

Aviation Night Noise Effects (ANNE)

Subjective study report

Authors: Charlotte Clark¹, Elena Marcus¹, Joan Morris¹, Franziska Marcheselli², Mari Toomse-Smith², Dhriti Mandalia², Rebecca Steinbach², Mathias Basner³, James Trow⁴, George Gibbs⁴.

¹ Population Health Research Institute, City St George's, University of London, London, UK

² National Centre for Social Research, London, UK

³ Unit for Experimental Psychiatry, Division of Sleep and Chronobiology, University of Pennsylvania, Perelman School of Medicine, Philadelphia, USA

⁴ Noise Consultants Limited, Warrington, UK

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Abbreviations

AEDT	Aviation Environmental Design Tool
AIC	Akaike's information criterion
ANNE	Aviation Night Noise Effects
BIC	Bayesian information criterion
BRS	Bristol Airport
CAA	Civil Aviation Authority
CI	Confidence Interval
dB	Decibel level
Defra	Department for Environment, Food and Rural Affairs
DfT	Department for Transport
EMA	East Midlands Airport
ERF	Exposure Response Function
FAA	Federal Aviation Authority
GLA	Glasgow Airport
HA	Highly annoyed
HA _v	Highly annoyed for the 5-point verbal scale scored according to ISO/TS 15666 - using a cut-off of the top 40% of the 5-point scale (scoring 4 'very' or 5 'extremely')
HA _N	Highly annoyed for the 11-point numeric scale scored according to ISO/TS 15666 - using a cut-off for the top 28% of the 11-point scale (scoring 8, 9 or 10)
HA _{vw}	Highly annoyed for the 5 -point verbal scale scored according to ISO/TS 15666 weighted to provide a 28% cut-off to aid comparison with responses on the 11-point numeric scale
HSD	Highly sleep disturbed
ICBEN	International Commission on Biological Effects of Noise
IQR	Interquartile Range
ISO/TS	International Organization for Standardization/Technical Standard
L _{Aeq}	Average sound level (A-weighted)

L _{Aeq,8h}	Average summer night noise exposure measured over an 8-hour night-time period of 23.00-07.00 hours for the 92-day summer period (16 th June to 15 th September 2022)
LCI	Lower 95% Confidence Interval
L _{den}	Average noise exposure over the day, evening and night-time period (A-weighted) for a 365-day period
LGW	London Gatwick Airport
LHR	London Heathrow Airport
L _{Asmax}	Maximum sound level (A-weighted) with 'slow' time constant
L _{night}	Average night-time noise exposure over the 8-hour night period of 23.00-07.00 hours for a 365-day period
LOAEL	Lowest Observed Adverse Effect Level
LTN	Luton Airport
MAN	Manchester Airport
N60	Number of aircraft noise events equal to and above 60dB
NatCen	National Centre for Social Research
NCL	Noise Consultants Limited
NNAS 2012	National Noise Attitude Survey 2012
NS-SEC	The National Statistics Socio-economic classification
Overflights	The number of overflights (as defined by CAP1498 (Civil Aviation Authority, 2017)) experienced by a ground-borne observer over a given period of time
SE	Standard Error
SD	Standard Deviation
SEL	Sound Exposure Level
SGUL	St George's, University of London
SOAEL	Significant Observed Adverse Effect Level
SoNA 2014	Survey of Noise Attitudes 2014
SPL	Sound Pressure Level
STN	Stansted Airport
SWEMWBS	Short Warwick Edinburgh Mental Wellbeing Scale
UCI	Upper 95% Confidence Interval
WHO	World Health Organization

WHO ENG 2018	World Health Organization Environmental Noise Guidelines 2018
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1 Introduction

1.1 About the study

The National Centre for Social Research (NatCen), St George's, University of London (SGUL), Noise Consultants Ltd (NCL), and the University of Pennsylvania were commissioned by the Department for Transport (DfT) to deliver the Aviation Night Noise Effects (ANNE) study. The ANNE study is examining the associations of aviation noise exposure during the night-time period with annoyance, subjective sleep disturbance, and objective sleep disturbance.

The study has two parts: the first was a large-scale cross-sectional survey carried out among residents living near eight UK airports to assess associations of aircraft noise exposure at night and subjective sleep disturbance and annoyance. The second part will recruit a sub-sample from the cross-sectional survey into an objective sleep disturbance study, where physiological assessments of sleep disturbance will be linked to aircraft noise exposure at the participant's home.

This report presents key findings from the cross-sectional survey.

1.2 Study aims

The cross-sectional survey was designed to address the following aims:

1. To estimate the association of night aviation noise on subjective sleep disturbance and annoyance for a sample of residents living near UK airports using a range of time-average metrics ($L_{Aeq,8h}$, L_{night} , $N60^1$, overflights) and for different hourly periods between 21.00-08.00 hours using the $L_{Aeq,1h}$ metric.
2. To examine if the effects of night aviation noise on annoyance differ by age, ethnicity, noise sensitivity, and pre-existing illness.
3. To examine how the effects of night aviation noise annoyance differ by non-acoustic factors.

Analyses are based on external noise metrics and are for the full sample. The study is **not** designed to examine airport specific findings (i.e., the sample size at individual airports means it is not possible to produce airport-specific findings).

The findings of the ANNE survey can be considered in the light of how they might inform *lowest* observed adverse effect level values and *significant* observed adverse effect level values. The Noise Policy Statement for England (Department for Environment Food and Rural Affairs, 2010) defines these as:

¹ N60 indicates the number of events (i.e., flights) where the noise level from the flight is equal to or exceeded 60dB L_{ASmax} within a given time period, e.g., 8 hours or one hour. N60 is estimated for the 92-day summer period.

- A 'Lowest Observed Adverse Effect Level' (LOAEL value) – “above this level the average person will begin to experience observable, or measurable, adverse effects on health and quality of life as a result of noise exposure.”
- A Significant Observed Adverse Effect Level (SOAEL value) – “above this level significant adverse effects on health and quality of life from noise exposure can begin to be observed in an average person.”

For LOAEL values, it is necessary to identify where effects begin: for example, for noise effects on health it could be defined where there is any deviation from ~0% highly annoyed (HA) or ~0% highly sleep disturbed (HSD) or it could be defined according to a threshold where a certain percentage) of the population exhibit the response, such as the 10% HA and 11% HSD² used in the WHO Environmental Noise Guidelines 2018 (WHO ENG 2018) (World Health Organization, 2018). In this report, LOAEL values are considered in terms of where HA or HSD are 10%.

It can be challenging to identify 'significant' effects to inform SOAEL values. The terminology is borrowed from toxicology, where a significant effect equates to mortality or serious morbidity. For environmental noise, it is challenging to know and understand what 'significant' might mean. It could be where the relationship climbs steeply or where a certain percentage of the population show a response, but to date, there has been little academic or industry/stakeholder debate about how SOAEL values are defined or agreement as to a method for their identification (AECOM Limited, 2013). In practice, SOAEL values tend to vary little across schemes and are based on legal precedence of values used in other schemes.

Air Navigation Guidance (Department for Transport, October 2017) sets out the following: “There is no one threshold at which all individuals are considered to be significantly adversely affected by noise. It is possible to set a Lowest Observed Adverse Effect Level (LOAEL) that is regarded as the point at which adverse effects begin to be seen on a community basis. As noise exposure increases above this level, so will the likelihood of experiencing an adverse effect. In line with this increase in risk, the proportion of the population likely to be significantly affected can be expected to grow as the noise level increases over the LOAEL. For the purposes of assessing and comparing the noise impacts of airspace changes, the government has set a LOAEL of 51dB $L_{Aeq,16hr}$ for daytime noise and 45 dB $L_{Aeq,8hr}$ for night-time noise”.

² At the outset, the WHO ENG 2018 proposed to use 3% HSD absolute risk as its benchmark to inform its guideline value for aircraft noise at night. However, 11% HSD absolute risk was used following the evidence review, due to a lack of studies examining lower levels of exposure (below 40dB L_{night}) to be able to establish lower risks of HSD (see page 62 of the WHO ENG 2018 for further details).

2 Methodology

2.1 Sample design

The target population of the cross-sectional survey is residents of households who live in proximity to a UK airport which operates flights during the period of 21.00-08.00.³ Proximity was defined on estimated annual night-time aviation noise exposure around each airport (L_{night}) using 2022 data, rather than by geographical distance to an airport.

A two-stage sampling framework was employed:

- Stage 1: purposive sampling of airports with night-flights based on sampling airports with freight versus passenger flights; night-flight restrictions; quota scheme; voluntary restrictions; different ambient background noise/populations (urban/rural) and availability of exposure data to use for sampling. All eligible airports were classified according to each of these characteristics and airports were selected within specific categories so that airports with different patterns of night-time noise exposure were included. The eight airports selected for the study were:
 - Bristol Airport (BRS)
 - East Midlands Airport (EMA)
 - Glasgow Airport (GLA)
 - London Gatwick Airport* (LGW)
 - London Heathrow Airport* (LHR)
 - London Stansted Airport* (STN)
 - London Luton Airport (LTN)
 - Manchester Airport (MAN)

* Noise designated airports⁴.

