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Review

EFFECT OF NOISE ON PERFORMANCE, STRESS, AND BEHAVIOUR OF ANIMALS

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ABSTRACT

The paper deals with findings in animal's response to noise. Factors including species, gender, age, and length of exposure on metabolism, performance, health, reproduction, and behaviour are discussed. The review covers research carried out on farming animals mainly, but contains also general literary sources on response from laboratory animals. This paper summarises the auditory range and some typical levels of sound that have been recorded for farm animals inside and outside housing, during transport and lairage stay. Effects of continuous and sudden noise on animals are also presented in detail. More physiological and behavioural responses have been described as increased hormonal production, increased heart rate, and reduction in production. Animal species exhibit a wide variety of responses to noise. Some animal species are more sensitive than others, because they may exhibit different forms or strengths of responses.

Key words: noise; animal; housing; performance; stress; behaviour

INTRODUCTION

In current animal husbandry noise has become an increasingly great but little noticed problem. Noise produced in intensive animal housing by ventilation system, feeding and excrement removal lines and by animals themselves is a potential stressor and affects not only animals but also the tending personnel.

The purpose of the current study was to determine effects of noise on animals, especially farming animals, and compare the results of previous studies on noise assessment in particular housing situations to demonstrate the impact and significance of the noise problem for design of housing, and management practices. This topic is also relevant to the welfare of animals, because high-frequency noise and intermittent sounds are generally perceived as the most alarming.

Sensitivity to noise

Noise is described as unwanted sound, either chronic or intermittent, and can be described in terms including its frequency, intensity, frequency spectrum, and shape of sound pressure through time (Burn, 2008). Decibel (dB) is the unit for measuring the intensity of sound. It is equal to ten times the logarithm to the base ten of the ratio of the intensity of the sound to be measured to the intensity level of sounds of some reference sound, usually the lowest audible note of the same frequency (B = log 10 (P 1/P 2), where B = Bel, and P 1 and P 2 are power levels. 1 Bel is equal to 10 decibels). Frequency means the number of vibrations per second of the air in which the sound is propagating and it is measured in Hertz (Hz) (Berglung *et al*., 1999).

The interpretation of noise assessment in animal housing is difficult as goals and methodology differ

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substantially between studies (Schäffer *et al.*, 1997). Whether or not a sound is to be described as noise therefore depends on the subjective notion as to whether listening brings about agreeable or disagreeable feelings. The condition under which a recipient is subjected to noise is important (Algers *et al*., 1978). The effects of noise on animal productivity and behaviour depend not only on its intensity or loudness (dB), its frequency (Hz), and its duration and pattern (including vibration potential), but also on the hearing ability of the animal species and breeds, the age and physiological state of the animal at the time of exposure. It also depends on the experience of the animal what sounds the animal has been exposed to during its lifetime (noise exposure history of the animal) and to the predictability of the acoustic stimulus (Castelhano-Carlos and Baumans, 2009).

How animals perceive noise? The effect of noise on the central nervous system is dependent on the state of the brain. In an exhausted individual the compensatory mechanisms are more vulnerable than in a rested individual. Intense noise exposure can damage the cochlea and inner ear and lead to a cascade of auditory effects along the entire central auditory cascade (Castelhano-Carlos and Baumans, 2009). A sudden and unexpected noise gives a dilatation of the pupil (Algers *et al*., 1978). Sound levels of approximately 40 dB are suggested as the appropriate level during the night. Sound levels above this have been shown to decrease the quality of sleep (Algers *et al.*, 1978). However, the noise levels in most husbandry buildings are considerably greater than 40 dB.

Susceptibility to noise hearing is species dependent, and it has been shown to be genetically determined (Henry, 1992; Lanier *et al.*, 2000). Animals have a different spectrum of audible sounds with maximum sensitivity at frequencies that are inaudible to humans (Voipio, 1997). The rat´s peak sensitivity lies between about 8 and 50 kHz (Burn, 2008). The lowest frequency rats have been reported to hear is 0.25 kHz and the highest is 80 kHz. When comparing rat and human hearing sensitivity, human values were about 10-20 dB higher than rat´s. Humans are most sensitive to noise in the range of 500 Hz to 4 kHz which includes the range of normal speech (i.e. within this range we can hear quieter sounds) (Castelhano-Carlos and Baumans, 2009).

The sensitivity of cattle, sheep and pigs to sound, and the levels to which they are exposed, has been reviewed by more authors. Cattle hear high-frequency sounds much better than humans, their high-frequency hearing limit being 37 kHz, compared with only 18 kHz for humans (Heffner, 1998). Their best audible sound is also at a higher frequency, at about 8 kHz, compared with 4 kHz for humans (Phillips, 2009). However, thresholds for discomfort for cattle was noted at 90-100 dB, with physical damage to the ear occurring at 110 dB (Phillips, 2009). Indeed, cattle, with an auditory range between 25 Hz and 35 kHz, can detect lower pitched sounds than other farm species (Heffner and Heffner 1993). Dairy breeds are more sensitive to noise than beef breeds (Lanier *et al*., 2000).

The auditory range of sheep is 125 Hz to 40 kHz with the most sensitive frequency a little higher than cattle and pigs at 10 kHz (Heffner, 1998). Sheep are most sensitive at 7 kHz (Ames and Arehart, 1972).

