional use will still be permitted, and village associations for example, will be able to apply for an exemption and thus obtain permission to set off fireworks in a responsible and safe manner during New Year's Eve (Tweede Kamer, 2025). As a result of the decision, the penal provisions will also be reviewed, and the industry will be compensated (Tweede Kamer, 2025). The changes will entail amendments to several pieces of legislation, which need to be in place before the ban can come into force. The police and local authorities also need to have a plan for how supervision will be carried out. The aim is for the ban to apply from the turn of the year 2026-2027.

9.5 The current situation

Under current EU legislation, it is not possible for a member state to ban fireworks completely, as this would constitute a restriction on free trade. However, there is some flexibility in the pyrotechnics directive, which allows countries to take measures to ban or restrict the possession, use and/or sale to the general public of fireworks in categories F2 and F3 for reasons of public order or safety, health or environmental protection (chapter 1, article 4, 2). Sweden has not made full use of this option in the same way as, for example, Ireland, Romania and the Netherlands, where sales to the general public have been restricted to only the least dangerous fireworks in category F1 (chapter 1, section 7, p. 3, Statutory Instrument no. 174/2015; article 7 of Law no. 126/1995; Tweede Kamer, 2025). In general, we also do not have rules that are as strict as those in Denmark, regarding when fireworks may be sold and used (section 2, the Statutory order of the act on fireworks and other pyrotechnic articles, LBK no. 2 of 03/01/2019). Some municipalities that have attempted to significantly restrict their use, with the support of the public order act, have found that proposed regulations restricting the use of fireworks have been rejected by higher courts because they were considered to impose unnecessary constraints and unjustified restrictions on individual freedom (chapter 3, section 12, POA, Sundsvall Administrative Court, judgment in case no. 3003-2018).

No member state has taken animal welfare into account in its application of the EU pyrotechnics directive, but it is clear that the issue has become increasingly important in the debate on fireworks, and the Commission has noted that one of the shortcomings of the legislation is the lack of animal welfare provisions (European Commission, 2022; European Commission, 2025).

Although uniform legislation in the member states is central to the EU, there are national differences when it comes to fireworks. Several member states have banned mail order sales or certain fireworks for the general public, changed age limits, restricted use in time or introduced licensing requirements. Penalties also vary, with half of member states imposing prison sentences (European Commission, 2025). Despite the increasing criminal use of fireworks, including legal ones, the current pyrotechnics directive focused primarily on free trade and paid less attention to safety. Member states are therefore unable to adopt stricter national rules, for example for fireworks in the high-risk category F4 (only for professional use) a factor that the European Commission identifies as complicating safety management (European Commission, 2025). A revision of the pyrotechnics directive could either give member states greater scope to restrict or ban fireworks at national level, or make EU rules stricter across the board. It would also provide a possibility to specify animal welfare as a basis for restrictions and not, as is currently the case, only public order or safety, health or environmental protection. Regardless of which path is chosen, an effective national control organisation is required for the legislation to be effective. Access to fireworks via online orders also needs to be regulated to a greater extent than is currently the case, in order to prevent circumvention of the regulations and to increase traceability (European Commission, 2025).

9.6 Conclusions

The Swedish legislation on fireworks is governed by the EU legislation (Directive 2013/29/EU). Hence, it is not possible for an EU member state to ban fireworks completely or adopt stricter national rules restricting high-risk fireworks (category F4, used by professionals only), as this would breach the rules on free trade. However, there is some flexibility which allows member states to take measures to ban or restrict the possession, use and/or sale to the general public of fireworks in categories F2 and F3 for reasons of public order or safety, health or environmental protection. In contrast to some other EU members states, such as Ireland and Romania, who only allow sales to the public of the least dangerous and non-aversive fireworks (F1), Sweden has not made full use of this flexibility. In comparison to countries like Denmark, Sweden also does not have as strict rules when fireworks can be sold and used. There is no consideration of animal welfare in neither the Swedish nor the EU legislation concerning fireworks. A proposed revision of the EU pyrotechnics directive may result in member states getting greater possibilities to restrict or ban fireworks at national level, or making EU rules overall stricter, and that animal welfare and protection become criteria for restrictions.

10. Recommendations

Legislators and competent authorities should recognise that many of the fireworks that are allowed in Sweden today are highly aversive, and cause fear, anxiety and stress and a significant risk of suffering for many animals, irrespective of species. Thus, from an animal welfare perspective, it would be best for both domesticated and wild animals if adverse forms of fireworks were banned completely. However, according to current EU regulations, this is not possible in Sweden at present.

Based on the available scientific knowledge and current legislation, and with a focus on animal welfare and protection, our recommendations are as follows:

- Only category F1 fireworks. e.g., sparklers, firecrackers, should be sold to and used by the general public; other categories should only be used by professionals with permits/training and in an organised manner.

- Subsequently, the use of fireworks (F2 to F4) by professionals with permits/training and in an organised manner should only be permitted during strict limited periods of time, a few hours on specified festive nights, such as New Year´s Eve and Walpurgis Night. At other times of the year, permission may be granted by the municipality where the fireworks are to be used, after specific applications.

- When granting permits, we recommend that municipalities implement animal sensitive policies and activities, and:

- particularly consider whether the location of fireworks is suitable from an animal welfare perspective. Restrict publicly organised fireworks near companion, sport, research animal and livestock holdings, zoos and sensitive wildlife areas; establish buffer zones around farms and other animal facilities,

- consider whether the use of fireworks disturb domestic and wild animals during particularly sensitive periods, e.g. reproduction and rearing periods, migration,

- initiate and require early notifications systems that allow the public (i.e. animal owners) to be informed of planned fireworks well in advance, allowing time for relocation of animals or other protective measures,

- encourage quieter alternatives during publicly organised fireworks; e.g. promote silent or low-noise, and non-explosive, fireworks, laser or drone shows during public celebrations,

- promote public awareness campaigns that encourage consideration for animals during festive periods.

• The European Commission's recently published an evaluation of the Directive regulating the use of fireworks highlighting significant shortcomings with regard to animal welfare and public safety (European Commission, 2025). In the event of a review of the directive, it is important that Sweden advocates to either give Member States greater opportunities to establish stricter national rules and bans, or that EU regulations become overall stricter, and emphasises the consideration of animal welfare and protection.

• Efficient official control is needed for the legislation on fireworks to be effective.

• Access to fireworks via online orders also needs to be regulated to a greater extent than is currently the case, in order to prevent circumvention of the regulations and to increase traceability.

• We encourage funding for applied research and extension programmes focusing on systematic monitoring of disturbance, adapted animal welfare assessments, and protective measures for domestic and wild animals. Research findings and programme measures can be integrated into legislation, guidelines, management plans and best practices.

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