High Speed 2 Limited

Phase One

Noise effects on Livestock

236118-57/ R01- Issue

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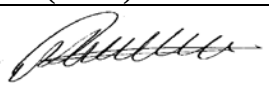
		Signature			
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Appendices

1 Background

The House of Commons Select Committee made the following request:

We want a proper look at how animals in such conditions might be affected and whether better mitigation should be provided in this particular case. The RSPCA (not Petitioners) might be invited to contribute a paper. Mr Goss also needs a sensible solution on how to move livestock around the farm once the railway arrives.

Promoter's Response to Date:

With respect to the noise impact on Mr Goss' livestock, the promoter will work with the relevant animal and noise experts to commission an investigation of the likely impacts on livestock from railway noise, which will include identifying potential mitigation measures for any likely impacts. The promoter will aim to conclude such work ahead of Royal Assent to the Bill. Alongside this, the RSPCA will also be invited to contribute their thoughts on this issue.

The scope of this study considers operational railway noise only, and not construction noise. A number of protective measures are identified in the HS2 Phase One Environment Statement to control construction noise and vibration, including the requirement that best practicable means (BPM) will be applied during construction works to minimise noise (including vibration) at neighbouring residential properties and other sensitive receptors. Additional site specific mitigation may be also identified in the local environmental management plans.

Livestock is defined using the definition from The Agriculture Act 1968 as:

any creature kept for the production of food, wool, skin or fur or for use in the farming of land or for such purpose as the Minister may by order specify.

On this basis the assessment considers cattle, pigs, sheep, alpaca and other camelids, goats, chickens, deer (farmed), turkeys, ducks and horses within the scope of the assessment.

2 Consultation

2.1 Review previous consultation responses

HS2 has sought comment on the scope and methodology to be adopted for the assessment of operational sound, noise and vibration through both the consultation on the HS2 Phase One Scope and Methodology report and the Phase 2a Scope and Methodology report.

A review of the responses to the consultation on these documents has been undertaken and any relevant comment referring to effects on livestock from railway noise are presented in the following sections.

2.1.1 Phase One SMR consultation

In response to the HS2 Phase One Scope and Methodology report engagement the summary consultation report (CT-001-000/3) has been reviewed. No comments regarding sound and livestock were identified in this report.

2.1.2 Phase 2a Consultation

In response to the HS2 Phase 2a Scope and Methodology report consultation two comments were received regarding noise effects on livestock.

The following comment was made by the Country Landowners and Business Association (CLA):

6.6.46 – There was a commitment in Phase 1 to do a fresh study into the impact of both construction and operating noise on cattle and horses in particular. The result of this research should be build (sic) into this methodology as soon as it is available, even if it mean (sic) re-visiting and re-assessing impacts in some sensitive locations."

The following comment was made by the National Farmers Union:

At 6.6.44 the effects of "Operational Sound" is addressed as to how it will affect livestock from operational trains but not construction.

The NFU believes that due to the length of the construction period being so long, the noise from construction must also be addressed. Constructional noise could drastically affect the yield of milking cows. It is also important to address the effect on grazing livestock in a field which runs adjacent to the line and not just buildings as identified in at 6.6.46.

This study forms the assessment identified in CLA comment, albeit limited to operational railway noise. The NFU comment refers to construction noise only.

For information, clause 6.6.46 of the consulted SMR states:

An interim criterion of sound exposure level of 100dB(A) will be used to identify potential significant adverse effects upon agricultural livestock. In the absence of natural or man-made wayside barriers, this would include receptors within a distance of up to 25m from the nearside track for trains travelling at a maximum speed of 360km/h; at lower speeds this distance may be reduced.

This same criterion was used as a basis for scoping potential impacts on HS2 Phase One and referenced in the Environmental Statement technical appendix "Sound, noise and vibration - Methodology, assumptions and assessment (route-wide)" ref.: SV-001-000.

2.2 Specific consultation

HS2 contacted the following bodies via email seeking their comment to the outline scope for this study on 15th August 2016:

- National Farmers Union (NFU);
- Country Landowners and Business Association (CLA);
- Central Association of Agricultural Valuers (CAAV);
- Royal Society for the Protection of Animals (RSPCA); and
- British Horse Society (BHS).

No comments were received in response to this email.

Following on from this correspondence a document titled "Draft scope of study of the effect of sound on livestock" was issued, again for comment, to the same bodies on the 8th September 2016, a copy is presented in Appendix A.

Responses have been received from the RSPCA and BHS. These are presented in Appendix A. The responses were then used to refine the literature review and the questions to be posed during the farm visits in Section 5, and where appropriate the assessment.

3 Review of case law

3.1 Review Land's Tribunal claims

A review of the Land's Tribunal claims in the last 20 years has been undertaken in order to determine any claims referring to noise on livestock. The review did not identify any such cases. However, one case which was settled prior to the Tribunal, and hence did not show in the record, was the case between Mr Ivor Record and London and Continental Stations and Property, regarding railway noise from HS1 at an equestrian centre in Shepway. It is understood that the compensation settlement was a fraction of the claim and it was accepted in the settlement that there was no material noise impact on the equestrian centre consistent with the HS1 noise assessment criteria. The HS1 criteria are consistent with the criteria set out in the environmental statement for HS2 Phase One.

3.2 Review information provided by NFU Mutual

Information has been requested through the process described in Section 2.2. Presently no response has been received from the NFU. NFU Mutual contacted HS2 by phone to confirm that they did not wish to respond to the study.

4 Review of literature

4.1 Phase One ES information

The literature reviewed for the HS2 Phase One Environmental Statement is presented in Appendix SV-001-000, Annex F "Effects of noise on animals". The assessment concluded that:

Having considered the foregoing literature, the approach to assessment of noise effects on fauna arising from operation of the Proposed Scheme has been developed on the basis of the FRA interim criterion[1]. A screening distance[2] equivalent to SEL 100 dB(A) has therefore been used to identify relevant ecological species or agricultural livestock along the route which may potentially be subject to significant adverse effects.

4.2 Literature review

Expert review has been sought from Stephen Turner (ex-Defra) and Dr. Stephen Stansfeld (WHO advisor) who were members of HS2's Acoustic Review Group. They undertook, along with HS2 and Arup, a review of available literature regarding noise and livestock. They have consulted Professor Andy Smith, University of Cardiff and Professor Paul Lepper, University of Loughborough for suitable references on the subject.

The resulting literature which forms the review can be categorised into the following themes, which are discussed fully in the briefing note presented in Appendix B:

- Sound level
- Reproduction and milk production
- Habituation
- Frequency content
- Vibration

4.2.1 Sound level

A paper from *Di and Zheng*[3] considered a level of 70 dB L_{dn}[4] which is current conventional railway design standard in China. The study found adverse effects when rats were exposed to 70 dB L_{dn} for 90 days. The paper is unclear regarding the importance of these effects. The paper concluded that the limit for High-

[1] Federal Railroad Administration (2012), High-speed ground transportation - Noise and Vibration Impact Assessment. U.S. Department of Transportation.
[2] 25m.
[3] Di G, Zheng Y. effects of high-speed railway noise on the synaptic ultrastructure and phosphorylated-CaMKII expression in the central nervous system. Environ Toxicol Pharmacol 2013; 35: 93-9.
[4] For HS2 given that the daytime and night-time levels are close to 10dB apart, 70 dB L_{dn} is equivalent to a daytime level of 70 dB$L_{pAeq,\ 16hour}$ and night-time level of 60 dB $L_{pAeq,\ 8\ hour}$.

Speed trains should be 70 dB L_{dn} as it is for conventional trains. The authors stated that they were exercising the precautionary principle when suggesting this limit. The sound level identified was predicted at the animal's ear.

British Standard BS5502; Part 32: 1990 Buildings and structures for agriculture Part 32: Guide to Noise attenuation, recommends that:

In the absence of any quantitative level with regard to the effect of noise on animals it is recommended that the maximum duration of daily exposure should be 8 h per day at 90 dB(A).

For *McLean and Tarnopolsky*[5], their review of effects on mice, rats and guinea pigs had exposures in the range of 90 -120 dB $L_{pAmax.}$ These levels did result in a reported effect, initially, however, the paper concluded that when a novel stimulus is presented repeatedly, the orientation reaction habituates to zero after 1-30 presentations.