- Stage 2: stratified random population survey of addresses around each selected airport. Addresses around the selected airports were classified by L_{night} and overflight data. Noise bands for sampling were estimated using 2016 L_{night} noise grids obtained from Department for Environment, Food and Rural Affairs (Defra) and the Scottish Government, as generated under their respective Environmental Noise Regulations. The noise exposure grids were adjusted by the Civil Aviation Authority (CAA) to account for changes in the number of night-time aircraft movements between 2016 and forecast for 2022. The lowest noise exposure level is dictated by the lowest

³ The standard definition of the night period is 23.00-07.00 and is used in both UK planning and aviation policy. The Department for Transport currently uses the period 23.30-06.00 as the period when movement and noise quotas apply at noise designated airports. This period is commonly referred to as the 'night quota period'. 'The ANNE study is also incorporating two hours before (21.00-23.00 – referred to in the report as 'evening') and the hour after (07.00-08.00 – referred to in the report as 'morning').

⁴ An airport 'designated' for noise regulation by the Government. A designated airport has government restrictions which run alongside those governed by local planning authorities through the planning process. 'London Heathrow, London Gatwick, and London Stansted are designated airports.

value reported by each airport competent authority to Defra and the Scottish Government in 2017. Estimations of the location of addresses within the 35.0-47.9 dB noise exposure band, which were not available from the existing noise data described above (which typically modelled down to mid to late 40 dBs across the airports), was informed through analysis of flight tracks using radar data received from the airports and the use of overflight cones. For more information, please see the Technical Report.

- A stratified random sample of addresses was selected to ensure that a range of night-exposure experiences were included in the sample.

For more information on the sample design, please see the Technical Report.

2.2 Questionnaire content

The ANNE study data were collected via an online questionnaire and a paper questionnaire (to enable those who are less technologically literate and/or those without internet access to respond).

Information on a variety of topics were collected. Established and standardised questions were used to ensure continuity and comparability with previous UK national noise surveys (such as SoNA 2014 (Survey of Noise Attitudes)) where possible. Key survey content included:

- Aircraft noise annoyance during the night-time period including the evening and morning hours using annoyance questions based on the recently updated ISO/TS15666:2021⁵;
- Additional noise attitude questions from SoNA 2014/NNAS 2012 (National Noise Attitude Survey) (Civil Aviation Authority, 2021a, Notley et al., 2014) ;
- Subjective sleep disturbance including information on time to fall asleep, sleep latency, number of awakenings, window opening, and sleep quality based on established noise and sleep surveys⁶;
- Sleep disturbance during the night-time period including the evening and morning hours using the sleep question adapting the ISO/TS15666:2021 annoyance question format;
- Items from the Pittsburgh Sleep Quality Index (Buysse et al., 1989)⁵;
- Short Warwick Edinburgh Mental Wellbeing Scale (SWEMWBS) (NHS Health Scotland et al., 2008);

⁵ The ANNE study asked participants to rate their annoyance over the 92-day summer period, whereas the ISO/TS15666:2021 asks participants to rate annoyance over the past 12 months. The question was therefore adapted to the past tense for example, “*Thinking about this summer, when you were here at home, how much does noise from aircraft, airports or airfields bother, disturb or annoy you during the night (11pm to 7am)?*”

⁶ The subjective sleep disturbance questions and Pittsburgh Sleep Quality Index items matched those used in other international studies, including the ongoing Federal Aviation Authority study in the United States (see Smith et al., 2022 for details of the pilot work for this study).

- Sociodemographic and household factors e.g., age, sex, homeownership, employment status, noise sensitivity;
- Health status;
- Noise mitigation (e.g., presence of double or secondary glazing); and
- Non-acoustic factors (e.g., attitudes to the airport/aviation; coping behaviours).

The full questionnaire can be found in the Technical Report. A summary of the origin of key questions is in Section 6.9.

The questions were ordered so that the primary outcomes of annoyance and sleep disturbance appeared early in the questionnaire and before questions on noise attitudes and behaviours, which might influence annoyance and sleep disturbance responses. ISO/TS 15666:2021 requires that annoyance is asked near the beginning of the survey for this reason. Questions on sociodemographic factors were asked towards the end of the questionnaire, as in previous national noise surveys, which is often the norm for social surveys.

2.3 Data collection

The fieldwork took place over 9 weeks (28 October 2022 to 3 January 2023). All sampled addresses were sent an invitation letter that invited two adults aged 18 and older in the household to complete a 20-minute online questionnaire. Participants were able to self-select which two household members took part. A reminder letter was sent a week later and encouraged non-responders to take part. A second reminder letter was sent three weeks after the invite letter; this contained up to two paper questionnaires and pre-paid return envelopes. Due to postal strikes that were happening at the time of the survey, it was decided to send a third reminder letter six weeks after the initial invite letter, to encourage all non-responders again. Fieldwork was extended to 3 January 2023 to allow time for postal questionnaires to arrive.

A copy of the participant materials can be found in the Technical Report.

As a thank you for their participation, a £10 shopping voucher was given to each participant that completed the questionnaire. Participants were offered the choice of either an online e-voucher code or a physical voucher.

2.4 Survey response

Table 1 summarises the address-level response rates⁷. In total, 15,774 addresses were issued with the survey. In remote surveys, no information is known about the reason for non-response in individual addresses. However, it was assumed that around 9% of addresses in the sample (1,420) were not residential and were therefore ineligible to complete the survey.⁸ A total of 2,899 eligible addresses participated in the survey, this is where the

⁷ These data are unweighted: later data analyses are weighted and hence present different values.

⁸ When estimating the proportion of ineligible addresses on a push-to-web survey, it is best practice to assume the same ineligibility rate as a recent face-to-face survey which uses the same sample frame and sampling

questionnaire was fully completed by at least one adult aged 18 and older in the household. The adjusted address-level response rate, i.e., the proportion of eligible addresses where the questionnaire was fully completed by at least one adult aged 18 and older, was 20%.

Of the 2,899 addresses responding to the survey, 1,284 households yielded two participants who fully completed the survey and 1,615 yielded one participant who fully completed the survey. Of the 2,899 households, 588 were single adult occupancy households and 2,311 contained two or more adults.

A total of 4,183⁹ individual responses were received; 26% from the paper questionnaire (1,085) and 74% (3,098) from the online survey.

Table 1: Summary of address-level response

Issued addresses			
	Number (n)	Issued (%)	Eligible (%)
Address level response			
Issued addresses	15,774	100	
Assumed ineligible addresses ¹	1,420	9	
Assumed eligible (residential addresses)	14,354	91	100
Responding addresses ²	2,899		20
2 fully participating individuals	1,284		9
1 fully participating individual	1,615		11
<i>in single-adult addresses</i>	588		4
<i>in multi-adult addresses</i>	2,311		16
Refusal ³	14		0
No response	11,441		80
¹ It was assumed that 9% of addresses in the sample (1,420) were not residential and were therefore ineligible to take part in the survey. This assumption has been applied to all issued addresses because the estimate of ineligible addresses in each noise band or area is difficult to predict. ² Responding addresses are defined as those households where at least one person has fully completed the survey. ³ Refusal includes refusal by telephone or email.			

In terms of sampled airports, the highest address-level response rates were achieved in the East Midlands (28%), followed by Bristol and Gatwick (25%). Lower proportions of households living near Glasgow airport completed the survey (12%) (Table 2).

approach, and for which detailed outcomes are known for the entire issued sample. Ineligibility rates in postcode address file (PAF) face-to-face surveys tend to fall between 8% and 10% and 9% is the rate recorded in the most recent face-to-face British Social Attitudes Survey (2019) and has been used as an appropriate default for this study.

⁹ The 4,183 excludes 18 respondents who were deemed to have completed the survey 'too quickly' – see Section 2.5 for further details.

Table 2: Address-level response by sampled airport

Issued addresses				
	Issued addresses	Assumed eligible addresses ¹	Participating addresses ²	Household response rate ³
Airport	n	n	n	%
Bristol	197	179	44	25
East Midlands	460	419	119	28
Gatwick	312	284	72	25
Glasgow	799	727	90	12
Heathrow	9,942	9,047	1,766	20
Luton	432	393	74	19
Manchester	3,296	2,999	663	22
Stansted	336	306	71	23
Base	15,774	14,354	2,899	20
¹ It was assumed that 9% of addresses in the sample (1,420) were not residential and were therefore ineligible to take part in the survey. This assumption has been applied to all issued addresses because the estimate of ineligible addresses in each noise band or area is difficult to predict. ² Participating addresses are defined as those households where at least one person has fully completed the survey. ³ Household response rate is the proportion of participating addresses of assumed eligible addresses.				

Table 3 presents the number of participants at each sampled airport. The individual response rate has not been included because not enough information is known about the definitive number of eligible addresses or the number of eligible adults at each address.

Table 3: Number of individuals responding by sampled airport

Participating individuals	
	Participating individuals
Airport	n
Bristol	63
East Midlands	175
Gatwick	106
Glasgow	124
Heathrow	2,535
Luton	101
Manchester	971
Stansted	108
Base	4,183

Table 4 shows the breakdown of the issued sample and household response rates achieved in each sampled noise exposure band used to inform sampling. Overall, response was evenly spread and ranged from 19% to 22% across the noise exposure bands.