Pigs’ hearing range is similar to that of humans, but with a shift toward ultrasound (Kittawornrat and Zimmerman, 2011). The auditory range of pigs is between 55 Hz and 40 kHz and their sense of hearing is more sensitive in the range 500 Hz to 16 kHz, particularly acute around 8 kHz (Heffner and Heffner, 1993). The frequency range for reasonable detection varies between 42 Hz and 40.5 kHz, with a region of best sensitivity from 250 Hz to 16 kHz (Heffner, 1998). Heffner and Heffner (1993) showed that the frequency range of pigs was an octave higher than the human frequency range, 40 Hz - 40 kHz. In addition, they found that the quietest sound which pigs can hear is 8 dB louder than the minimum sound level which humans can hear. However, the sound pressure level at which sound becomes painful to pigs is unknown.

Marler *et al.* (1973, cit. Algers *et al.*, 1978) observed that birds had the greatest increase of auditory threshold in the higher frequency ranges after exposure to noise of 95-100 dB.

Animals not only have to accept the noise, but they also emit (Manteuffel *et al*., 2004; Brumm *et al.*, 2009). Rodents not only produce sounds that we can hear, but also produce and hear frequencies that are inaudible to humans (above 20 kHz), perceiving sounds up to 80 kHz stimulus (Castelhano-Carlos and Baumans, 2009). Vocalisations of animals are important for communication and they also respond to the vocalisations of other species (Phillips, 2009) as might be expected in herd animals that evolved in multi-species grazing environments and which can be prey of carnivores. Previous research with cattle and pigs has indicated that vocalizations are an indicator of stress.

Cattle vocalisations generally range between 50 and 1,250 Hz (Kiley, 1972; cit. Watts and Stookey, 2000). Vocalisations of newly-weaned calves with fundamental frequencies as low as 31 Hz have been recorded (Watts and Stookey, 2000). Weeks *et al.* (2009) recorded mean levels of vocalisations from cattle in the range 80-90 dB and sheep vocalisations at around 70 dB. The use of high-frequency vocalisation was a powerful indicator of behavioural thermoregulation in pigs (Hillmann *et al.*, 2004; Malmkvist *et al*., 2004).

Noise and its source

Several studies have been published showing the different sounds that can occur inside the animal facility (Castelhano-Carlos and Baumans, 2009). Husbandry procedures cause the loudest sounds, especially if metallic equipment is involved or if the work is performed in a hurried manner (Burn, 2008). Noise experienced during housing of farm animals can be short-term or chronic (Clough, 1999). The sources of noise can be technical devices, routine works (opening and closing doors, changing pens, washers, push carts, workers' speech, feed dispensing), basal sound levels caused by mechanical ventilation, animals activities (climbing and chewing on fences), and by their vocalizations (Žitňák *et al*., 2011; Mihina *et al.*, 2012). Sound pressure levels exceeding 75 dB have also been reported at frequencies in excess of 60 kHz in some laboratory animal housing (Morgan and Tromborg, 2007). A background sound level of 50 dB has been suggested to avoid disturbance to animals or personnel (Clough, 1999). According to Venglovský *et al.* (2007), short-lasting but intensive noise can have harmful effect not only on animals but also on personnel. This issue requires further monitoring and attention. Although differences exist in perceived loudness of the same sound, occupational noise limitations have been established for workers, and employees should be provided appropriate hearing protection and monitored for their effects (Mc Bride *et al.*, 2003; Lendelová *et al.*, 2013). The noise contributes to the development of some diseases and disorders caused by stressful conditions such as high blood pressure and other psychosomatic diseases (Šístková and Peterka, 2009).

Weeks *et al.* (2009) measured 75-90 (mean 84) dB in cattle barn, while Algers *et al.* (1978) found the noise range from 61-73 dB. Weeks (2008) noted typical values for grazing cattle at 35 dB. The noise environment in animal production contributes not only means of mechanization end equipment, but also the noise emission emerging manifestation of living animals (biological noise). The background noise level (biological noise) emerging from the biological manifestations of dairy cows ranged from 72.7-83.8 dB (Šístková *et al.*, 2010).

The average levels of noise measured by Algers *et al.* (1978) were 58.6 dB for fattening pigs. They reported that pigs in mechanically ventilated buildings were frequently exposed to noise levels greater than 70 dB. In another study the noise recorded in fattening units of pig farms ranging from 69-78 dB. Talling *et al.* (1998) recorded noise at six farms, on five transporters and at four abattoirs. The average sound pressure level measured in mechanically ventilated pig buildings was 73 dB, naturally ventilated buildings were on an average 10 dB quieter. The frequency content of the sound present on farms ranged from 20-6.3 kHz. Peaks in frequency, probably caused by fans, were identified in the mechanically ventilated buildings but not in the naturally ventilated buildings. A diurnal variation in overall sound pressure level was noted in naturally ventilated buildings but not in mechanically ventilated ones. Weeks *et al.* (2009) measured the sound from gates clanging at a consistent 85 dB. The sound levels varied between 85-138 dB in pig fattening halls and included the vocalisations of the pigs as well as background noise (Weeks *et al*., 2009).