The criterion included in the Phase One ES falls within the range of the information discussed above. On a precautionary basis, it is recommended that screening criteria corresponding to lowest extent of the ranges provided, specifically 70 dB L_{dn} and 90 dB L_{pAmax}, are considered to identify areas where further study is required.

4.2.2 Reproduction and milk production

No link was found between reproduction and milk production rates in connection with maximum noise levels as a result of aircraft noise[6]. It is unclear as to the specific levels considered in the study but levels in the range 73 – 99 dBL_{pAmax} are identified.

4.2.3 Habituation

Where guidance is provided most papers suggest that habituation can occur reasonably quickly, *McLean and Tarnopolsky*[5] suggests after 10 – 30 presentations. If each HS2 pass-by was regarded as a discrete acute event then it could be argued that the existing animals will have habituated during the testing and commissioning phase of the scheme before the passenger service commences. During the testing and commissioning phase the trains would be first run at low speed, almost walking pace, and then incremental increased to operational speeds. This process occurs over a period of 6-12 months enabling habituation to occur in this period. However, newly purchased or born animals would have to become habituated during the operation of the railway, although this is likely to only take a very short period of time, i.e. less than 1 day.

[5] McLean EK, Tarnopolsky A. Noise, discomfort and mental health. A review of the socio-medical implications of disturbance by noise. Psychological Medicine 1977; 7:19-62.
[6] Pepper CB, Nascarella MA, Kendall RJ.A review of the effects of aircraft noise on wildlife and humans, current control mechanisms, and the need for further study. Environ Management 2003; 32:418-432.

4.2.4 Frequency content

The RSPCA's consultation response (see Appendix A) requested that the assessment also consider frequency content, specifically:

Details concerning noise levels, frequency of trains etc. for the HST line should be presented within the report.

Frequency can be considered in terms of how often a train passes a location, or the frequency content of the sound as the train passes. The number of trains is considered in the sound level section regarding the maximum level during a train event. This section considers the spectral content of a train pass-by event.

A normalised one-third octave band spectra[7] for a typical high-speed train is presented in Figure 1. The typical train pass-by spectra is weighted toward the middle frequencies with reduced content in the frequencies above 1 kHz octave band. The spectra also shows that there are little differences between typical current UK mainline trains and mitigated high speed trains.

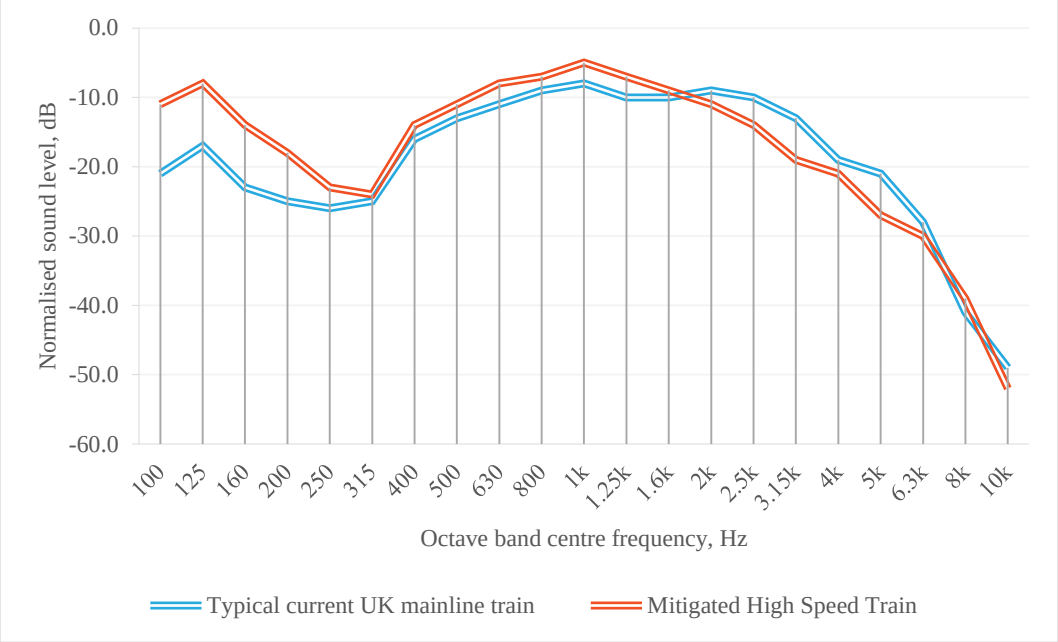


Figure 1: High speed train pass-by spectra measured at 150m from the railway.

The screening criteria is proposed in terms of an A-weighted decibel level (see Appendix D Glossary). Further review is required to determine if livestock have a particular sensitivities to railway noise which would not be considered using this weighting. The spectral A-weighting is used to replicate human spectral response to sound. Typically humans have most sensitivity to sound in the 1 – 2 kHz range, which corresponds to the highest levels in the normalised sound level presented for conventional and high speed trains.

[7] Derived by taking the one-third octave band value from the overall sound level for a train pass-by event.

Cattles' hearing ranges from 23 Hz to 35 kHz, with a well-defined point of greatest sensitivity at 8 kHz[8]. This is also referred to by *Grandin*[9] who highlights that it is especially important to avoid high pitched noise around 6kHz to 8kHz.

The research from Hefner, Hefner and Koay[10] identified alpaca, pigs and deer greatest sensitivity in the range 4- 8kHz. Hefner and Hefner[8] also identified that horses greatest sensitivity is in the range 1 – 16kHz and sheep at 10kHz. Hill, Koay, Hefner and Hefner[11] identified that chickens greatest sensitivity is in the range 2 – 4kHz. Hefner and Hefner[12] identified that goats have greatest sensitivity at 2kHz.

Considering the shape of the train spectra and the greatest sensitivity for the livestock types identified. It is considered unlikely that cattle, horses, sheep, goats, alpaca, pigs and deer would have a particular sensitivity to high speed trains in terms of the frequency content of the sound.

We have been unable to find any research into the audio response of turkeys and ducks. We have no reason to believe that turkeys or ducks would not be particularly sensitive to sound.

The hearing threshold plots are presented in Appendix C.

4.2.5 Vibration

In the response from the RSCPA, see Appendix A, they requested that the assessment also consider vibration, specifically:

Consideration should be given to the effect vibrations may have on livestock in close proximity to the line.

In the papers considered, Gygax and Nosal[13] reported that high somatic cell counts in milk (which may indicate an immune response to a pathogen causing mastitis) are influenced by vibration experienced by the cows during milking. However, the levels of vibration resulting from the milking equipment itself, is likely to be several magnitudes greater than the vibration associated with a high speed railway line.

It is therefore unlikely that cattle will be affected by vibration from the proposed scheme, and we have no reason to believe that other livestock would be particularly sensitive to vibration.

[8] Hearing in large mammals: Horses (Equus caballus) and cattle (Bos taurus). - Heffner, Rickye S.; Heffner, Henry E.
[9] Grandin T. Handling methods and facilities to reduce stress on cattle. Vet Clin North Am Food Pract 1998;14:325-41.
[10] Hearing in alpacas (Vicugna pacos): Audiogram, localization acuity, and use of binaural locus cues - Koay, Gimseong; Heffner, Rickye S.; Heffner, Henry E.
[11] Audiogram of the chicken (Gallus gallus domesticus) from 2 Hz to 9 kHz – Hill, Evan; Koay, Gimseong; Heffner, Rickye S.; Heffner, Henry E.
[12] Hearing in domestic pigs (Sus scrofa) and goats (Capra hircus) - Heffner, Rickye S.; Heffner, Henry E.
[13] Gygax L, Nosal D. Short communication: contribution of vibration and noise during milking to the somatic cell count of milk. J Dairy Sci 2006; 89: 2499-502.