Table 4: Address-level response by sampled noise exposure band

Issued addresses				
	Issued addresses	Assumed eligible addresses ¹	Participating addresses ²	Household response rate ³
Noise exposure band (decibels, dB - L _{night})	n	n	n	%
35 - 47.9 ⁴	5,805	5,283	1,036	20
48 - 49.9	1,220	1,110	210	19
50 - 51.9	1,230	1,119	231	21
52 - 53.9	1,224	1,114	233	21
54 - 55.9	1,205	1,097	218	20
56 - 57.9	1,462	1,330	291	22
58 - 59.9	1,814	1,651	346	21
≥ 60	1,814	1,651	334	20
<i>Base</i>	<i>15,774</i>	<i>14,354</i>	<i>2,899</i>	<i>20</i>
¹ It was assumed that 9% of addresses in the sample (1,420) were not residential and were therefore ineligible to take part in the survey. This assumption has been applied to all issued addresses because the estimate of ineligible addresses in each noise band or area is difficult to predict. ² Participating addresses are defined as those households where at least one person has fully completed the survey. ³ Household response rate is the proportion of participating addresses of assumed eligible addresses. ⁴ This noise band was split into varying groups that were dependent on available airport data. Due to the variation, addresses exposed to less than 48dB have been grouped together for ease.				

Table 5 presents the number of participants responding in each sampled noise exposure band.

Table 5: Number of individuals responding by sampled noise exposure band

Participating individuals	
	Participating individuals
Noise exposure band (decibels, dB - L _{night})	n
35 - 47.9	1,458
48 - 49.9	286
50 - 51.9	325
52 - 53.9	322
54 - 55.9	329
56 - 57.9	426
58 - 59.9	532
≥ 60	505
<i>Base</i>	<i>4,183</i>

2.5 Completion times

The target mean survey time was 20 minutes. Timestamp data for the online survey indicated that on average it took participants 15 minutes to complete. The maximum survey length time was 38 minutes.

Table 6: Time to complete the online survey in minutes

Mean	Median	Min	Max
15	14	5	38

Cases were removed from the sample if the survey was completed too fast. This was judged on the actual time a participant took to complete the survey versus their estimated time given the route that they went down the questionnaire. Estimated time was based on the median time taken to answer each question. This means there was not an absolute completion time which was deemed too fast, and it differed by participant depending on how they answered the questions (i.e. not all questions were relevant to all participants).

Following an analysis of timestamp data, 18 cases were deemed too fast and were removed from the sample: the sample size of 4,183 is the sample with these 18 cases removed. Completion times for these participants ranged from 4 to 13 minutes.

2.6 Analysis plan

a) Weighting

The survey data were weighted to take account of non-response, so that the results are representative of the best available population estimates of the characteristics of residents exposed to aviation noise at night. For more information about the weighting process please see the Technical Report. All analyses are weighted. This approach is consistent with previous aviation noise surveys (e.g., SoNA 2014) and is also consistent with standard practice in survey research for national surveys.

Weighting for the ANNE study followed three steps:

1. Address selection weighting to correct for unequal probability of selection and to make the sample of addresses representative of the addresses in the sample frame.
2. Non-response weighting to any bias which may have been caused by systematic differences in the number of completed surveys (i.e., the number of responding adults) returned by participating households.
3. Calibration weighting to reduce any residual non-response bias at the individual level. This final stage sought to combine the results of the previous stages and then 'force' the profile of the final weighted sample to be in-line with the best available population estimates of the characteristics of residents exposed to aviation noise.

The processes for deriving the weights are described in detail in Section 5 of the Technical Report.

b) Airport specific analyses

This section describes the statistical analyses conducted on the data. All analyses are carried out for the sample combined across the eight airports.

The study does not have statistical power to examine differences between airports (i.e., the samples at each airport do not contain the number of individuals at every airport that would be required for effects for individual airports to be estimated with statistical accuracy and robustness). The study was designed to provide a national, not an airport specific assessment of aviation night noise effects. Some data are presented by airport, e.g., to show the distribution of the noise metrics across airports, but this is the exception and not the norm. The use of purposive selection to identify airports allowed for the selection of designated airports, as well as airports covering a range of factors including number of movements, freight flights, passenger flights, and population exposed covering a wide geographical spread and rural/suburban/urban and city areas. Once the airports were selected, representative addresses around each airport were sampled. See the Technical Report for further details of the sampling framework for the study.

c) Statistical analysis

This report includes basic descriptive statistics for the ANNE sample, describing who the sample were, as well as their noise exposure, aircraft noise annoyance, self-reported sleep disturbance, wellbeing, and attitudes to aviation.

All analyses were conducted in Stata (Version 18) – a statistical analysis software package.

All analyses were performed using the weighting described in the technical report by declaring the data to be survey data within Stata, with the airports being the first sampling unit, the ten noise bands being the strata, and each participant having a weight assigned due to the sampling strategy.

To examine the exposure-response functions (ERFs) between noise exposure and the outcomes of interest (e.g., annoyance, sleep disturbance, wellbeing), inferential statistical testing was undertaken using generalised linear models.

ERFs are established by:

1. Plotting the data points (e.g., %HA) for each noise exposure (e.g., $L_{Aeq,8h}$), and
2. Using statistical analyses, in the form of a regression to establish a line between the data points, indicating the ERF.

The shape of the line will vary according to which type of regression (i.e., the underlying mathematical approach) is used, and whether the health outcome is continuous or categorical (e.g., annoyance scored on a continuous scale from 1 to 5, versus annoyance scored as being 'highly annoyed' (yes or no)) (See Section 3.3 for more information).

For the ANNE study, the fit of a number of different regression models were compared to determine the most appropriate shape of the line that gets drawn between the data points. Section 6.1 describes the models tested and the decision making for arriving at the chosen approach.

This process found that for binary outcomes, such as highly annoyed, that one straight line did not summarize the data well, with several points in the middle of the data being a long way away from the predicted values. This appeared to be due to the level of response remaining fairly constant above a specific level of noise exposure. A model fitting two simple straight lines summarised the data better, with the first showing increasing levels of annoyance with increasing noise up to a specific noise level (the "knot") and the second describing annoyance above this noise value. The best model was identified by assuming different values of the "knot", fitting the two lines and then comparing the Bayesian Information Criteria (BIC) which is a measure of how well the models predict the observed values (Kuha, 2004)¹⁰. Similarly, for continuous outcomes linear regression models were fitted with splines including one or two knots.

The models fitted with knots are a departure from the original (and often seen traditional regression approaches seen in noise and health research), which model two parameters – the intercept and the slope. The two-parameter models did not fit the ANNE data well, as visually there seemed to be less increase in annoyance after a certain noise level. So instead, we chose to fit models of a logistic regression with a single knot (having 4 parameters - the slope of each line plus the intercept and the value of where the knot occurred). The second portion of the "line" could also have a slope and therefore the model chosen was the increasing slope up to a knot and after (four parameters). The knot was determined according to the BIC values. The emphasis was on a simple model that could be interpreted readily.

The data point shown on red in the ERF plots are the mean for the outcome across the 1dB band, e.g., the mean for the outcome for those with noise exposure ranging between 46-46.9dB: this is why the data point sits off-set from the exposure as plotted on the x-axis.

Further information about the statistical analyses is provided in the Appendix, including a description of how to interpret the ERFs and analyses (see 6.2 in the Appendix).

For N60 and overflights, the number of categories describing the exposure available for analyses (the x-axis) were less than seven. The proportion or mean score for each category only is presented, and these relationships are not statistically analysed for several reasons. For both N60 and overflights the categories are not equally defined numerically, which makes them unsuitable for plotting and interpreting any line drawn between the data points. Further, for overflights, there were only four categories, which even with a two-parameter model (straight line) would seriously limit model fit and interpretation.

Sensitivity analyses were run additionally adjusting the exposure-response function analyses for airport and household clustering using multilevel modelling (see Section 6.3 in the Appendix for an example). The results showed little change in the relationships (as seen by the similarity in coefficients/estimates between the different models for the regression lines) between aviation noise exposure and the annoyance, sleep disturbance and wellbeing outcomes when these factors were taken into account. Therefore, the unadjusted analyses are presented in this report, which will more easily enable comparison with other studies.

¹⁰ AIC (Akaike's Information Criterion) were also calculated for all models and they were consistent with the BIC.

3 Results

3.1 Sample characteristics

Table 7 shows the demographic information for the sample of the ANNE study, describing the make-up of the sample in terms of age, sex, ethnicity, employment factors and noise sensitivity. The sample came from a wide age range (18-75 years or older), with a smaller proportion of under 25-year-olds and over 65-year-olds participating compared to the other age groups. This is a usual pattern for push-to-web surveys, which tend to have lower response rates from younger populations, due to busyness and interest, and from older populations, sometimes due to lack of access to technology. 52% of the sample were female. Nearly two-thirds of the sample were White English/Welsh/Scottish/Northern Irish/British (63%), with 9% other White background, 5% Indian, 4% African, 3% Chinese, 2% Pakistani, 2% Caribbean, 2% other Asian background, 1% White Irish, 1% Arab, 0.7% White and Black Caribbean, 0.7% White and Asian, 0.7% Latin American, and 0.6% Bangladeshi.

In terms of occupation, nearly one-third of the sample (32%) were ‘modern professional’, with fewer of the sample coming from ‘routine manual and service occupations’, ‘semi-routine manual and service occupations’ or ‘technical and craft occupations’. 7% of the employed participants reported working nightshifts. Around one-tenth (9%) of the sample reported that their employment was linked in some way to the aviation sector. 0.8% were a member of a group campaigning against a local airport or the aviation industry. One-sixth reported problems with hearing (16%). The noise sensitivity of the sample ranged from 1 ‘not at all sensitive’ to 7 ‘very sensitive’. The median score was 4. One-tenth of the sample (10%) reported being ‘very sensitive’ to noise.