Observations from 13 laying hen farms showed that most noise was produced by feed supplier and distribution systems (Oh *et al*., 2011). During the period 2008-2010 noise measurement was carried out on two poultry farms accounting for a total capacity of 650,000 heads of poultry (broilers, layers, and pullets). Measured values of equivalent sound level in the surroundings of farms were low (38.1-43.8 dB), the high value of noise on the farm has been caused by the handling of feedstuffs (79.3 dB, when the measurement performed 6 m from the containers) and the ventilation systems (67.1 dB, when the measurement performed 3 m from the suction-fan) (Šístková, 2011).

Generally, the sources of harmful noise in animal housings are various: feeding 104-115 dB, mating 94-115 dB, high-pressure cleaning 105 dB, feed mixing 88-93 dB (Venglovský *et al*., 2007). According to Šístková *et al*. (2010), hygienic limits are exceeded only during distribution of feed and bedding and thus only for a short time.

Studies reviewed the claims by farmers linking adverse effects of aircraft or helicopter noise on livestock. Farm owners concluded that aircraft overflights can affect feed intake, growth, or production rates in domestic animals (Cottereau, 1978). Helicopters are commonly used for managing wildlife populations, but their effect on wildlife behaviour is often ignored. The severity of response to disturbance may vary with species, group size, social groups, sex, age, vegetation cover, season, terrain, and distance from the aircraft or helicopter (Gladwin *et al*., 1988).

The exposure of farm animals to noise has been identified as a potential stressor not only in housing (Talling *et al*., 1998; Schäffer *et al*., 2001; Correa *et al.*, 2010) but also during the transport and at the abattoir (Agnes *et al*., 1990; Geverink *et al*., 1998; De la Fuente *et al.*, 2007). The average noise level measured during transport was 91 dB at the frequency range 20 - 16 kHz (Talling *et al.*, 1998). Animals are often exposed to acute noise levels before slaughter in lairages where noise is caused by ventilation fans and operational equipment. The negative impact of noise on animal welfare in lairages has also been reported by Grandin (1998) and Geverink *et al*. (1998).

Noise developed during transport was shown to increase the heart rates of free-ranging cattle (Albright and Arave, 1997), while cattle habituated to the sounds of cars and trucks will readily graze along highways and seldom react (Grandin, 1997). Sheep appear to adapt to increased noise levels, particularly when these are relatively continuous, such as the noise of transport vehicles at around 60-90 dB, although they may show an initial rise in heart rate. Sheep in lairage appeared more responsive to mechanical noise such as metal banging and hosing than to noises of animal origin. Weeks *et al.* (2009) found mean sound levels from clanging gates and other fittings in 11 sheep lairages to be 76 dB and they recorded sheep vocalisations at around 70 dB. One study that measured sound levels during the transport of lambs found that the sound pressure level was continuously above 90 dB (Algers *et al*., 1978).

Other experiments have shown that pigs are exposed to higher sound pressure levels during transport and at the abattoir with different intensity, frequency and duration (Correa *et al*., 2010). Talling *et al.* (1998) noted that noise recorded in fattening units of pig farms ranges from 69 to 78 dB, from 88 to 96 dB at below 16 kHz during transport and between 85 and 97 dB at the abattoir. In four lairages they measured noise levels between 76 and 86 dB, with up to 97 dB in the prestunning pens. The movement of machinery as well as pig vocalisations was found to be a major source of noise and it was concluded that the sound levels and types of sound pigs were exposed to in transit and in lairage were likely to be aversive, and should therefore be regulated to improve welfare (Talling *et al*., 1998). Rabaste *et al.* (2007) recently measured sound levels in Canadian lairages in the range 82-108 dB.

The noise intensity to which poultry is exposed in slaughterhouses during slaughter is relatively high, varying in the range of 80-100 dB (Chloupek *et al*., 2009).

Health and performance

Scientific sources indicate that noise in farm animal environments is a detrimental factor to animal health. Especially longer lasting sounds can affect the health of animals. Noise directly affects reproductive physiology or energy consumption (Escribano *et al*., 2013). Noise may also have indirect effects on population dynamics through changes in habitat use, courtship and mating, reproduction and parental care (Rabin *et al.*, 2003). Male rats exposed to noise showed oligospermia and modifications of the testicle structure. The ovaries and the uterus diminished significantly in female rats after a noise exposure of 110 dB for five minutes 15 times per day for 11 days at 375-500 Hz. Remaining estrus occurs after noise exposure as well. Increase in abortion frequency and fetus resorption, or reduction of fetus weight have been also registered (Algers *et a*l., 1978).

According to Geber (1966) noise is received by the mother‘s ear, the different brain cells integrate the signals. The hypothalamus and the hypophysis are activated; the adrenal cortex and medulla are stimulated and secrete their respective hormones. The uterine blood flow, gas-interchange, nutrition and interchange of waste products between fetus and mother are decreased. The reproductive function of rats can also be affected by sounds. Zondek (1964, cit Castelhano-Carlos and Baumans, 2009) showed that exposure of rats to noise of 50-80 kHz at 80-90 dB in the four days during the mating period reduced fertility by 73.2 %. Exposure to 100 dB of 3-12 kHz for one minute during the four days of copulation reduced fertility by 70-80 %.