4.2.6 Summary

The evidence can be summarised as follows:

- At a sound level of 70 dB L_{dn}, which for HS2 is equivalent to a daytime level of 70 dB$L_{pAeq, 16hour}$ and night-time level of 60 dB $L_{pAeq, 8 hour}$ is identified as a precautionary screening criteria at the animal's ear;
- No link was found between reproduction and milk production rates at maximum noise levels up to 99 dBL_{pAmax};
- Exposures in the range of 90 -120 dB L_{pAmax} may result in an effect, but that the reaction habituated to zero after 10-30 presentations.
- Most papers suggest that habituation can occur reasonably quickly, which would occur during the testing and commissioning phase before the passenger service commences;
- It is unlikely that livestock would have a particular sensitivity to the frequency of the sound from high speed trains compared to conventional trains; and
- It is unlikely that livestock will be affected by vibration from the proposed scheme.

On the basis of the summary above, in addition to the criteria specified for the HS2 Phase One environmental statement, the following livestock screening criteria for High Speed 2 train sound levels railway have been identified at the animal's ear:

- Daytime 70 dB $L_{pAeq, 16hour}$;
- Night-time 60 dB $L_{pAeq, 8hour}$; and
- During a train pass-by 90 dB L_{pAFmax}[14]

These screening criteria are more onerous that those currently defined in the scope and methodology report with Phase 1 and Phase 2 operating.

Where a screening value is exceeded then a number of factors will be considered including, the ability for the animal to move away from the sound source to an area where the level is below the screening value, the current baseline sound level, the livestock species being considered and the HS2 Phase One ES information.

5 Farm visits

A desktop review of the West Coast Main Line (WCML) and East Coast Main Line (ECML) railways identified more than 50 farms with buildings close to the existing railways that could have comparable sound levels to those likely to be experienced at farm buildings close to HS2 Phase One.

Five farms were selected for site visits. Four of which are subject to existing railway sound levels from the WCML which were comparable to those likely to

[14] Where the animal is habituated to the source then this screening criterion is not applicable.

be experienced at farm buildings on HS2 Phase One. The aim of the visits was to discuss any limitations on the use of the land as a result of the exposure to railway sounds. The fifth farm, Upper South Farm is owned by Mr Goss, who is referred to within the House of Common Select Committee report, whose land is located adjacent to HS2 Phase One.

5.1 Upper South Farm

A visit was undertaken at Upper South Farm, near Quainton adjacent to the HS2 Phase One route. The visit was used to determine how Mr Goss uses the site, the location of the animal sheds and to obtain sound level information whilst the animals are within buildings. The results are summarised as follows:

Within the livestock shed, the ambient noise levels are as follows:

- During the daytime in the range: 46 - 58 dB $L_{pAeq,\ 16\ hour}$
- During the night-time in the range: 39 - 43 dB $L_{pAeq,\ 8\ hour}$

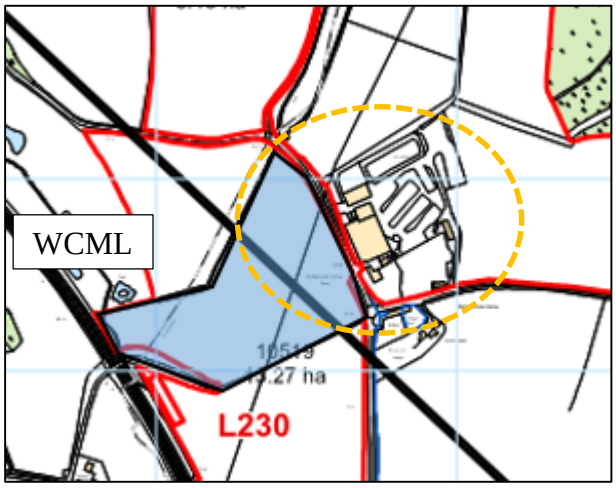
These sound levels are below the livestock screening criteria proposed in this document.

5.2 Shelton-under-Harley Farm

A visit to Shelton-under-Harley Farm was undertaken on 24 January 2017. The information was provided by brother and mother of the farmer, Mr David Pearce.

Shelton-under-Harley Farm is located next to existing WCML to the south of Baldwin's Gate. The farm house and buildings are located on a hill approximately 350m from the existing railway.

The field between the house and the WCML is used for young calves so that they can be more closely observed from the farm buildings. This field, shaded in blue (10519), typically holds 50-60 young calves. Approximately 250 more mature animals tend to use the back fields on the opposite side of the farm buildings (10690 and 10545).



The milking cows and calves are usually housed overnight in the shed(s) next to the house.

The owner says that the young calves sometimes react to the noise from trains operating on the WCML and the occasional helicopter flyover. No land limitations were identified.

Baseline sound measurements undertaken as part of the HS2 Phase 2a project have been compared to the sound levels shown in the Defra Noise maps for this location. At this location the Defra maps slightly over predict

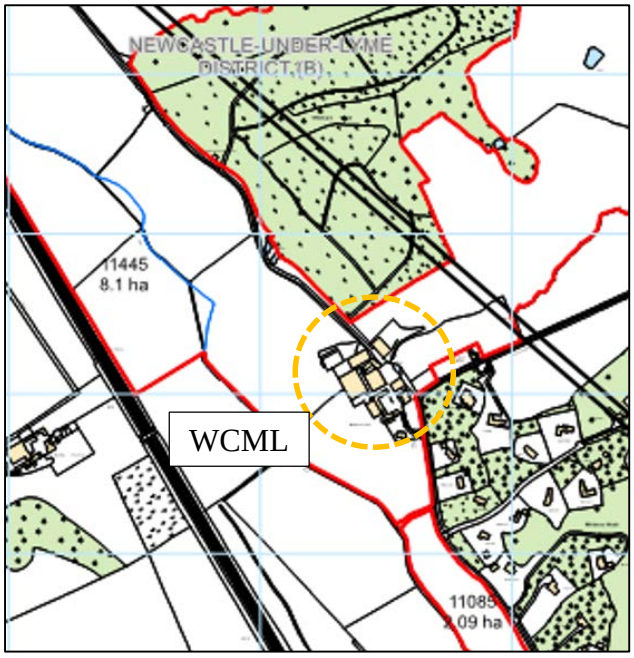
the railway sound levels and the summarised sound levels are based upon the measured levels. The daytime sound levels are summarised as follows:

- Closest part of the field marked in blue: 70 – 75 dB $L_{Aeq, 16\ hour}$;
- Midpoint of the field marked in blue: 55 – 60 dB $L_{Aeq, 16\ hour}$; and
- Farm buildings: 50 – 55 dB $L_{Aeq, 16\ hour}$.

The highest sound levels on the field closest to the WCML are greater than the screening criteria identified in this document.

5.3 Snape Hall Farm

A visit to Snape Hall Farm was undertaken on 24 January 2017. The information was provided by the farmer, Mr Christopher Slater. Snape Hall Farm is located close to the WCML to the north of Baldwin's Gate. The farm buildings including the animal sheds are located approximately 300m from the WCML. There are fields between the farm buildings and the WCML and also to the north and east of the farm buildings that are used by his animals.



The owner didn't express any particular concerns regarding the impact of noise from the WCML on his animals, and no constraints on the use of his land were identified.

Baseline sound measurements undertaken as part of the HS2 Phase 2a project have been compared to the sound levels shown in the Defra Noise maps at this location. At this location the Defra maps are consistent with the measured levels, and the daytime sound levels are summarised as follows:

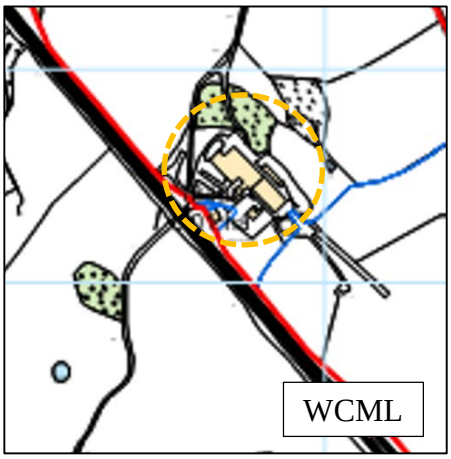
- Closest part of the field between the farm and the WCML: 70 – 75 dB $L_{Aeq, 16\ hour}$;
- Midpoint of the field marked in blue: 55 – 60 dB $L_{Aeq, 16\ hour}$; and
- Farm buildings: 50 – 55 dB $L_{Aeq, 16\ hour}$.

The highest sound levels on the field closest to the WCML are greater than the identified screening criteria identified in this document.