Table 7: Demographic information for the ANNE study sample¹¹

Demographic Information			
		n	%
Age (q36)	18-19y	111	3%
	20-24y	190	5%
	25-34y	995	24%
	35-44y	806	19%
	45-54y	730	17%
	55-64y	599	14%
	65-74y	477	11%
	75y or older	256	6%

¹¹ Unless stated, the total number of participants is 4,183. Some questions were not administered to all participants (e.g., those who have never had a job were not asked about their occupation). In these instances, we report the different total number of participants in the table. Not all participants answered every question (e.g., some questions were skipped as participants may not have wanted to provide this information) and missing data for each question are reported in the tables. For some items the total percentages may exceed 100% and the total frequency of participants may exceed 4,183. This is due to the use of weights in the analysis and the subsequent rounding of results.

Demographic Information		
	n	%
Missing	19	0.5%
Sex at birth (q37)		
Male	1987	48%
Female	2168	52%
Missing	28	0.7%
Gender (q38)		
Man/boy	1975	47%
Woman/girl	2168	52%
In another way	2	0.05%
Missing	38	0.9%
Ethnic group (q39)		
White – English/Welsh/Scottish/Northern Irish/British	2634	63%
White - Irish	51	1%
White – Gypsy or Irish Traveller	0	0%
White - Roma	21	0.5%
Any other white background	386	9%
White and Black Caribbean	30	0.7%
White and Black African	10	0.2%
White and Asian	30	0.7%
Any other mixed/multiple ethnic background	26	0.6%
Indian	224	5%
Pakistani	100	2%
Bangladeshi	24	0.6%
Chinese	128	3%
Any other Asian background	91	2%
African	174	4%
Caribbean	89	2%
Any other Black/Black British/African or Caribbean background	18	0.4%
Arab	52	1%
Latin American	30	0.7%
Any other ethnic group	34	0.8%
Missing	32	0.8%
Do you have any problems or difficulties with your sense of hearing? (q49)		
Yes	666	16%
No	3501	84%
Missing	16	0.4%
Does your job require overnight shift work? (q53) (n=2773)		
Yes	200	7%
No	2564	92%
Missing	9	0.3%
Occupation (q57)		
Modern professional	1325	32%
Clerical and intermediate	443	11%
Senior managers or administrators	627	15%
Technical and craft occupations	209	5%

Demographic Information		
	n	%
Semi-routine manual and service occupations	260	6%
Routine manual and service occupations	222	5%
Middle or junior managers	338	8%
Traditional professional	480	11%
Missing/not in work	279	7%
Are you a member of any group campaigning against a local airport or the aviation industry? (q60)		
Yes	34	0.8%
No	4116	98%
Missing	33	0.8%
Do you currently have work, or have you ever worked, in any of these kinds of employment? (q58) (n=4023)		
Working for an airport	75	2%
Working for an airline	114	3%
Working for another company that does business at an airport	123	3%
Work that is not an airport but gets some benefit from the airport being there	65	2%
Other work related to the aircraft or air travel industry	125	3%
None of these	3612	90%
Any airport related employment ¹²	380	9%
Missing	31	0.8%
Noise sensitivity (q50)		
1 Not at all sensitive	428	10%
2	448	11%
3	571	14%
4	1046	25%
5	862	21%
6	411	10%
7 Very sensitive	407	10%
Missing	11	0.3%
Mean (SD)	4.04 (1.72)	
Median (IQR)	4 (3-5)	

Table 8 shows information about housing factors and household members for the sample. One-quarter of the sample owned their dwelling (27%), with just over a further one-third buying their dwelling on a mortgage (38%). One-fifth rented their dwelling from a private landlord (21%) and one-tenth (12%) rented from a housing association or local authority. Three-fifths of households had three or more members (62%), with nearly one-third having two members (30%) and 8% being single-person households.

Just over half the sample worked full-time (55%) and just under one-fifth were retired (17%). Around two thirds of those in full- or part-time work reported sometimes working from home

¹² Percentage is based on the full sample (n=4,183).

(68%). 5% of the sample reported that someone in the household had work that was linked to the aviation sector.

Nearly half the sample had lived in their home for more than ten years (45%) and one-eighth (13%) for less than one year. One-third of the sample (35%) live in a flat, maisonette or apartment, one-quarter (27%) lived in a semi-detached dwelling, one-fifth (19%) in a mid-terrace dwelling, and 14% in a detached dwelling. Most of the sample reported sleeping on the first floor of their building. 90% of the sample reported having access to a garden, balcony, or terrace.

Table 8: Dwelling and household information for the ANNE study

Demographic and Dwelling Information		
	n	%
How much do you like living in this neighbourhood? (q1)		
1 - Definitely like	1557	37%
2	1182	28%
3	597	14%
4	363	9%
5	276	7%
6	124	3%
7 Definitely don't like	81	2%
Missing	4	0.1%
Home ownership (q40)		
Being bought on a mortgage	1585	38%
Owned outright by household	1123	27%
Rented from local authority	201	5%
Rented from housing association	281	7%
Rented from private landlord	870	21%
Shared ownership	47	1%
Tied to employment	7	0.2%
Other	64	2%
Missing	6	0.1%
Household size¹³ (q41-42)		
1	333	8%
2	1260	30%
3	1068	26%
4	717	17%
5	538	13%
6 or more	249	6%
Missing	17	0.4%
Employment (q51)		
Working full time (30 hours a week or more)	2310	55%
Working part time	463	11%
Unemployed and looking for work	156	4%
Retired from paid work altogether	699	17%
In full-time education	158	4%

¹³ Household size as reported here includes adults (≥18 years old) and children (<18 years old).

Demographic and Dwelling Information		
	n	%
Looking after the home or family	171	4%
Something else	209	5%
Missing	16	0.4%
Do you ever work from home? (q52) (n=2773)		
Yes	1881	68%
No	874	32%
Missing	18	0.6%
Does anyone in the household have work that includes any of these kinds of employment? (q59) (n=3850)		
Working for an airport	26	0.7%
Working for an airline	64	2%
Working for another company that does business at an airport	55	1%
Work that is not an airport but gets some benefit from the airport being there	36	0.9%
Other work related to the aircraft or air travel industry	50	1%
None of these	3502	91%
Any airport related employment	203	5%
Missing	145	4%
In what year was your home originally built? (q61)		
Before 1919	837	20%
1919-1940	726	17%
1941-1960	416	10%
1961-1990	706	17%
1991-2000	255	6%
2001-2010	196	5%
2011-2020	97	2%
After 2020	16	0.4%
Don't know	920	22%
Missing	14	0.3%
How long have you lived in this home? (q62)		
Less than 6 months	313	7%
6 months but less than 1 year	238	6%
Longer than 1 year but up to 2 years	396	9%
Longer than 2 years but up to 5 years	652	16%
Longer than 5 years but up to 10 years	708	17%
More than 10 years	1867	45%
Missing	10	0.2%
(If less than 6 months) How many months have you lived in this home? (q63) (n=313)		
0	30	10%
1	40	13%
2	31	10%
3	50	16%
4	80	26%
5	81	26%
Missing	1	0.3%

Demographic and Dwelling Information		
	n	%
Type of house (q64)		
Flat, maisonette or apartment	1467	35%
Bungalow	108	3%
House – mid terrace house	805	19%
House – semi detached	1146	27%
House – detached	581	14%
Other	71	2%
Missing	4	0.1%
On which floor of the building do you sleep? (q65)		
Median (IQR)	1 (1-2)	
Range	0-21	
Missing	91	2%
Access to garden or other private outdoor space (q66)		
Yes – garden	3177	76%
Yes – terrace	301	7%
Yes – balcony	652	16%
No – none	428	10%

Representativeness of the ANNE sample with the general population

To assess the similarity of the ANNE sample to the general population, Table 9 compares key demographic factors for the ANNE sample with the Census 2021. The ANNE sample contains individuals from England and Scotland, but the Census 2021 is for England and Wales. Bearing these geographical differences in mind, the ANNE sample had the same biological sex make up as the Census 2021. The age range of the ANNE sample was similar to the Census 2021, with the exceptions that the ANNE sample had slightly fewer 20-24-year-olds and over 75-year-olds, and slightly more 25-34-year-olds and 35-44-year-olds. Overall, the age range of the ANNE sample can be considered fairly similar to the general population.

The ANNE sample was more ethnically diverse than the Census 2021 population; representing the ethnic diversity of the populations around many of the airports, compared with England and Wales, in general. The ANNE sample had fewer White – English/Welsh/Scottish/Northern Irish/British participants (63%) compared with the Census 2021 (74%). The ANNE sample had a higher number of African, Caribbean, Chinese, Indian, and other White background participants, compared with the Census 2021.

The ANNE sample were less comparable to the Census 2021 in terms of socio-economic classification (NS-SEC), sampling a greater number of people from ‘higher managerial, administrative, and professional occupations’, and fewer from ‘semi routine and routine occupations’, than in the general population. These patterns of participation by socio-economic classification are often found in national surveys. The ANNE sample also had a higher number of people who worked full-time, and fewer who were retired or working part-time than the Census 2021.