Zondek *et al.* (1964, cit Castelhano-Carlos and Baumans, 2009) also showed the influence of sound on the gonadotropic functions in mature rabbits. Losses have been reported from mink farms in the form of premature births and insufficient lactation in connection with exposure to sonic booms. There are reports that the females kill their own offspring (Algers *et al*., 1978).

Neural and neuroendocrine systems are possible mechanisms for the effects of noise on feed efficiency. Sound emission at the frequency of 2 kHz in noise of 75 dB, 85 dB, and 95 dB was found to contribute to appetite reduction of animals (Cwynar and Kolacz, 2011). Algers and Jensen (1991) found reduced milk yield in dairy cows exposed to 1.4 h of 80-100 dB of noise twice daily. A three weeks study found no differences between intensities of 70 dB abd 80 dB noise when produced in an autotandem milking parlour (Kauke and Savary, 2010). Sudden noise of 105 dB could, however, decrease the quantity of milk at the next milking. An ejection in progress might even be interrupted (Algers *et al*., 1978). According to Kovalčík and Šottník (1971), noise as high as 80 dB had no negative effect on dairy cows. Feed intake was increased, milk yield was unchanged, and indices of the rate of milk-releasing were improved. However, immediate exposure to a high-intensity noise (105 dB) resulted in decreased feed consumption, milk yield, and intensity of milk release. Gradual increase of noise to 105 dB resulted in a less-negative response. Gygax and Nosal (2006) investigated on 50 dairy farms the effect of vibration and noise on somatic cell counts in milk. Somatic cell counts increased with an increasing intensity of vibration but not with acoustic noise.

Unexpected high intensity noise (above 110 dB), such as low altitude jet aircraft overflights at milking time could reduce effectiveness of the milk ejection reflex, decrease efficiency of milk removal, increase residual milk, and lead to overall reduction in milk yield. However, a majority of the studies reviewed suggests that there is little or no effect of aircraft noise on cattle. Adverse effects of low-altitude flights have been noted in some studies but have not been uniformly reproduced in other reports (Manci *et al.*, 1988). A number of studies investigated the effects of aircraft noise and sonic booms on the milk production of dairy cows. Milk yields were not affected. Beyer (1983) found that helicopters caused worse reaction than other low-aircraft overflights. However, helicopters at 9 to 18 m overhead did not affect milk production and abortion rates of cows and heifers (Dufour, 1980; Gladwin *et al*., 1988). Cows exposed to recorded jet noise just before milking showed no behavioural or productivity responses during 21days treatment periods (Head *et al*., 1993).

Noise at 75 dB increased average daily weight gain of lambs and improved their feed efficiency compared to control and the 100 dB groups. Acclimatization to sound was evident (Ames, 1978).

Pigs exposed to 90 dB prolonged or intermittent noise decreased growth (Otten *et al*., 2004). The number of pigs farrowed and the number of survivors were not influenced by exposure of the parents to loud sound during mating, or exposure of sows to reproduced sounds at 120 dB for 12 hours daily beginning 3 days before farrowing and continuing until their piglets were weaned (Bond, 1971). Studies using simulated aircraft noise at levels of 100 dB to 135 dB found only minor effects on rate of feed utilization, weight gain, food intake, and reproduction rates of boars and sows (Manci *et al*., 1988; Dufour, 1980).

According to Campo *et al*. (2005) noise seems to affect adversely the productive performance of the birds.

When poultry are transported to intermittent loud noise, rate of laying eggs and growth rate were decreased and mortality increased (Oh *et al*., 2011). Broiler chickens exposed to 110 dB aircraft noise for five minutes every 20 minutes each day and every three nights for nine weeks from birth showed no difference in growth compared to a control group. Egg productivity was affected at exposure levels as high as 120 to 130 dB. Noise at 90 dB seemed not to affect productivity and egg quality of laying hens (Oh *et al*., 2011).

Generally, exposure to sudden, intense noise cause reduced egg production in fowls. Pheasants are reported to have broken their eggs, while suffocation in panic-struck was observed in fowls (Algers *et al*., 1978).

Exposition to 120 dB for 84 days showed no significant influence in quantitative and differential sperm counts of roosters, but these sperms used on insemination worsened the hatchability of eggs (Algers *et al*., 1978). Noise acting for a long time reduces productivity of eggs. More severe responses are possible depending on the number of birds, frequency of noise exposure, environmental conditions, and on experience of animals (Gladwin *et al*., 1988). Study involving turkeys examined the differences between simulated versus actual over flight aircraft noise (Bowles *et al.,* 1990). Findings suggested that turkeys habituated to noise quickly and no growth rate differences between the experimental and control groups were noted while there was increased difficulty for handling individuals.

Metabolism and stress

Noise has been demonstrated to induce a variety of physiological changes in mammals, such as changes in the cardiovascular homeostasis and in the secretion of hormones. Through hearing impulses are given to the brain stem and the hypothalamus. From formatio reticularis the sympathetic nervous system is influenced. Via the hypophysis, adrenocorticotropic hormone (ACTH), and thyroid-stimulating hormone (TSH) the hypothalamus gives signals to the adrenal medulla and the thyroid gland. The parasympathetic nervous system is also influenced and has a mainly reversed effect compared to the sympathetic nervous system (Algers *et al*., 1978; Manteuffel, 2002).