5.4 Lower Den Farm

A visit to Lower Den Farm was undertaken on 24 January 2017. The information was provided by the wife of the farmer, Mr John Moss.

The WCML passes through the farm land close to the owner's house and the livestock shed. The WCML is approximately 80m from the livestock shed which houses around 200 dairy cows. During the winter most of the animals are kept in the shed, while some walk around southern part of the farm.



During the summer, cows walk around all the fields on the farm land. Occasionally they use the bridge to walk over the WCML to the field to the west of the railway.
The owner explained that his animals appeared to get used to the train noise and no constraints on the use of their land were identified.

Baseline sound measurements undertaken as part of the HS2 Phase 2a project have been compared to the sound levels shown in the Defra Noise maps at this location. At this location the Defra maps are consistent with the measured levels, and the daytime sound levels are summarised as follows:

- Closest part of the field to the south of the farm building next to the WCML: 70 – 75 dB $L_{Aeq,\ 16\ hour}$;
- Midpoint of the field described above: 65 – 70 dB $L_{Aeq,\ 16\ hour}$; and
- Farm buildings: 55 – 60 dB $L_{Aeq,\ 16\ hour.}$

The highest sound levels on the lower half of the field closest to the WCML are greater than the screening criteria identified in this document.

5.5 Bower End Farm

A visit to Bower End Farm was undertaken on 24 January 2017. The information was provided by the wife of the farmer, Mrs Bernard Kettle.

The WCML runs along the eastern boundary of Bower End Farm. The farm buildings are located approximately 200m from the WCML.
The farm has a mixture of sheep and cattle. Sheep are usually kept on the eastern side of the farm and cattle on the west. During the night and during the winter animals are kept in the shed.

The owner explained that noise from the WCML passing on the border of their land does not appear to affect the livestock. No constraints on the use of their land were identified.

Baseline sound measurements undertaken as part of the HS2 Phase 2a project have been used to compare the sound levels shown in the Defra Noise maps at this location. The daytime sound levels are summarised as follows:

- Closest part of the field between the farm and the WCML: 65 – 70 dB $L_{Aeq, 16 hour}$;
- Midpoint of the field marked in blue: 50 - 55 dB $L_{Aeq, 16 hour}$; and
- Farm buildings: <50 dB $L_{Aeq, 16 hour.}$

The highest sound levels on the field closest to the WCML are equal to the screening criteria identified in this document.

6 Comparison

A review of the Phase One Proposed Scheme has been undertaken and the farms in Table 1 have been identified and reviewed against the proposed additional screening criteria, defined in Section 4.2.6.

Assessment Location	**Farm Name**	**HS2 train sound levels (with Phase 2 open and year 15 traffic) - outside the farm building[15]**			**Comments**
		Day[16]	**Night[17]**	**Max[18]**	
314738	Hunters Leaze	69	60	81/84	The predicted Proposed Scheme only levels are below additional livestock screening criteria.
810001	Goat Centre	59	50	66/69	
700338	Standalls Farm	51	42	61/64	
311007	Putlowes Farm	61	51	78/81	
294049	Glebe Farm	53	44	69/72	
903019	Needle Farm	65	56	83/86	
903020	Upper South Farm	69	60	81/84	
288944	Portway Farm	52	43	67/70	
280949	Turweston Glebre	52	44	61/64	

Table 1: Farms close to HS2 Phase One and comparison of the HS2 predicted sound levels against the proposed screening criteria.

No further mitigation is proposed as a result of the livestock screening criteria identified in this document.

[15] It should be noted that the proposed additional screening criteria is at the animal's ear, not outside the building.
[16] $L_{pAeq,07:00-23:00}$
[17] $L_{pAeq,23:00-07:00}$
[18] L_{pAFmax} - In the Proposed Scheme only column, two values are presented. The first is the value for the HS2 mitigated train and the second is the value for the TSI compliant train. For further information refer to Main ES Volume 5: Appendix SV-001-000.

7 Summary

In response to the House of Commons Select Committee request a study of operational railway noise on livestock has been undertaken. The study has considered:

- Previous responses to HS2 consultation;
- Information requested from external parties including the RSPCA;
- A review of case law;
- A revised literature review conducted in conjunction with Stephen Turner (ex-Defra) and Dr Stephen Stansfeld (WHO advisor). Based upon this review, an additional screening criteria for livestock at the animal's ear have been identified;
- A large number of farms have been identified close to the WCML and ECML which are subject to railway sound levels comparable with those close to HS2 Phase One;
- Visits to four farms close to the WCML have not identified any particular concerns with regard to railway noise, other than one location where the farmers expressed a view that the young calves on their farm sometimes react to noise from the passing trains. Each of the farms have area which are equal to or greater than the additional screening criteria; and,
- A review of farms adjacent to HS2 Phase One has been undertaken and the predicted HS2 operational sound levels at these farms has been compared to additional screening criteria.

The report does not identify any requirement for further noise mitigation.

Appendix A

External consultation

A1 Draft Scope of Study on the Effect of Sound on Livestock

The study will consider three core work streams:

1. Compare existing situations with those likely to be found adjacent to with HS2 Phase One when it becomes operational, through the following:
    a. A review of the HS2 Phase One route to identify livestock farms adjacent to the scheme and predicted the likely incident sound levels with and without HS2 Phase One, on livestock sheds and grazing areas;
    b. Review publically available information, including Defra noise mapping, to identify livestock farms adjacent to existing UK and, where information is available, continental railways with sound levels similar to those predicted with HS2 Phase One;
    c. Compare the current sound level at locations on HS2 Phase One with the examples from existing railways; and,
    d. Propose visit to up to five farms with levels comparable to those likely to be experienced on Phase One. The aim of the visits are to discuss limitations on the use of their land as a result of the incident noise levels and undertake validation sound measurement for comparison with the Defra Noise Mapping.

2. Literature review
    a. Review the literature used as the basis of assessment as defined in the HS2 Phase One Environmental Statement.
    b. Identify and review any additional studies or literature, though consultation with key groups and other external resources.
    c. Review previous consultation responses for HS2 documents. The review will aim to highlight consultation responses concerning operational sound and livestock.
    d. Review Land's Tribunal claims.

3. Consultation
    a. Seek information from the following bodies:
        i. National Farmers Union (NFU)[19];
        ii. Country Landowners and Business Association (CLBA);
        iii. Central Association of Agricultural Valuers (CAAV);
        iv. Royal Society for the Protection of Animals (RSPCA); and

[19] Part of NFU (NFU Mutual) provides insurance and will additionally be requested to provide information on the number / types of claims regarding noise and livestock.

v. British Horse Society (BHS).

Considering the information from these three work-streams, the criteria used as the basis of the HS2 Phase One Environmental Statement will be reviewed and potentially amended if appropriate.

HS2 Ltd
7th September 2016

A2 Response from RSCPA

Points relating to the HST report queries

The report should consider species other than just cattle, i.e. poultry, sheep, horses, goats and more exotic species such as camelids, i.e. all species that are likely to be affected by the new line.

The report should include interviews with livestock producers where their land is positioned next to an existing railway line to get their perspectives, this should cover:

a) The frequency of trains passing their land and associated noise levels.

b) How they manage their livestock. This should cover how they introduce new stock to land adjacent to the line as well as which animals they place in land adjacent to the line

c) The effects of the trains on their livestock. This should cover livestock of different ages (eg calves and their mothers), and different stages of production (eg heavily pregnant ewes or recently weaned calves)

d) The size and stocking density of fields adjacent to the line and how the animals use the space available to them.

Habituation by farm animals should be considered, including the period required for new livestock to adapt, how habituation is affected by species and the age of the animal.

Mitigation measures to reduce any potentially detrimental impact on livestock welfare should be examined.

Ability of livestock to move away from the HST railway line should be considered.

Details concerning noise levels, frequency of trains etc for the HST line should be presented within the report.

Consideration should be given to the effect vibrations may have on livestock in close proximity to the line. We don't anticipate that this would have the same "shock" affect as the sound, but may be a cause of distress to some species if significant vibrations are felt as trains pass.