Table 9: Demographic and dwelling information for the ANNE study compared with the Census 2021

Demographic and Dwelling Information		ANNE sample	Census 2021
		% (n)	% (n)
Sex¹⁴	Female	52% (2168)	52% (24,378,969)
	Male	48% (1987)	48% (22,826,358)
	Missing	0.7% (28)	Not applicable
Age	18-19y	3% (111)	3% (1,355,142)
	20-24y	5% (190)	8% (3,602,126)
	25-34y	24% (995)	17% (8,050,540)
	35-44y	19% (806)	16% (7,737,381)
	45-54y	17% (730)	17% (7,912,152)
	55-64y	14% (599)	16% (7,484,643)
	65-74y	11% (477)	13% (5,923,120)
	75y or older	6% (256)	11% (5,140,223)
Ethnic group			
White – English/Welsh/Scottish/Northern Irish/British		63% (2,634)	74% (44,355,038)
White – Irish		1% (51)	0.9% (507,465)
White – Gypsy or Irish Traveller		0% (0)	0.1% (67,768)
White – Roma		0.5% (21)	0.2% (100,981)
Any other white background		9% (386)	6% (3,667,997)
White and Black Caribbean		0.7% (30)	0.9% (513,042)
White and Black African		0.2% (10)	0.4% (249,596)
White and Asian		0.7% (30)	0.8% (488,225)
Any other mixed/multiple ethnic background		0.6% (26)	0.8% (467,113)
Indian		5% (224)	3% (1,864,318)
Pakistani		2% (100)	3% (1,587,819)
Bangladeshi		0.6% (24)	1% (644,881)
Chinese		3% (128)	0.7% (445,619)
Any other Asian background		2% (91)	2% (972,783)
African		4% (174)	3% (1,488,381)
Caribbean		2% (89)	1% (623,119)
Any other Black/Black British/African or Caribbean background		0.4% (18)	0.5% (297,778)
Arab		1% (52)	0.6% (331,844)
Latin American		0.7% (30)	<i>Not reported</i>

¹⁴ The question regarding sex differs in the two samples. The ANNE study asked participants “*At birth, were you described as...*”. The Census 2021 question asked, “*What is your sex?*”.

Demographic and Dwelling Information	ANNE sample	Census 2021
	% (n)	% (n)
Any other ethnic group	0.8% (34)	2% (923,775)
Employment (q51)¹⁵		
Working full time (30 hours a week or more)	55% (2310)	40% (19,492,661)
Working part time	11% (463)	17% (8,281,004)
Unemployed and looking for work	4% (156)	3% (1,675,185)
Retired from paid work altogether	17% (699)	22% (10,513,713)
In full-time education	4% (158)	6% (2,740,634)
Looking after the home or family	4% (171)	5% (2,317,340)
Something else	5% (209)	7% (3,545,834)
The National Statistics Socio-economic classification (NS-SEC)		
Higher managerial, administrative and professional occupations	71% (2,740)	39% (16,023,710)
Intermediate occupations	9% (336)	14% (5,551,417)
Small employers and own account workers	6% (213)	13% (5,131,554)
Lower supervisory and technical occupations	6% (225)	6% (2,620,604)
Semi-routine and routine occupations	9% (350)	28% (11,378,676)

In summary, the airports were purposively sampled to include diversity in terms of operational and contextual factors. The participant sample for each airport was designed to be representative of the local population. The largest samples came from London Heathrow and Manchester airports, who have the largest populations exposed to aviation noise at night. We have undertaken sensitivity analyses, adjusting the analyses for airport level variation, to assess if the findings of the study were driven by the London Heathrow or the Manchester samples. However, adjusting for airport level effects had little influence on the results. See Section 6.3, Table 62 and Table 63 for further details of the sensitivity analyses. This means that the findings of the ANNE study represent the national picture, not an airport specific picture, and can be used to inform national policy.

Overall, the ANNE sample was representative of the general population, with the exceptions that the sample had slightly fewer participants who were White-English/Welsh/Scottish/Northern Irish/British; younger and older; from 'semi routine and routine occupations'; and who were retired or working part-time. In contrast, the ANNE sample had slightly more participants who were aged 25-45 years; from 'higher managerial, administrative, and professional occupations'; and who worked full-time. Overall, these differences were moderate and to be expected in social surveys, with the exception of socio-economic factors. The differences in terms of socio-economic classification were fairly large,

¹⁵ For the Census 2021 figures, people who were classed as being economically active as well as being a full-time student were assigned to the relevant employment group. The student group comprises people who were economically inactive only.

meaning that the ANNE sample is made up of participants with higher socio-economic classification than found in the general population. The implications of this for the ERFs found in the study are discussed later in the report.

3.2 Noise exposure¹⁶

This section provides a summary of the key aircraft noise exposure metrics for the ANNE study sample.

The following aircraft noise exposure metrics were examined:

- $L_{Aeq,8h}$ (92-day) – average summer night noise exposure measured between 23.00 and 07.00 for the 92-day summer period (16th June to 15th September 2022);
- L_{night} (annual) – annual average night-time noise exposure between 23.00 and 07.00 for 365-day period for 2022 estimated using all tracks for each airport as occurred in 2022, therefore reflecting actual conditions;
- $L_{Aeq,1h}$ (92-day) – average summer noise exposure for one-hourly periods between 21.00 and 08.00 for the 92-day summer period (16th June to 15th September 2022);
- N60 (92-day) – average summer night-time number of aircraft noise events equal to or above 60 dB between 23.00 and 07.00 for the 92-day summer period (16th June to 15th September 2022); and
- Overflights (92-day) – average summer night-time number of overflights passing over the participant's home based on:
 - a 48.5 degree at the ground receiver at 7,000ft and 4,000ft between 23.00 and 07.00 for the 92-day summer period (16th June to 15th September 2022); and
 - a 60 degree at the ground receiver at 7,000ft and 4,000ft between 23.00 and 07.00 for the 92-day summer period (16th June to 15th September 2022).¹⁷

All noise exposure metrics (i.e., $L_{Aeq,8hr}$, L_{night} , $L_{Aeq,1hr}$, and N60) have been prepared using 2022 datasets obtained directly from the airports. These datasets have included radar flight tracks and aircraft noise event measurement data from each of the airport's fixed noise monitoring terminals. Using this data, a noise model for each airport has been developed in

¹⁶ These metrics are all external/outdoor noise metrics. Attenuation within individual households can vary widely.

¹⁷ CAP1498 CIVIL AVIATION AUTHORITY 2017. CAP1498: Definition of overflight. Second Edition ed. London, United Kingdom: Civil Aviation Authority. defines an overflight as "an aircraft in flight passing an observer at an elevation angle (approximately the angle between the horizon and the aircraft) that is greater than an agreed threshold, and at an altitude below 7,000 ft."

AEDT 3.0e (Aviation Environmental Design Tool – a software system that models aircraft performance in space and time to estimate fuel consumption, emissions, noise, and air quality consequences used internationally). Each model has been prepared adopting the best standard of modelling described by the CAA in publication CAP2091 (Civil Aviation Authority, 2021b). Using the datasets obtained from each airport, flight profiles have been developed for each aircraft operating between 21.00 and 08.00 with aircraft noise data within the model adjusted to represent aircraft event levels measured at the noise monitoring terminals. All modelling has been based on the individual flight tracks from the radar data. Overflights have been calculated directly from radar flight tracks using proprietary software.

A full description of the methodology used to generate the aircraft noise exposure metrics is presented in the Technical Report.

In this report the following terminology and definitions of time-periods for the night-time are used:

- 8-hour night-time period – 23.00-07.00;
- Night-quota period – 23.30-06.00;
- Evening – 21.00-23.00; and
- Morning – 07.00-08.00.

A wide range of aircraft noise exposures were sampled in the ANNE study, including low levels, up to high levels. Table 10 shows that exposure to aircraft noise at night for the $L_{Aeq,8h}$ metric for the sample ranged from >30dB to 68dB. Table 11 shows that exposure to aircraft noise at night for the L_{night} metric ranged from >30dB to 66dB L_{night} .

Table 10: Participants categorised by $L_{Aeq,8h}$ (92-day average summer night) for total sample and by airport¹⁸

Noise exposure variable									
	BRS	EMA	GLA	LHR	LGW	MAN	STN	LTN	TOTAL
<36dB	0	4	0	108	0	11	7	40	170
	0%	2%	0%	63%	0%	7%	4%	24%	100%
36-<38dB	2	0	0	248	0	4	1	9	265
	1%	0%	0%	94%	0%	1%	1%	4%	100%
38-<40dB	5	3	1	104	12	24	6	1	155
	3%	2%	0%	67%	8%	15%	4%	0%	100%
40-<42dB	5	3	3	119	4	24	8	0	166
	3%	2%	2%	72%	3%	14%	5%	0%	100%
42-<44dB	0	10	1	241	4	24	19	0	299
	0%	3%	0%	81%	1%	8%	6%	0%	100%
	1	14	20	210	17	44	13	2	321

¹⁸ Please note that these figures are weighted and total number of participants per airport will differ from the actual number of participants per airport reported in Table 3.