Noise may be a potential stressor causing the organism to react in farm animal husbandry. High noise exposure has also been reported to cause cellular effects. Ultrastructural alterations in myocardium and adrenal glands have been shown in rats exposed to noise of 100 dB for 12 h. DNA damage was also found to be associated with noise exposure (Castelhano-Carlos and Baumans, 2009). Loud sound is well known for adverse effects on blood pressure and heart rate in humans and animals (Geverink *et al.*, 1998; Morgan, Tromborg, 2007). The most obvious effect is a general stress reaction with higher secretion of ACTH giving an increase of adrenocortical hormones in the blood (Burrow *et al*., 2005). Reactions occur in the circulatory system and in the gastrointestinal motility via the sympathetic nervous system. Other effects are sleep disturbances, changes in the glucose metabolism of the liver, changes in the enzymatic activity of the kidneys, and an increase of eosinophils percentage in blood, and immunosuppression (Algers *et al*., 1978).

Noise research has been carried out mainly on man and laboratory animals. These investigations have shown that noise causes a general stress reaction influencing most organs. Stress reaction causes short-term effects and also partly long-term effects. Physiologically, prolonged exposure to intense noise is associated with increased activity of the autonomic nervous system. Its prolonged activation is correlated with increased activity in the hypothalamic-pituitary-adrenal system, elevated metabolic rates, increased blood pressure, and tachycardia (Ames, 1978; Morgan and Tromborg, 2007). According to Weeks (2009) loud noise can cause disturbance of sleep. Long-term noise exposure caused a decrease in plasma glucocorticoids and an increase in plasma catecholamines, ACTH and cortisol concentrations (Otten *et al*., 2004; Kanitz *et al*., 2005). However, not only prolonged stress but also repeated distress is dangerous. Kanitz *et al.* (2005) indicated that exposure of domestic pigs to repeat noise stress causes changes in neuroendocrine regulations.

The physiological responses of dairy cows to noise were reported by Broucek *et al*. (1983). The sound of a tractor engine (97 dB) significantly increased glucose concentration and leucocyte counts and markedly reduced the level of hemoglobin in the blood. The same authors treated primiparous cows individually by the 30 min noise of 110 dB, frequency 1 kHz in an open-field arena. Highly significant increase of glycemia, non-esterified fatty acids content and creatinine under the effect of accoustic exposition were recorded. Haemoglobin level dropped highly significantly. After the repetition of stress after the 2nd calving similar trend was recorded, but the changes were smaller. It refers to the habituation (Broucek *et al.*, 1988a). In another study by Broucek *et al.* (1988b), cows were divided into three groups: mothers and daughters, sisters after mothers and sisters after bulls. The reaction of daughters was, in contrast to mothers, less pronounced. In increasing glucose and creatinine, a highly significant relationship ($r = 0.659$***; $r = 0.549$**) was noted between mothers and their daughters. A non-significant correlation was found in the elevation of non-esterified fatty acids ($r = 0.568$) and creatinine ($r = 0.492$) between older and younger sisters. The reactions of primiparous cows on noise load were influenced by their fathers. We found the differences in frequency of heart rate, haemoglobin, non-esterified fatty acids, glycaemia, and thyroxine contents.

In another trial, pure-tone sound (1 kHz, 110 dB) increased blood glucose, nonesterified fatty acids and creatinin values in blood serum, and decreased the level of hemoglobin, with a slight decrease in thyroxin in plasma. Waynert *et al.* (1999) reported that beef cattle subjected to noise exposure for 1 min per day over 5 days displayed an overall steady reduction in heart rate.

Sounds produced by humans might also be stressful for farm animals. Loud cry causes stress responses in farm animals (Hemsworth *et al.*, 2003). Shouting on dairy cows appears to be very aversive (Pajor *et al.*, 2000). Noise made by humans shouting and slamming of metal gates increases heart rate and activity in cattle (Waynert *et al*., 1999). Lanier *et al.* (2000) also noted that cattle appeared more stressed by intermittent loud human vocalisation, particularly when high-pitched like a child's. Unexpected high intensity noise, such as low altitude jet aircraft overflights with more than 110 dB at milking time could provoke increase peripheral or mammary release of catecholamines (Albright and Arave, 1997).

Arehart and Ames (1972) observed that the adrenal and pituitary weights declined in sheep after noise exposure. Prolonged exposure to loud noise of 100 dB for 8 h increased their respiration rate. Lambs which were not previously exposed to loud noise had elevated heart rates when exposed to 100 dB. It was found that in comparison to a control group carried out in a 65 dB, the increased intensity of sound emission causes stress in experimental animals (Cwynar and Kolacz, 2011).

Ames (1971) published trial with growing lambs. Each animal was exposed to a control period (63 dB background), followed by 3 weeks treatment periods of 75 and 90 dB. Noise intensities of 90 dB noise inhibited the release of thyroxine and triiodthyronine. Significant decrease in the lymphatic tissue of the thymus was recorded in guinea-pigs intermittantly exposed to 139-144 dB noise for 8 hours a day for six weeks (Algers *et al*., 1978). Manci *et al.* (1988) and Gladwin *et al.* (1988) demonstrated no adverse effects on the thyroid and adrenal gland condition of pigs subjected to observed aircraft noise.