A3 Response from BHS

Our primary concern would be the safety and welfare of the horse and rider. Horses over time become habituated to loud noises and adapt very well when in a grazing situation for example. Horses behaviour is greatly influenced by their environment with some horses being significantly unnerved by the sudden introduction of a loud noise and a train moving at great speed when ridden; causing them to rely on their instinct to flee in situations of danger. Having said that I am aware that some areas will be provided with screening in an attempt to negate the effect of sound and visual impact.

Appendix B

Literature review

STAcoustics

Briefing Note

To: HS2 Phase 2A ERG

From: Stephen Turner & Stephen Stansfeld

Date: 12th September 2016 **Document reference:** st/16/52

Subject: Noise on Livestock - ERG Task 03

1.0 This note has been prepared in response to ERG Task 03: Noise on Livestock, dated 15th July 2016.

2.0 In particular, the task concerns the impact of HS2, Phase 1 on Upper South Farm, Doddershall, where the tenant farmer, Mr Goss, has expressed concern about the potential noise impact on his cattle. It is understood that there is a cattle shed some 40m from the proposed line of HS2.

3.0 The House of Commons Select Committee were sympathetic to Mr Goss' petition and noted:

> *"The tenant of Upper South Farm at Doddershall, Mr Goss, has a cattle shed which will be very near to the line. The Promoter estimated that the closest façade was 40m away …"*
>
> *"We want a proper look at how animals in such conditions might be affected and whether better mitigation should be provided in this particular case. The RSPCA might be invited to contribute a paper. Mr Goss also needs a sensible solution on how to move livestock around the farm once the railway arrives."*

4.0 This note describes the work that has been carried out, including, as requested:

- Considering the approach used in the Phase One ES; and
- Provide expert advice on the principles of a receptor based assessment methodology for noise impact on livestock, based on available published evidence and the authors' network of researchers / experts in this subject area around the world.

5.0 The work has been undertaken in 3 phases. These were:

1) A brief literature review seeking relevant available research evidence;
2) An evaluation of that evidence to derive a possible assessment narrative; and

3) The implementation of that assessment taking account of the predicted impact on the farm of noise from HS2 operations.

Literature Review

6.0 Stephen Stansfeld undertook the literature review. It was found that there is relatively little literature specifically about the effects of environmental noise on cattle. Consequently, a broader search was carried out looking for noise effects on health in animals. The aim was to obtain a greater understanding of cross species effects on health and the mechanisms of effects involved.

7.0 Much of the research work that has been carried out have been studies on rats and mice. Although these studies are clearly less relevant, the underlying biological pathways and responses may be similar.

8.0 Many animal studies are carried out in the laboratory which, although they lack the ecological validity of field studies, do allow for greater control of confounding factors.

9.0 Studies of marine animals were not felt to be relevant and were excluded from the search.

10.0 A number of literature searches were carried out in PubMed. These included the following search terms:

- environmental noise effects on cows;
- noise effects on cows;
- noise effects on horses; and
- environmental noise animal effects.

11.0 The search on environmental noise and effects on animals yielded 2990 references.

12.0 Reviews were also sought separately and where possible review papers were examined to obtain a general overview of noise effects on animals. Some of the earlier papers relevant to cows and noise were in German or Russian without an English translation.

13.0 Stephen Stansfeld also consulted Prof Andy Smith, University of Cardiff, Professor Paul Lepper, University of Loughborough and attempted to contact Professor Mardi Hastings, Georgia Institute of Technology for suitable references on the subject.

14.0 Appendix A provides the outcome of the literature review and includes a commentary by Stephen Stansfeld.

Potential Assessment Narrative from the Literature Review

15.0 The element was led by Stephen Turner. The methodology involved evaluating the text of the literature review and identifying which references might contribute to a possible assessment narrative that could assist in understanding the potential impact from HS2 operations on Upper South Farm.

16.0 The first element considered were the noise levels to be found on farms in general (**Solecki**) and then the noise that cattle routinely experience (presumably during milking) (**Gygax and Nosal**), and any associated effects.

17.0 The levels expected from HS2 could be compared with these values.

18.0 From the research about the effect of acute exposure (**McLean and Tarnoplosky**), it may be possible to determine the possible effect of each HS2 event. It is noted that this research found that habituation occurred after 10 – 30 presentations. That would mean that if each HS2 pass-by was regarded as a discrete acute event, subject to the actual level of exposure, there could be an argument that the animals will have habituated after about one day of full timetable.

19.0 There is some research that investigated the effect of acoustic features (**Grandin**) and it may be possible to compare the features of HS2 events (e.g. frequency content) with those investigated in that study to determine whether any specific effects can be discerned.

20.0 It might also be possible to relate the sound from HS2 with the dose used by **Johnson & Van Jonack** on lactation effects. More tenuously, probably, the effects explored by **Pepper** might be of some assistance.

21.0 An examination could be made regarding how the HS2 exposure relates to the dose used by **Potvin** to look at adaptation and what assistance could be provided by the **Di and Zheng** work specifically associated with High Speed Trains.

22.0 Finally, if the breed of cattle on the farm is known the paper by **Lanier** might be of interest.

Initial Assessment

23.0 The papers identified above were examined in more detail in order to determine what data were available that might assist in the evaluation of the impact of HS2 on cattle. This work was also led by Stephen Turner.

Solecki

24.0 The focus of this paper was primarily on the personal noise exposure of farmers. Unfortunately, it was not found possible to relate any of the data to the noise levels routinely experienced by cattle.

Gygax and Nosal

25.0 This research concerned the noise and vibration levels experienced by cattle in the milking parlour. Noise levels were measured at a height of 1.2m in the milking stall head area. The text stated that a B&K 2232 meter was used. That meter provides 'A- weighted' maximum levels, either with a fast or slow time weighting.

26.0 Detailed noise results were not presented, but it seems that the median value was 73 dB. (Whether the time weighting was fast or slow is not stated)

27.0 The study found that there was no increase in somatic cell count with increasing noise.

28.0 The study also included the impact of applying mitigation measures to some of the milking parlours. Although reductions in noise level of between 3 dB(A) and 24 dB(A) (median decrease of 6 dB(A)) were achieved, no association between somatic cell count and noise was found.

McLean & Tarnopolsky

29.0 This paper presented a wide ranging review of the impact of noise on both humans and animals. In terms of the Orientation Reaction or Arousal Reaction, the paper concluded that when a novel stimulus is presented repeatedly, (e.g. an HS2 pass-by), the Orientation Reaction habituates to zero after 10 – 30 presentations.

30.0 The various studies evaluated in this review examined the effects on mice and rats and included exposure to levels of 90 – 120 dB, across a range of frequencies.

31.0 From this work, it could be concluded that even though there may be some adverse arousal reaction when HS2 first starts to operate, the effect would diminish to zero.

Grandin

32.0 This paper examined how to reduce stress in cattle by the use of different handling methods. About the only conclusion of note stated that it is especially important to avoid high-pitched noise around 6kHz – 8kHz as this is where a cow's hearing is at its most sensitive.

33.0 No noise levels were quoted, but the conclusions drawn were that *"loud yelling and constant whistling should be stopped, and if pneumatic equipment is used, air exhausts should be muffled to prevent hissing".*

34.0 Given this conclusion, any assessment of the impact of HS2 could include an examination of the expected frequency content of a train pass-by, and see how much energy there would be in the frequency range of 6kHz – 8kHz.

Johnson and Van Jonack

35.0 Disappointingly, this paper only described possible effects in general terms and no noise data were provided.

Pepper

36.0 This paper was a review into the effects of aircraft noise on wildlife and humans. It did report studies that had found that milk production in dairy cattle was reported to have ceased temporarily due to fright. No further detail was provided and, overall, Pepper concluded that aircraft noise and sonic booms did not substantially impact production.

37.0 Some comment was made regarding possible effects on reproduction rates. However, a study on mink found that any adverse reaction was brief and there were no noticeable effects on reproduction. Similarly, a study on cattle,

which examined the impact of aircraft noise, found no association between reproductive function and noise exposure.

38.0 Although no noise data were presented, the text implies that the noise dose comprised quite high L_{Amax} levels. If the expected maximum values for HS2 are no worse than the implied values in this review, it may be concluded that no adverse effect on reproduction would be expected.