Noise exposure variable									
44-<46dB	0%	4%	6%	65%	5%	14%	4%	1%	100%
46-<48dB	6	7	18	166	7	49	11	4	268
	2%	3%	7%	62%	3%	18%	4%	1%	100%
48-<50dB	3	3	27	177	2	73	4	8	298
	1%	1%	9%	59%	1%	25%	1%	3%	100%
50-<52dB	5	8	5	173	10	79	5	4	288
	2%	3%	2%	60%	3%	27%	2%	1%	100%
52-<54dB	4	11	3	191	9	64	3	3	289
	1%	4%	1%	66%	3%	22%	1%	1%	100%
54-<56dB	14	10	8	237	8	76	6	7	365
	4%	3%	2%	65%	2%	21%	2%	2%	100%
56-<58dB	0	14	0	396	4	265	13	8	699
	0%	2%	0%	57%	1%	38%	2%	1%	100%
58-<60dB	6	9	0	231	10	107	0	5	367
	2%	2%	0%	63%	3%	29%	0%	1%	100%
≥60dB	0	36	0	115	3	74	0	6	233
	0%	15%	0%	49%	1%	32%	0%	3%	100%
Total (N)	50	130	86	2717	90	918	96	97	4183
Median	52.0	55.1	48.0	50.0	49.7	55.6	45.2	37.2	50.7
IQR	46.3-55.0	45.3-60.4	45.2-49.6	43.0-56.5	44.4-54.7	49.5-57.5	42.0-51	32.8-54.9	44.0-56.7
Range	37-59	31-67	38-55	34-64	39-62	25-68	33-58	28-61	25-68

Table 11: Participants categorised by L_{night} for total sample and by airport

Noise exposure variable									
	BRS	EMA	GLA	LHR	LGW	MAN	STN	LTN	TOTAL
<36dB	2	4	0	156	0	12	8	41	222
	1%	2%	0%	70%	0%	5%	4%	19%	100%
36-<38dB	5	0	1	256	7	11	4	9	292
	2%	0%	0%	88%	2%	4%	1%	3%	100%
38-<40dB	5	3	3	65	9	23	5	0	113
	4%	3%	3%	58%	8%	20%	5%	0%	100%
40-<42dB	0	9	1	141	1	23	20	0	195
	0%	5%	1%	72%	0%	12%	10%	0%	100%
42-<44dB	1	7	13	250	12	46	14	0	342
	0%	2%	4%	73%	3%	13%	4%	0%	100%

Noise exposure variable									
44-<46dB	6	10	21	214	15	53	9	4	332
	2%	3%	6%	64%	5%	16%	3%	1%	100%
46-<48dB	3	8	21	168	0	61	8	4	274
	1%	3%	8%	61%	0%	22%	3%	2%	100%
48-<50dB	5	3	15	144	8	86	6	7	275
	2%	1%	5%	52%	3%	31%	2%	2%	100%
50-<52dB	4	8	4	165	8	66	2	4	262
	2%	3%	1%	63%	3%	25%	1%	1%	100%
52-<54dB	14	9	8	225	11	74	4	5	350
	4%	3%	2%	64%	3%	21%	1%	2%	100%
54-<56dB	0	12	0	232	7	220	11	8	489
	0%	2%	0%	47%	1%	45%	2%	2%	100%
56-<58dB	6	8	0	377	7	150	4	8	560
	1%	1%	0%	67%	1%	27%	1%	1%	100%
58-<60dB	0	15	0	230	4	48	0	7	304
	0%	5%	0%	76%	1%	16%	0%	2%	100%
≥60dB	0	33	0	94	0	45	0	0	173
	0%	19%	0%	55%	0%	26%	0%	0%	100%
Total (N)	50	130	86	2717	90	918	96	97	4183
Median	50.0	54.8	46.2	49.8	48.3	54.1	43.2	36.7	50.0
IQR	44.6-52.9	45.0-60.0	44.0-48.2	42.7-56.2	42.7-52.6	48.0-56.1	40.8-49.5	31.5-54.0	43.5-55.7
Range	36-56	30-66	37-53	32-64	37-60	25-66	31-56	26-59	25-66

Table 12 shows the noise exposure (median & interquartile range (IQR)) for $L_{Aeq,1h}$ (92-day) throughout the night-time period between 21.00-08.00. Median noise exposure for the one-hour periods ranged from 30dB for 01.00-02.00 to 57dB for 07.00-08.00, with exposures higher, (above 50dB) in the evening and morning hours. Median exposures fell slightly in the night-time period but remained above 50dB between 02.00 and 04.00 hours.

Table 13 shows the number of aircraft noise events equal to or above 60dB (N60) per night between 23.00-07.00 estimated for the 92-day period for the sample. A wide range of exposures were sampled, ranging from 0 events to 72 aircraft noise events. There were differences between the samples from each airport in terms of the number of aircraft noise events above 60dB experienced, with the median ranging from 9.9 to 47.9 events across the eight airports.

Table 12: Median noise exposure (interquartile range) for $L_{Aeq,1h}$ periods from 21.00-08.00 (92-day average summer night, dB), for total sample and by airport

Noise exposure variable $L_{Aeq,1h}$									
	BRS	EMA	GLA	LHR	LGW	MAN	STN	LTN	TOTAL
$L_{Aeq,1h}$ (21.00-22.00)	53 (49-59)	51 (40-60)	52 (48-53)	54 (47-60)	53 (48-60)	51 (44-53)	-	50 (36-58)	52 (46-58)
$L_{Aeq,1h}$ (22.00-23.00)	52 (47-56)	56 (48-62)	52 (48-53)	53 (46-60)	52 (48-59)	57 (50-58)	47 (43-53)	42 (38-59)	53 (47-59)
$L_{Aeq,1h}$ (23.00-00.00)	51 (45-57)	57 (47-62)	49 (45-50)	48 (41-55)	51 (47-58)	57 (50-59)	48 (43-55)	40 (37-57)	50 (42-57)
$L_{Aeq,1h}$ (00.00-01.00)	47 (42-55)	54 (42-61)	34 (29-37)	40 (33-47)	50 (44-57)	56 (50-59)	47 (42-53)	38 (34-55)	44 (35-51)
$L_{Aeq,1h}$ (01.00-02.00)	47 (42-54)	55 (46-61)	47 (43-50)	25 (25-30)	48 (42-54)	56 (49-58)	45 (43-51)	35 (30-53)	31 (25-49)
$L_{Aeq,1h}$ (02.00-03.00)	45 (40-53)	56 (47-62)	46 (42-48)	-	47 (39-53)	56 (50-59)	41 (35-48)	34 (29-51)	52 (45-58)
$L_{Aeq,1h}$ (03.00-04.00)	42 (37-49)	54 (42-61)	42 (39-46)	-	44 (36-50)	54 (48-57)	41 (33-49)	34 (25-46)	50 (42-56)
$L_{Aeq,1h}$ (04.00-05.00)	36 (31-44)	53 (45-59)	40 (35-43)	42 (34-48)	40 (31-46)	50 (44-53)	40 (37-46)	32 (25-49)	44 (35-50)
$L_{Aeq,1h}$ (05.00-06.00)	41 (37-45)	56 (47-60)	41 (36-44)	49 (41-55)	43 (39-48)	49 (42-52)	39 (36-43)	33 (26-47)	47 (41-54)
$L_{Aeq,1h}$ (06.00-07.00)	59 (54-60)	54 (45-58)	54 (52-57)	58 (50-64)	52 (47-57)	56 (51-59)	48 (44-53)	43 (37-60)	56 (50-62)
$L_{Aeq,1h}$ (07.00-08.00)	59 (54-60)	53 (46-57)	56 (53-58)	57 (50-63)	53 (48-59)	59 (54-61)	48 (45-53)	44 (37-61)	57 (50-62)

Note: London Heathrow airport does not have any scheduled departures between 22.50-06.00 or scheduled arrivals between 22.55-04.50. Heathrow airport has a voluntary ban in place that prevents flights scheduled between 04.30-06.00 from landing before 04.30.

Table 13: Participants categorised by N60¹⁹ (92-day) for total sample and by airport

Noise exposure variable									
	BRS	EMA	GLA	LHR	LGW	MAN	STN	LTN	TOTAL
<1	0	4	0	7	0	11	12	47	80
	0%	5%	0%	9%	0%	13%	14%	59%	100%
1-<5	7	1	3	503	6	53	17	4	594
	1%	0%	1%	85%	1%	9%	3%	1%	100%
5-<10	4	21	21	213	10	21	12	0	302
	1%	7%	7%	71%	3%	7%	4%	0%	100%
10-<20	11	8	61	358	15	24	18	14	510
	2%	2%	12%	70%	3%	5%	3%	3%	100%
20-<50	29	31	0	1635	26	145	36	32	1934
	1%	2%	0%	85%	1%	8%	2%	2%	100%
≥50	0	64	0	0	33	664	1	0	763
	0%	8%	0%	0%	4%	87%	0%	0%	100%
Total (N)	50	130	86	2717	90	918	96	97	4183
Median	21.8	46.9	11.4	22.3	38.0	54.6	15.9	2.8	24.7
IQR	14.5-21.8	18.5-59.5	10.0-11.4	7.9-27.6	15.8-54.5	47.6-55.9	2.8-30.6	0.2-24.1	11.4-35.2
Range	2-29	0-72	2-11	1-43	2-64	0-72	0-52	0-25	0-72

Table 14 to Table 17 show the overflight data for the ANNE sample per night between 23.00-07.00 estimated for the 92-day period. For both the 4,000ft and the 7,000ft definitions (see Figure 1 and Figure 2), many participants were exposed to <1 overflight using either the 48.5 or the 60 degree measure. As would be expected, the numbers exposed to >1 overflight were slightly higher for the 7,000ft measures (given the wider geographical spread of the definition), but relatively few were exposed to >1 overflights during the night-time period.