Physiological and behavioural studies have identified noise stress during housing (Schäffer *et al*., 2001). Pigs exposed to 90 dB prolonged or intermittent noise increased cortisol, ACTH, noradrenaline to adrenaline ratios (Otten *et al*., 2004). Acute sound exposure was found to increase heart rate (Talling *et al*., 1996). This response was stronger for a frequency of 8 kHz than for 500 Hz and for an intensity of 97 dB than for 85 dB. The heart rate of piglets increased more in response to high frequency sounds (Talling *et al*., 1996; Kittawornrat and Zimmerman, 2011). Trials showed that pigs respond with an increase in heart rate and plasma glucocorticoids when exposed to a short-term noise stress (Talling *et al*., 1998). A single and shortterm noise exposure of pigs at 120 dB was found to increase plasma glucocorticoid concentrations, but had no effect on plasma catecholamines (Kemper *et al.*, 1976; cit. Venglovský *et al*., 2007). In another study, Kanitz *et al.* (2005) exposed pigs to daily or three times weekly noise at 90 dB for two hours. This caused both short-term adrenocortical and long-term stress effects.

Cannulated pigs were exposed to either a daily stimulation with noise (2 h, 90 dB), or to the same stimulus three times a week. Noise exposure caused an increase of corticosteroid binding globulin, ACTH and cortisol levels in daily stimulated pigs in first week followed by a subsequent decrease until week 4. The ACTH and cortisol response of the second group increased after week 1 and was significantly elevated in week 4. There were also significant structural modifications in the adrenal gland of first group of pigs resulting in differentiated effects on the adrenal cortex and medulla (Kanitz *et al.*, 2005). These findings show that pigs are very sensitive to noise and they should not be exposed to constant or sudden noise. Therefore, noise levels above 85 dB must be avoided in that part of any building where pigs are kept (Fottrell, 2009).

Noise intensities of 115 dB were effective in interrupting brooding in hens (Gross, 1990). Acute noise exposures at 80 dB and 100 dB in broilers increased corticosterone level after 10 min of exposure (Chloupek *et al*., 2009). The chickens were exposed to sound of 95 dB which lasted 120 min every day during different age periods. This chronic stress caused significant changes in histological structure of their adrenal glands (Žikić *et al*., 2011).

Noise treatment of 80 dB resulted in a significant elevation of heterophil to lymphocyte ratio indicating stress response of the broilers. Noise treatment of both 70 and 80 dB intensities also resulted in a significant elevation of basophil granulocytes (Bedanova *et al*., 2010). Chloupek *et al*. (2009) simulated slaughterhouse sounds to which broilers were exposed for 10 min in the test room. Noise stimuli of both 80 dB and 100 dB intensities induced a highly significant elevation in the plasma corticosterone level in broilers when compared to the control birds. McFarlane and Curtis (1989) reported that continuous noise for seven days at the level 80 or 95 dB did not have a significant effect on the plasma corticosterone concentration of broiler chickens. The noise during transport increased heart and breathing rates, and secretion of stress hormone of poultry (Oh e*t al.*, 2011).

Although the current legislation requires that the noise level be minimised, the noise intensity to which poultry is exposed during production life is relatively high, varying in the range of 80-90 dB.

Behaviour

It has been stated in literature that excessive noise has an influence on behaviour and coordination. Mammals in particular appear to react to sudden higher intensity noise, with responses including the startle response, freezing, and fleeing from the sound source. Compared with chronic background or repetitive noise, this aperiodic or unpredictable noise is especially effective for provoking distress responses. Most animals become less responsive to sounds emitted for long periods or at regular intervals.

The degree of animal reaction varied with species of animal, age and individual. The character of the behaviour reactions observed that domestic animals experience from excessive noise is disturbing their well being (McAdie *et al*., 1993; McGlone and Swanson, 2010). Animal activity may be increased at background noise. Particular states of emotion may thus be accompanied by specific behaviours. Animals were also reported to tend to be more active in the morning periods than in the afternoon periods tested, which might be related to the arrival of staff and beginning of the working day with a general increase in noise levels (Castelhano-Carlos and Baumans, 2009).

An understanding of animal response to helicopters or aircrafts is important in predicting the consequences of the disturbance on the ecology, welfare and behaviour of exposed free kept farming or wildlife animals (Tracey and Flem, 2007). Although some studies reported the effects of aircraft noise on domestic animals as inconclusive, a majority of the literature reviewed indicates that domestic animals exhibit behavioural responses to overflights but generally seem to habituate to the disturbances over a period of time.

Exposure of laboratory animals to noise induced increased abnormal behaviour, suppressed exploratory behaviour, and impaired learning. It has been reported that guinea pigs will jump when exposed to sudden very loud noise (139-143 dB), reduce activity and remain huddled together for up to 30 minutes afterwards. Tooth grinding was also observed in male guinea pigs subjected to frequent loud noise over a period of 6 weeks (Johnson, 2006).