Potvin

39.0 This paper contained a general discussion but provide no data that could be used for assisting in assessing the impact of HS2 on cattle.

Di & Zheng

40.0 The noise dose for this study was high-speed rail, but the tests were carried out on rats. The noise dose was measured from actual movements and adjusted to produce an L_{dn} level of 70 dB(A). This value was chosen because it related to a design standard for conventional railway in China which, at the time the paper was prepared (2012), was also applied to high speed lines. The control group was exposed to an L_{Aeq} of 35 dB.

41.0 The conclusions drawn were that there were changes in the synaptic morphology of the exposed group. The authors stated that this type of response could lead to an adverse effect in terms of learning and memory. They noted that as the hearing range of rats is similar to humans, there could be a similar adverse response and recommended that there should be a limit from high speed trains of 70 dB(A), L_{dn}.

42.0 At this stage, it has not been possible to determine the importance of these observed effects, but given the recommendation, it seems that keeping exposure to below 70 dB(A), L_{dn} would avoid any issue.

43.0 Regarding cattle, their different hearing response may mean a different outcome. Therefore, with regard to Upper South Farm, it may be worth determining the expected noise exposure in terms of L_{dn} and seeing how that relates to 70 dB.

Lanier

44.0 This study examined the responses of different cattle types at livestock auctions. In particular, for sound, it was the “ringman” calling out the bids, that provided the intermittent stimulus.

45.0 The study found differences in response between cattle type. Thus, if the breed of cattle at Upper South Farm is known, it may assist the assessment process to determine whether that breed is relatively more or less sensitive to intermittent sounds.

Conclusions

46.0 This review has provided some information regarding the effects of noise on cattle. There was little cattle-specific information but from what has been examined, it seems, for the most part, that there is unlikely to be much, if any, adverse effect.

47.0 However, some suggestions have been made regarding how the expected noise exposure from HS2 operations at Upper South Farm might be evaluated in order to provide a more robust assessment of this issue.

Stephen Stansfeld & Stephen Turner

12th September 2016

Doc Ref: st/16/52

Appendix A

Environmental noise and livestock: a review of the relevant literature on health effects

Stephen Stansfeld

Introduction

A1. A literature review was carried out at the request of HS2 to cover the effects of environmental noise on domestic farm animals, particularly cows, but also horses, sheep, goats and pigs, in relation to exposure to noise from high speed trains. This was in response to a farmer whose cattle sheds are close to the proposed high speed rail track.

A2 There is relatively little literature specifically on environmental noise and cows so a broader search was carried out for noise effects on health in animals to get a greater understanding of cross species effects on health and the mechanisms of effects involved. Much of the work carried out has been laboratory studies of rats and mice which are clearly less relevant although the underlying biological pathways and responses may be similar. Studies of marine animals were not felt to be relevant and were excluded. Many animal studies are carried out in the laboratory which lacks the ecological validity of field studies but does allow for greater control of confounding factors.

Method

A3 A number of literature searches were carried out in PubMed. These included the following search terms: (environmental noise effects on cows), (noise effects on cows; noise effects on horses), and (environmental noise animal effects). The search on environmental noise and effects on animals yielded 2990 references. Reviews were also searched for separately and where possible review papers were examined to get a general overview of effects on animals. Some of the earlier papers relevant to cows and noise were in German or Russian without an English translation.

A4 I also consulted Prof Andy Smith, University of Cardiff, Professor Paul Lepper, University of Loughborough and attempted to contact Professor

Mardi Hastings, Georgia Institute of Technology for suitable references on the subject.

Results

A5 Environmental noise can have a range of effects on animals. These include effects on the neuroendocrine system, feeding patterns, reproduction and development, metabolism, cardiovascular health, cognition and sleep, hearing, the immune system and DNA integrity and genes (Kight & Swaddle, 2011). These will be reviewed so far as they are relevant to livestock and given there are studies on the subject.

General issues in relation to farm animals

A6 When contrasting the effects of noise on animals it is important to distinguish between farm animals and wildlife. In the wild it has been found that there is less species density in areas exposed to higher levels of noise which applies to small ungulates and carnivores. In general, farms are associated with quite high levels of noise based on agricultural machinery. One study estimated the mean level of exposure to noise for farmers was equivalent to 8-hour workday (LEQ,8h), equal to 90.5 dB (for the mean value referring to the whole year, the mean monthly exposure to noise reached a value equal to 75.8 ± 19.9 Pa^2**)** (Solecki, 2005). Farm machinery is often very noisy and exposure to trucks, ploughs, generators, and related equipment might cause an animal to become habituated to noise. Due to habituation noise may not affect farm animals as much as wildlife (Espmark et al, 1974).

A7 Cattle and horses have ears that are more sensitive than human ears. They are especially sensitive to high frequency sounds. Therefore, noises that are a whisper to humans are quite audible to cattle (Lanier et al, 2000).

The impacts of environmental noise

Physiological responses to acute noise exposure

A8 Acute exposure to environmental noise leads to physiological changes indicating arousal. These include peripheral vasoconstriction of blood vessels and the secretion of adrenal cortical hormones such as cortisol. An animal

responds to a novel sound with an orienting reaction including increased sensitivity of the sense organs, changes in muscle tone, EEG changes indicating arousal, vascular and respiratory changes. On repeated sound exposure these physiological responses usually habituate to zero over 10-30 presentations (McLean & Tarnopolsky, 1977) unless they possess novelty, indicate conflict or have acquired learned significance. Very loud stimuli evoke a defence startle response with similar, although not identical, physiological changes which habituate more slowly. In cows, stimuli that were most effective for eliciting a startle response were intermittent, high pitched sounds and sudden movements (Grandin, 1998).

A9 Studies of the effect of noise exposure in animals revealed that fright is a common response to loud noise (Pepper et al, 2003). This may be accompanied by a defence/startle response and is similar to the 'flight or fight response' described in humans, which in evolutionary terms may be evoked by the presence of a predator or foe. During a fright response the animal attempts to escape the noise by either running or flying away. Studies of noise show effects on heart rates in deer related to simulated aircraft noise. Such physiological response is significant because the flight response often requires the animal to expend large amounts of energy to escape the perceived threat (Pepper et al, 2003).

Effects on the neuroendocrine system

A10 Loud noise increases cortisol levels in several species (Kight and Swaddle, 2011) in keeping with activation of the adrenal cortex by noise. Effects of noise stress on the HPA axis can lead to downstream effects on the immune system. Perceived environmental stress, particularly noise in cattle is associated with a hypothalamic-adrenal cortex response (Mitchell et al, 1988). Calves exposed to noise simulating the effect of being transported showed increases in plasma noradrenaline and serum cortisol and non-esterified fatty acids. Noise has an important role in transport stress (Agnes et al, 1990). High pitched noises are particularly disturbing for cattle during movement (Grandin, 1998).

A11 Dairy goats exposed to simulated helicopter flights indoors and also exposed in a field study to flyovers of a Chinook helicopter did not show increased

heart rate or salivary cortisol concentration during these tests which produced a peak noise of 110 decibels (van de Staay, 2011). This suggests that some domestic animals may not be especially disturbed by loud transport noise. In general, neuroendocrine responses to noise are highly plastic and there is potential for recovery from noise effects in terms of hormonal responses (Kight & Swaddle, 2011).

Reproduction, development and milk production

A12 Environmental noise can have an impact on the embryonic stage of development through soundwave exposure to the foetus as well as through physiological impacts on pregnant females. Studies in giant pandas found that reproductive state was strongly influenced by stress level with increases in agitated behaviour and urine cortisol on days of louder exposure to noise (Kight & Swaddle, 2011).

A13 Environmental factors such as noise may influence the efficiency of lactation, reproduction and growth in cows (Johnson and van Jonack, 1975). Acute noise exposure has been shown to increase prolactin levels of dairy heifers which may have effects on milk production, particularly initiation and maintenance of lactation (Johnson & Vanjonack, 1975). To evaluate the effect of aircraft noise on hormonal and physiological outcomes investigators exposed pregnant cows and heifers to aircraft noise (Heuwieser, 1982 quoted in Pepper et al, 2003). The test site was a large field near an active airport and flyover parameters included the steepness of flight, sound frequencies and sound pressure level. After the flyover events (N=59) heart rate, respiration rate, locomotor activity and progesterone and estrogen concentrations were measured. No effects were found in relation to noise exposure.