It is important in considering the findings of the ANNE survey, that the data are not extrapolated beyond the levels of aviation night-noise examined in the study. It is not possible to speculate on the relationships beyond ~60dB $L_{Aeq,8h}$ values (or the upper values for the other noise metrics being examined) as these have not been examined in the study and represent exposures not typically found in the UK for aviation night-noise exposure. Similarly, whilst examining aviation exposures at low levels, the findings of the ANNE survey

¹⁹ Number of events with a maximum noise level over 60 dB between 23.00 and 07.00 hours. The categorisation of the number of events is based on CAP1498 (paragraph 3.30), with the cut-points being at set below the upper value, e.g. 1-<5=1 to 4.99; 5-<10 = 5-9.99.

should also not be extrapolated below $\sim <36\text{dB } L_{Aeq,8h}$ values (or the lower values for the other noise metrics being examined).

Figure 1 Overflight when an aircraft passes an observer above an elevation angle threshold (Civil Aviation Authority, 2017)

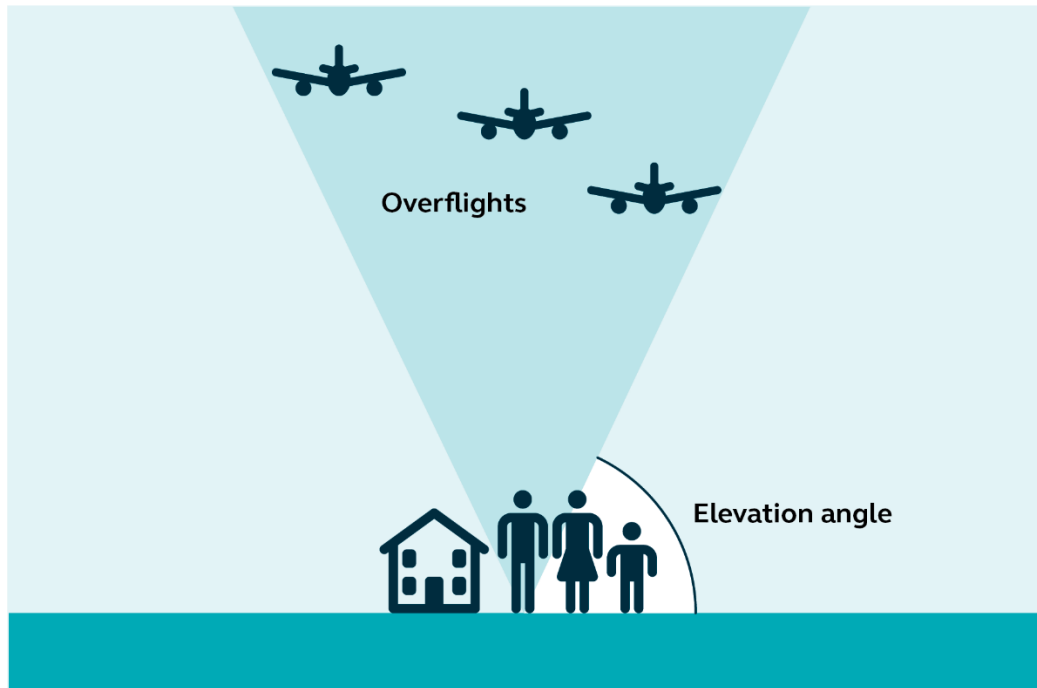


Figure 2 Lateral distance and altitude of aircraft on 60° and 48.5° elevation angle thresholds (Civil Aviation Authority, 2017)

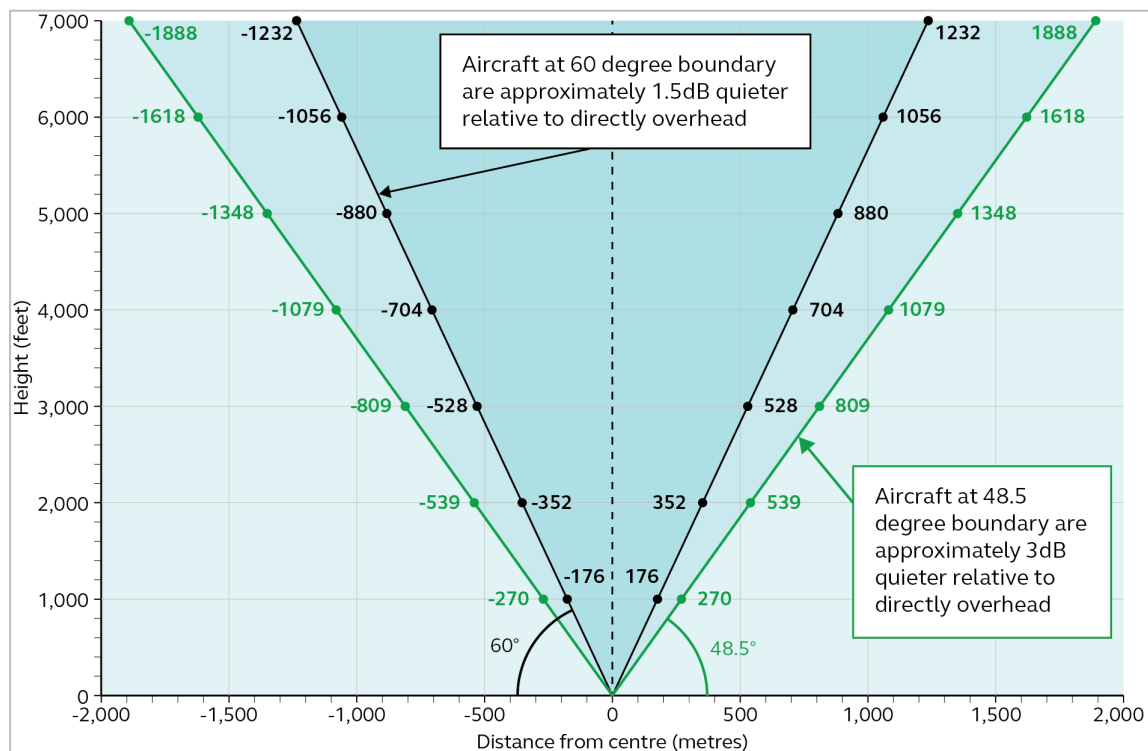


Table 14: Participants categorised by overflights (92-days) at 4000ft, 48.5° for total sample and by airport

Noise exposure variable									
	BRS	EMA	GLA	LHR	LGW	MAN	STN	LTN	TOTAL
<1	12	90	30	1147	32	231	58	70	1669
	1%	5%	2%	69%	2%	14%	3%	4%	100%
1-<10	6	14	39	610	31	293	10	17	1021
	1%	1%	4%	60%	3%	29%	1%	2%	100%
10-<20	13	15	16	918	16	28	20	10	1035
	1%	1%	2%	89%	2%	3%	2%	1%	100%
≥20	20	11	0	41	11	366	8	0	458
	4%	2%	0%	9%	2%	80%	2%	0%	100%
Total (N)	50	130	86	2717	90	918	96	97	4183
Median	13.3	0.02	2.1	1.7	6.5	6.3	0.04	0.02	2.4
IQR	1.1-48.9	0-9.2	0.3-9.7	0.2-15.6	0.6-16.2	1.0-49.4	0-11.7	0-1.2	0.2-15.7
Range	0.1-89	0-24	0-11	0-32	0-39	0-54	0-30	0-18	0-89

Table 15: Participants categorised by overflights (92-days) at 4000ft, 60° for total sample and by airport

Noise exposure variable									
	BRS	EMA	GLA	LHR	LGW	MAN	STN	LTN	TOTAL
<1	21	105	42	1653	50	375	64	83	2392
	1%	4%	2%	69%	2%	16%	3%	3%	100%
1-<10	14	12	36	487	18	284	13	12	875
	2%	1%	4%	56%	2%	33%	1%	1%	100%
10-<20	4	5	8	577	16	24	14	3	650
	1%	1%	1%	89%	2%	4%	2%	0%	100%
≥20	11	9	0	0	7	234	5	0	266
	4%	3%	0%	0%	3%	88%	2%	0%	100%

Noise exposure variable									
	BRS	EMA	GLA	LHR	LGW	MAN	STN	LTN	TOTAL
Total (N)	50	130	86	2717	90	918	96	97	4183
Median	2.6	0.01	1.5	0.4	0.8	2.5	0.02	0.01	0.6
IQR	0.1-16.7	0-0.1	0-5.1	0-5.4	0-10.2	0.3-21.5	0-5.4	0-0.3	0-6.5
Range	0-81	0-24	0-11	0-18	0-28	0-52	0-30	0-17	0-81

Table 16: Participants categorised by overflights (92-days) at 7000ft, 48.5° for total sample and by airport

Noise exposure variable									
	BRS	EMA	GLA	LHR	LGW	MAN	STN	LTN	TOTAL
<1	6	70	30	645	19	180	50	51	1050
	1%	7%	3%	61%	2%	17%	5%	5%	100%
1-<10	3	27	40	1027	40	334	17	36	1523
	0%	2%	3%	67%	3%	22%	1%	2%	100%
10-<20	21	22	16	988	20	34	21	10	1131
	2%	2%	1%	87%	2%	3%	2%	1%	100%
≥20	21	11	0	57	11	369	8	0	478
	4%	2%	0%	12%	2%	77%	2%	0%	100%
Total (N)	50	130	86	2717	90	918	96	97	4183
Median	16.5	0.5	2.1	5.9	7.4	7.0	0.7	0.9	5.9
IQR	13.5-49.2	0.1-10	0.3-9.8	1.1-15.7	1.0-16.3	1.4-49.7	0.1-11.8	0.3-2.2	1.0-15.8
Range	0.3-90	0-24	0-11	0-32	0-54	0-54	0-30	0-19	0-90