Different levels of background noise were shown to influence learning and behaviour in rats (Castelhano-Carlos and Baumans, 2009). Guinea-pigs showed the most marked reduction in activity when exposed as compared to rats which appeared least affected by noise exposure. After the noise was turned off there was an increase in the general activity of mice as well as of rats. At the beginning of the exposure all the animals huddled in a group. Another reaction of mice and rats was freezing into a motionless stance. When rats were exposed to 95 dB at 0.5-5 kHz for two 5-minutes‘ periods per day for 28 weeks, their behaviour changed and above all they became aggressive (Algers *et al*., 1978). Sudden sounds are probably also more startling than those with gradual onsets (Burn, 2008).

In open field behaviour, continuous noise of 85 dB was shown to increase defecation and reduce both social activities and non-social activities (sniffing, grooming or crawling) of rats when compared with 50 dB, 65 dB or 75 dB. Although noise of moderate intensity is commonly present during experiments on animal learning and memory, its impact has not been explored fully (Prior, 2006). Noise-exposed rats made fewer errors, explored less and finished their trials sooner. Results show that the acoustic environment is an important variable in studies with animal models of learning and memory.

Many studies indicate that sudden, novel sounds seem to affect cattle behaviour more than continuous high noise (Head *et al*., 1993; Grandin, 1998; Arnold *et al.*, 2007). When the aircraft was 152 m above ground level, the cattle ran for less than 10 meters and resumed normal activity within one minute. 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 and 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 and Tromborg, 2007). When the transmitter of ultrasound was switched on at a distance of 1 m, calves got up and orientated towards the sound source. After 30 s, all calves had their ears directed away from the sound source. After 10 min, some calves started to scratch their ears repeatedly. During the 10 minutes period of exposure, none of the calves would lay down again (Algers, 1984).

Arnold *et al.* (2008) examined the effect of noise on the choice behaviour of dairy heifers in a maze. The percentage of heifers that chose the quiet side of maze was increasing as the experiment progessed. Heifers exposed to the noise from milking parlour show escape-type behaviours, consistent with a fear response. They learned to avoid the noise. Pajor *et al.* (2000) assessed responses of dairy cows to various handling treatments. Exposure to noise increased avoidance behaviour, as indicated by increases in stopping and amount of required handler intervention. Broucek *et al.* (1988b) observed the effect of sire lineage on movement activity in dairy cows tested during noise at open-field arena.

Noise in the milking facility has direct implications for on-farm efficiency related to improving cow behaviour and human-animal interactions. Faster movement in response to noise persisted for the first 4 days of the treatment phase, with some evidence of habituation of this response on the fifth day (Waynert *et al.*, 1999). Responses to noise in commercial milking facilities may be influenced by processes of habituation. As dairy cows are regularly exposed to the milking environment, there is opportunity for reduction of any fear responses arising from exposure to noise.

Dairy heifers were exposed to the noise of 85 dB during the 23 m long transfer test raceway. Exposure to noise resulted in increases in heart rate and faster transit times. There were no significant effects of noise on latency to enter the raceway, or animal handling parameters (Arnold *et al.*, 2007). These data indicate that anthropogenic noise generated in the course of routine human activity may have adverse effects on cattle welfare.

The 90 dB of noise level in the short term has caused in sheep a departure from the source of the sound and accumulation of a cohesive group of individuals in the lying position (Algers, 1984). Responses to helicopter over-flights have the potential to alter the time budget of behaviour activities. Bighorn sheep responded to helicopter flights by decreasing their time spent foraging and they were the most sensitive to disturbance during winter (43 % reduction in foraging efficiency). Further analyses indicated a disturbance distance threshold of 250-450 m (Stockwell *et al*., 1991). Caribous (*Rangifer tarandus*) respond to the sound produced by aircraft flyovers with increased activity, although the degree of reaction varies with time of year (Maier *et al*., 1998). Similar effects of aircraft noise have been found in mountain sheep (Bleich *et al*., 1994; Weisenberger *et al*., 1996).

Changes in behaviour can adversely affect wildlife and reduce the effectiveness of management operations. Bleich *et al*. (1994) suggested that frequent disturbance by aircraft could cause animals to vacate their home territory. The distance from the source of disturbance is an important indicator of alert behaviour. Goats displayed alert behaviour when the helicopter was directly overhead and alert response decreased exponentially with horizontal distance from the helicopter. The distance moved decreased sharply when the helicopter was further than 150 m away. Goats were often disoriented and ran away to a distance up to 1.5 km in response to helicopter over-flights. However, Tracey and Flem (2007) found that helicopter flights did not cause mothers to abandon their young, nor adversely affect their immediate or long-term welfare. Feral goats displayed aversion and learnt to respond to helicopter disturbance (Tracey and Flem, 2007).

Horses are also very sensitive to noise. Algers (1984) wrote that after the start of noise stimul horses turned their heads and directed their ears towards the source and then immediately turned their ears away. At a new tone, the horses reacted with attention for a very short time and then turned their ears away again. All horses showed marked attention for the whole 10-min experimental period. The author recorded flight reactions when the noise source was switched on (Algers, 1984).

Several reviews presented a varied response of horses to low-altitude aircraft overflights. Observations noted that horses galloped in response to jet flyovers (Gladwin *et al.*, 1988). Intensive flight reactions, random movements, and biting/kicking behaviour were displayed. However, no injuries or abortions occurred, and evidence suggested that the mares adapted to the flyovers over the course of a month (Manci *et al*., 1988).