A14 High somatic cell counts in milk (which may indicate an immune response to a pathogen causing mastitis) are influenced by vibration and noise experienced by dairy cows during milking. On 12 farms the milking system was modified to reduce vibration and noise, somatic cell counts also dropped. Somatic cell counts increased with increasing intensity of vibration but not noise (Gygax and Nosal, 2006).

A15 Many studies have shown that milk production in dairy cattle has reportedly temporarily ceased due to fright. These tend to be temporary effects in relation to noise such as sonic booms (Pepper et al, 2003). However, in general, these studies concluded that aircraft noise and sonic booms do not substantially impact milk production.

Physiological arousal and feeding patterns in relation to environmental noise

A16 Animals that respond to noise stresses by increasing vigilance, hiding or retreating may correspondingly decrease the amount of time they spend foraging which could, potentially, decrease weight gain. The effect of simulating sonic booms has been assessed on cows, calves and steers. These animals seem to exhibit a startle response to the sonic boom but there was no noticeable effect on their feeding patterns. However, the sample size for this study was very small. (Pepper et al, 2003).

Cardiovascular health

A17 Heart rate data have demonstrated habituation to short term noise stimuli in ungulate species (Kight & Swaddle, 2011). It is unclear whether, and what type, of cardiac damage might result from chronic exposure to environmental noise stressors. The overall effects of noise exposure on animal lifespan have not been fully investigated.

Cognition and Behaviour

A18 Environmental noise may affect biological processes including animal interactions, behavioural responses to noise stimuli and cognitive development. At the same time animals' cognitive abilities may enable them to cope with higher levels of noise through learning (Potvin, 2016). Animals faced with new environmental noise sources may adopt several strategies to mitigate the negative effects of noise. Firstly, avoidance of the noise source, either temporarily or spatially. Secondly, changes in habitat selection, modification of acoustic signals made in the presence of noise, or thirdly, long-term adaptation (Potvin, 2016).

A19 Noise may be fear-inducing, as in humans, and studies in animals, particularly rats, have demonstrated that noise exposure can impair cognition. It is possible that noise exposure can influence expression of brain neurotransmitter levels although this has not been studied in farm animals. Two studies specifically examining high speed rail noise are reported. The effects of high speed railway noise on mice were examined. Mice were exposed to noise for 53 days at 70dbA Ldn. After 40 days of HSR noise exposure the concentrations of plasma dopamine in the exposed group were significantly higher than those of the control group while plasma noradrenaline and serotonin showed no significant difference between the two groups. The authors concluded that these tests indicated that at 70dB high speed railway noise can result in anxiety-like behaviours in mice. The physiological results showed that plasma dopamine is more sensitive to HSR noise compared to noradrenaline and serotonin. Exposure to rats of HSR noise at 70dB L_{dn} showed effects on the width of the synaptic cleft in neurones in the hippocampus, amygdala and temporal lobe - in the noise exposed group the thickness of post-synaptic receptor density decreased significantly. This reduction in synaptic transmission efficiency may have led to dysfunctions in learning and memory (Di and Zheng, 2013).

A20 There have been studies on behaviour in response to noise in cows and how this might differ according to breed. Not all breeds of cow are similarly susceptible to the effects of noise. A study by Lanier, et al (2000) found that Holsteins were more noise and touch sensitive than beef cattle. Cattle that became agitated during handling in an auction ring were those most likely to be startled by sudden intermittent sounds and movements. They found that reactivity to intermittent sounds and sudden movements is significantly related to a numerical rating of cattle temperament during handling in a commercial auction ring. Cattle that became agitated during restraint had lower weight gains and tougher meat. These temperamental characteristics are heritable and related to breed.

A21 Another study of behaviour and health in relation to noise exposure involved pigs. Four week old female pigs were exposed to ammonia, varying light intensity and mechanical noise at for 15 weeks. Pigs exposed to a high level of mechanical noise representative of artificial ventilation (80 versus 40dbA) were less submissive to aggressive acts than pigs less exposed to noise

(Parker et al, 2010). There was evidence for an interaction between high noise exposure and ammonia on the health scores of pigs but there was no measurable impact of these potential stressors on the productivity for pigs or of any of the physiological parameter measures. However, in this study most aspects of the pig's husbandry were optimal and it might be under less favourable conditions more pronounced effects of ammonia, noise and dim light would be observed (O'Connor et al, 2010).

Hearing

A22 Hearing impairment and deafness are two of the most obvious effects of extreme environmental noise exposure on sensory systems. Hearing impairment can result from auditory injuries arising from single extreme acoustic traumas or from chronic exposure to dangerous levels of noise. It is not clear whether this is relevant to hearing in cattle exposed to high speed train noise.

A23 One effect of noise, which is perhaps more relevant to birds is that noise can mask communication and reduce auditory awareness of approaching predators.

Genetic effects

A24 Acoustic stressors can also influence genes by leading to DNA damage or by altering gene expression. This research is still at an early stage.

Conclusions

- There is not strong evidence of long term effects of environmental noise on health in cows and other livestock. This is partly due to an absence of studies but also an absence of effects.
- Cattle and horses have more sensitive hearing than humans but farms are noisy places because of farm machinery and cattle may habituate to noise unlike wild animals.
- Cattle, like other animals, will respond to acute noise exposure with 'fright reactions' and acute physiological arousal including increased

cortisol but there is evidence that livestock adapt over time to exposure to noise.

- Exposure to noise may affect milk production through increased prolactin secretion but there may also be recovery from acute effects. Vibration rather than noise increases somatic cell counts in milk.
- Cows vary by breed in their sensitivity to noise. Research in pigs suggests some increased aggression in response to mechanical noise exposure.

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Appendix C

Hearing Threshold plots

Hearing plot for horse, cattle and sheep taken from “Hearing in large mammals: Horses (Equus caballus) and cattle (Bos taurus)”. - Heffner, Rickye S.; Heffner, Henry E.

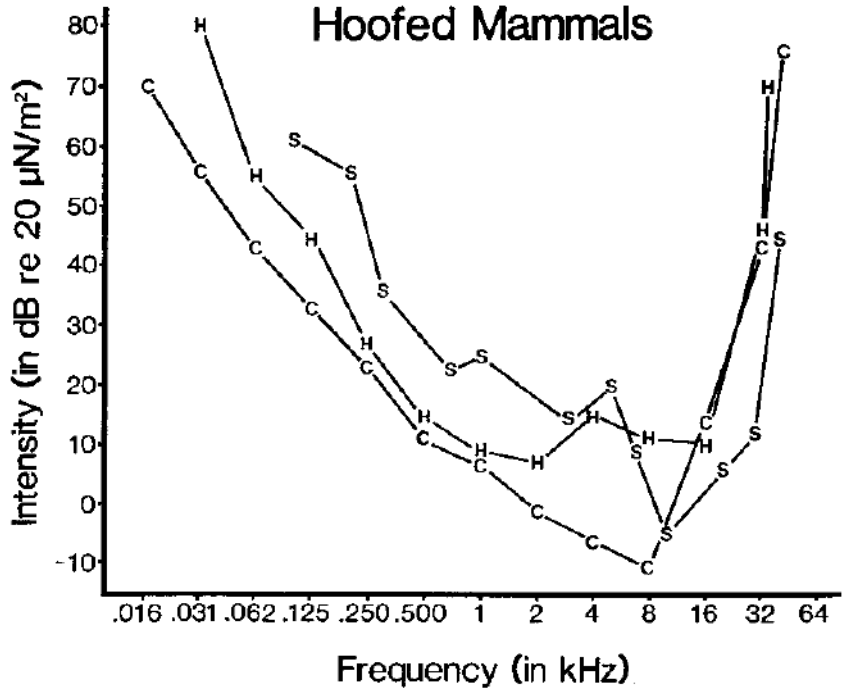
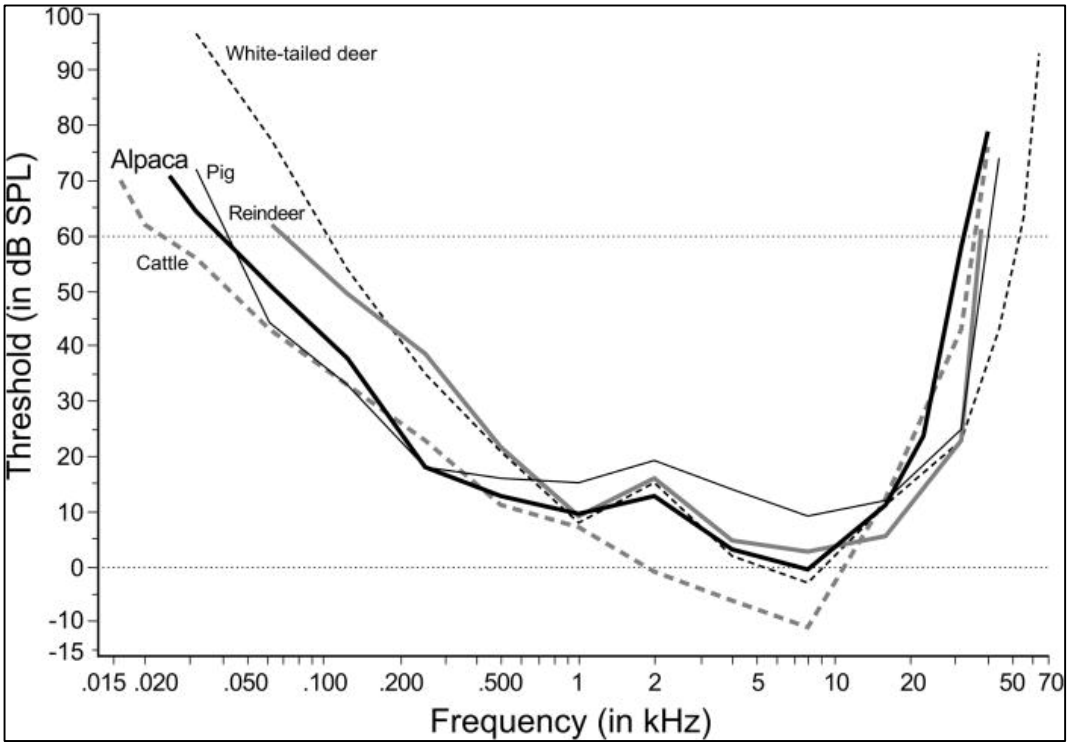
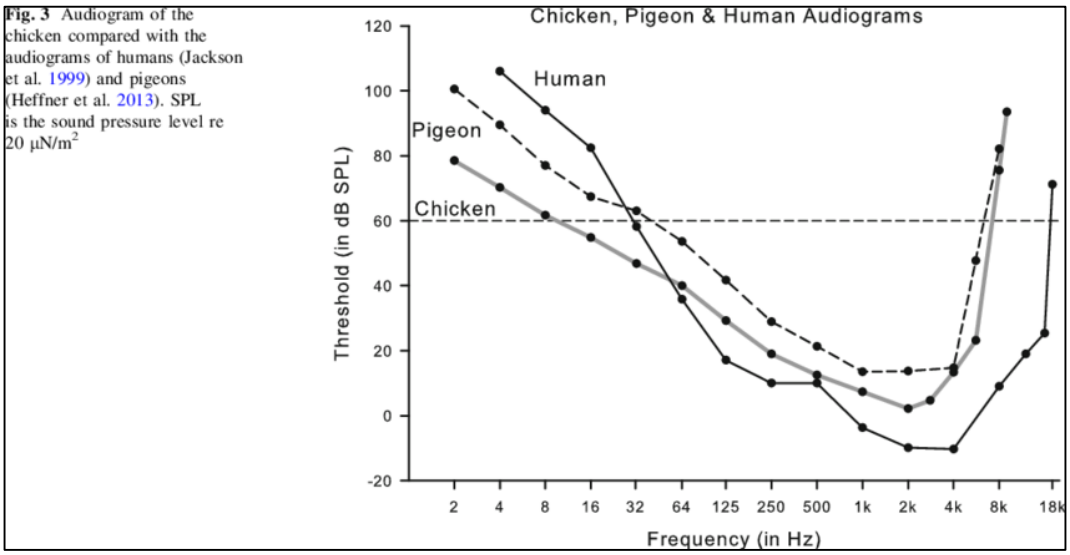


Figure 4. Average audiograms of horse (H), cattle (C), and sheep (S). (Audiogram for sheep from Wollack, 1963.)

Hearing plot for alpca, pigs and deer taken from *"Hearing in alpacas (Vicugna pacos): Audiogram, localization acuity, and use of binaural locus cues"* - Koay, Gimseong; Heffner, Rickye S.; Heffner, Henry E.



Hearing plot for chickens taken from *"Audiogram of the chicken (Gallus gallus domesticus) from 2 Hz to 9 kHz"* – Hill, Evan; Koay, Gimseong; Heffner, Rickye S.; Heffner, Henry E.



Hearing plot for goats and pigs taken from *"Hearing in domestic pigs (Sus scrofa) and goats (Capra hircus)"* - Heffner, Rickye S.; Heffner, Henry E.

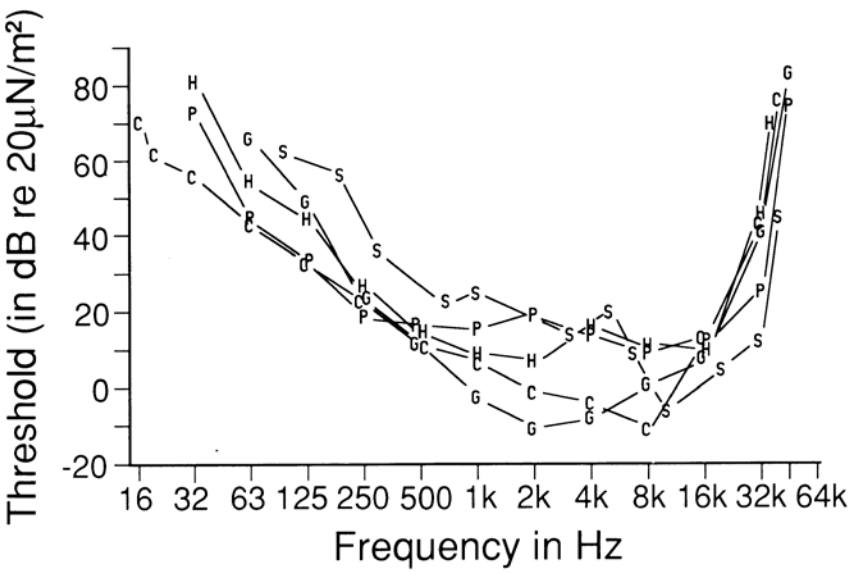


Fig. 3. Average audiograms of hoofed mammals. (C = cattle, G = goat, H = horse, P = pig, S = sheep. Heffner and Heffner, 1983a; Wollack, 1963.)

Appendix D

Glossary

The definitions are taken from the HS2 Phase One Volume 1 - Glossary and list of abbreviations[20].

decibel(s) or dB

Between the quietest audible sound and the loudest tolerable sound there is a million to one ratio in sound pressure (measured in Pascal (Pa). Because of this wide range, a level scale called the decibel (dB) scale, based on a logarithmic ratio, is used in sound measurement. Audibility of sound covers a range of approximately 0-140dB.

decibel(s) A-weighted

The human ear system does not respond uniformly to sound across the detectable frequency range and consequently instrumentation used to measure sound is weighted to represent the performance of the ear. This is known as the 'A weighting' and is written as 'dB(A)'.

equivalent continuous sound pressure level or $L_{pAeq,T}$

An index used internationally for the assessment of environmental sound impacts. It is defined as the notional unchanging level that would, over a given period of time (T), deliver the same sound energy as the actual time-varying sound over the same period. Hence fluctuating sound levels can be described in terms of an equivalent single figure value.

L_{pAmax}

L_{pAmax} is the maximum A-weighted sound pressure level attained during a given time interval, T (30 seconds, 5 minutes etc.) It is normally measured using slow (S) or fast (F) time weighting. It is generally used when assessing the likelihood of night-time sleep disturbance.

[20] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/259492/Glossary_ES_3.1.1.pdf