Auditory stimuli are used by pigs as a means of communication in all social activities (Gonyou, 2001). Pigs exposed to 90 dB prolonged or intermittent noise increased time lying down and decreased social interactions (Otten *et al*., 2004). According to Talling *et al.* (1996) pigs show an aversion to sudden loud noise during tested in an open-field. This response was stronger for a frequency of 8 kHz than for 500 Hz and for an intensity of 97 dB than for 85 dB, although habituation occurred relatively quickly (Kittawornrat and Zimmerman, 2011). Repeated exposure of pigs to noise levels of 90 dB has negative implications on their welfare (Kanitz *et al*., 2005).

Longer lasting sounds, for example continuous fan noise, can also affect pigs. Behaviour of piglets and sows during suckling in relation to sound levels were investigated by Algers and Jensen (1985). Sows were exposed to a relatively silent background noise of 59 dB or exposed to fan noise at a level of 85 dB. In the noise-exposed environment, the piglets failed to respond to the gruntings of the sow, which led to a disrupted pattern. Significantly decreased massaging of the udder and hence reduced milk production were recorded. Authors concluded that the noise-exposed piglets gained less milk than the ones in the silent environment. In the study of Algers (1984) with sudden noise exposure 10-day-old pigs an immediate attention and orientation reaction for about 10 s was noted. The 6-week-old pigs were immediately activated and started to orientate themselves towards the sound source. An intensive searching behaviour by all pigs started and continued for the whole 10 min period. Attention and waving of the ears were recorded initially in all sows (Algers, 1984). When suckling piglets were subjected to continuous loud noise, they were to a lesser extent attracted to the front teats and more frequently used the teats at the rear part of the udder (Algers and Jensen, 1991).

The intensity of 90 dB prolonged or intermittent noise increased time of lying down, and decreased social interactions (Otten *et al.*, 2004). Some trials showed that pigs respond with an increase in ambulation score when exposed to a short-term noise stress (Talling *et al*., 1996, 1998; Kanitz *et al*., 2005). Talling *et al*. (1996) found that within a continual 15 min exposure to noise, initial differences between treatment and pre-treatment locomotion in pigs decreased over the course of the trial. Habituation to noise has also been observed over repeated exposure on separate occasions.

Drastic effects have been noticed connected with sonic bangs caused by low crossing aircraft, mink and rabbits killing their young (Algers *et al*., 1978). Laboratory rabbits alter their behaviour when exposed to normal laboratory sounds in nonsound isolated housing (Jildge, 1991). Effect of noise on rabbits causes adverse effects including nervous and behavioural abnormalities and can cause a startled response and traumatic injuries to limbs and back (Marai and Rashwan, 2004). Particularly, most concerns about noise effects have traditionally focused on impairment of reproductive and maternal behaviours, although a few controlled studies have been done to support the observations of animal caretakers that noise inhibits production. With regard to the noise, threshold areas in the sensitive range of rabbits lie between zero and 20 dB sound pressure, which means a sensitive hearing.

The typical reaction of domestic fowls after exposure to sudden, intense noise is a short-term startle response. The reaction ceases as soon as the stimulus is ended, and within a few minutes all activity returns to normal. This suggests that the birds habituate relatively quickly (Gladwin *et al*., 1988). A significant negative effect of acute noise exposure at 80 dB and 100 dB on stressfulness and fearfulness in broilers was observed by Chloupek *et al*. (2009). Campo *et al*. (2005) found that laying hens exposed to noise at 90 dB (truck, train and aircraft noises) for 60 minutes were more fearful than control hens kept at 65 dB caused by bird vocalizations and fans. Algers *et al*. (1978) noted characteristic reactions to long lasting sound (95 dB, 500 Hz) as startle response, latent period, running, total immobility, small jerky head movements, and sleep-like behaviour in chickens. The reaction varied in form and strength according to the age of the experimental birds and was strongest in about 26-day old chickens. Sudden loud noises have also been reported to cause hysteria in various strains of chickens (Mitloehner *et al*., 2010). Book and Bradley (1990) reported higher panic and aggression in turkeys in response to noise stimuli simulating aircraft overflights. Wild birds have been reported to react with disrupted sitting (Algers *et al.*, 1978). Bright (2008) recorded noise (background machinery and hen vocalisations) in 21 commercial free-range laying hen flocks aged 35 weeks. Ten of the flocks were classified as feather pecking and 11 as non-feather pecking. For the acoustic parameters measured, there were no differences between the general flock noise of feather and non-feather pecking flocks.

Behaviour of adult animals in captivity is also affected by noise. In zoos and aquaria, noise from visitors increases as visitor numbers increase. Loud sound has been shown to increase vigilance and activity and agitation behaviours in pandas (Morgan and Tromborg, 2007).

CONCLUSION

The intention of this review is to document and compare the results of previous studies on noise assessment, in particular housing situations and to demonstrate the impact and significance of the noise problem for farm animal welfare, housing, design and management. Environmental and communication noises are present in animal housings. Although the majority of the literature suggests that farming animals and wildlife species exhibit adaptation after repeated exposure to noise, careful planning should be made before construction of the animal building, in order to avoid stressful environmental sounds both for the animal and personnel.

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