Table 17: Participants categorised by overflights (92-days) at 7000ft, 60° for total sample and by airport

Noise exposure variable									
	BRS	EMA	GLA	LHR	LGW	MAN	STN	LTN	TOTAL
<1	8	94	40	1127	33	342	53	69	1767
	0%	5%	2%	64%	2%	19%	3%	4%	100%
1-<10	20	22	38	939	34	318	23	24	1417
	1%	2%	3%	66%	2%	22%	2%	2%	100%
10-<20	10	6	8	651	15	23	15	4	731
	1%	1%	1%	89%	2%	3%	2%	1%	100%
≥20	12	9	0	0	7	235	5	0	268
	5%	3%	0%	0%	3%	88%	2%	0%	100%
Total (N)	50	130	86	2717	90	918	96	97	4183
Median	6.5	0.1	1.6	2.5	2.6	3.1	0.4	0.3	2.1
IQR	1.4-16.9	0.1-3.5	0-5.1	0.2-9.1	0.4-10.4	0.6-21.9	0-5.8	0.2-1.2	0.2-9.2
Range	0.2-83	0-24	0-11	0-18	0-29	0-53	0-30	0-17	0-83

Table 18 shows the correlations between the different aircraft noise metrics examined in the ANNE study. The relationships show the extent to which each noise exposure metric changes in relation to another, with values ranging from 0 (no linear relationship) to 1 (perfect linear relationship). These are presented to enable comparison of different metrics, which whilst highly related, are not exact proxies for each other. Table 18 shows that $L_{Aeq,8h}$ and L_{night} are very strongly and almost perfectly correlated²⁰ with each other ($r^2=0.994$). This is expected at a national level given that they represent the average noise exposure between 23.00-07.00 for a 92-day summer night-time (June to September) and average 12-month night-time (January to December) time-period, respectively. The analyses suggest there is little difference in average aircraft noise exposure for the summer 92-day period compared with annual exposure in the ANNE study.

$L_{Aeq,8h}$ also showed strong or very strong correlations with the $L_{Aeq,1h}$ metrics derived for the 21.00-07.00 time-period ($r^2=0.845$ to 0.942). An exception to this was the moderate correlation found between $L_{Aeq,8h}$ and 01.00-02.00 hours ($r^2=0.569$). Further examination of

²⁰ The following classification is used to interpret the correlations: 0.00-0.20 no or negligible correlation; 0.20-0.40 weak correlation; 0.40-0.70 moderate correlation; 0.70-0.90 strong correlation; 0.90-1.00 very strong correlation. Correlations on the borders between definitions would be treated conservatively: i.e., in the lower category.

the correlations between $L_{Aeq,1h}$ for 01.00-02.00 hours show that it was weak to moderately correlated with the $L_{Aeq,1h}$ metrics for the evening and morning hours. The two time-periods of 21.00-22.00 and 22.00-23.00 which are not included in the 8-hour night-time metric, showed strong correlations with $L_{Aeq,8h}$. $L_{Aeq,8h}$ showed a strong correlation with N60 ($r^2=0.726$), albeit weaker than those found for other time-averaged metrics.

a) Correlations between the key noise metrics

Table 18: Correlations between the noise metrics for the ANNE sample²¹

	L_{Aeq,8h}	L_{night}	N60	L_{Aeq,1h} (21.00-22.00)	L_{Aeq,1h} (22.00-23.00)	L_{Aeq,1h} (23.00-00.00)	L_{Aeq,1h} (00.00-01.00)	L_{Aeq,1h} (01.00-02.00)	L_{Aeq,1h} (02.00-03.00)	L_{Aeq,1h} (03.00-04.00)	L_{Aeq,1h} (04.00-05.00)	L_{Aeq,1h} (05.00-06.00)	L_{Aeq,1h} (06.00-07.00)	L_{Aeq,1h} (07.00-08.00)
L_{Aeq,8h}	1.000													
L_{night}	0.994	1.000												
N60	0.726	0.753	1.000											
L_{Aeq,1h} (21.00-22.00)	0.845	0.835	0.381	1.000										
L_{Aeq,1h} (22.00-23.00)	0.928	0.940	0.627	0.930	1.000									
L_{Aeq,1h} (23.00-00.00)	0.888	0.922	0.749	0.788	0.949	1.000								
L_{Aeq,1h} (00.00-01.00)	0.801	0.846	0.832	0.588	0.809	0.936	1.000							
L_{Aeq,1h} (01.00-02.00)	0.569	0.632	0.755	0.280	0.545	0.749	0.861	1.000						
L_{Aeq,1h} (02.00-03.00)	0.942	0.950	0.858	0.725	0.910	0.955	0.902	0.985	1.000					
L_{Aeq,1h} (03.00-04.00)	0.919	0.930	0.852	0.697	0.883	0.938	0.900	0.978	0.988	1.000				
L_{Aeq,1h} (04.00-05.00)	0.914	0.913	0.775	0.643	0.784	0.801	0.795	0.660	0.969	0.967	1.000			
L_{Aeq,1h} (05.00-06.00)	0.927	0.897	0.612	0.776	0.809	0.713	0.626	0.390	0.918	0.892	0.912	1.000		
L_{Aeq,1h} (06.00-07.00)	0.925	0.899	0.514	0.878	0.855	0.724	0.571	0.306	0.734	0.700	0.772	0.903	1.000	
L_{Aeq,1h} (07.00-08.00)	0.942	0.936	0.603	0.885	0.908	0.824	0.683	0.433	0.763	0.733	0.786	0.856	0.970	1.000

²¹ Total N differs by variable. For L_{Aeq,1h} (21.00-22.00), N=4,070, as there are no data during this period for Stansted airport. For L_{Aeq,1h} (02.00-03.00) and L_{Aeq,1h} (03.00-04.00), N=1,648 as there are no flights during these periods at Heathrow airport. For all other variables, N=4,183.

3.3 Aircraft noise annoyance at night

a) Scoring annoyance

Annoyance during various periods of the night-time was assessed using the ISO15666 question (ISO/TS15666:2021, 2021). Two questions were asked to assess annoyance during the night-time for the 92-day 'summer' period: one with a five-point verbal response scale ('not at all (1)', 'slightly (2)', 'moderately (3)', 'very (4)', and 'extremely (5)') and the second on an 11-point numeric response scale (ranging from 0 to 10). The Appendix (Section 6.4) provides the ISO reporting checklist, summarising use of the standard for the ANNE study.

Unfortunately, the paper questionnaire contained an error in the question format for the 11-point numeric scale, where a 10-point numeric response scale (ranging 1 to 10) rather than an 11-point numeric response scale was used. This means that the response of 'not at all' was incorrectly placed at 1 rather than at 0. This made the question non-compliant with ISO/TS15666. The data is therefore not analysed for the 11-point numerical scale question.

This error was not picked up in the pilot study, as the 11-point numeric scale had not been included in the pilot questionnaire due to concerns about survey length and repetition of the annoyance questions, given that they were also asked for each one-hour period of the night-time. The decision to include the 11-point numeric scale was made after the pilot study as it was felt that there would be enough time available in the survey to include both the 5-point verbal scale and the 11-point numeric scale after testing the survey response time in the pilot study.

It was also not possible to analyse the 11-point question for the sub-sample who completed the online survey. Whilst this question was compliant with ISO/TS15666, given how the ANNE survey data are weighted to take account of non-response (so that the results are representative of the best available population estimates of the characteristics of residents exposed to aviation noise at night) it was not possible to drop the paper based responses for this question and restrict analyses to the online survey. Whilst technically it could be possible to create a new weight that is only based on the online survey participants and therefore excludes the paper participants from the analyses, this was not recommended because it is likely to create (additional) bias as it would exclude, or under-represent, certain types of people e.g. those that don't have internet access and those who are less inclined to answer online (the latter cannot be measured directly and therefore it cannot be adjusted for).

When scores are available for both the 5-point verbal and the 11-point numeric scales, it is usual to transform the scores onto a 0 to 100 scale, (see Table 19 & Figure 3) so that the scores can be compared. For example, those responding 'Not at all' on the 5-point verbal scale are given a score of 10, and those responding 0 on the 11-point numerical scale are given a score of 4.5. These transformed data are then used as the outcome for analyses of 'mean annoyance' scores. However, as the 11-point numeric scale was not analysed, the transformation of the 5-point verbal scale is not required, and all 'mean annoyance' scores reported in the results section use the original 1 to 5 response scale, which makes interpretation easier as the numbers can be related to the verbal labels.

Table 19: Transformation of annoyance 5-point and 11-point scales to a 0 to 100 scale.

5-point verbal scale			11-point numerical scale		
Annoyance category	Scale boundary	Scale mid-point	Annoyance category	Scale boundary	Scale mid-point
Not at all	0.0 – <20	10	0	0.0 – <9	4.5
Slightly	20.0 – <40	30	1	9.0 – <18	13.6
Moderately	40.0 – <60	50	2	18.0 – <27	22.7
Very	60.0 – <80	70	3	27.0 – <36	31.8
Extremely	80.0 – 100.0	90	4	36.0 – <45	40.9
			5	45.0 – <55	50.0
			6	55.0 – <64	59.1
			7	64.0 – <73	68.2
			8	73.0 – <82	77.3
			9	82.0 – <91	86.4
			10	91.0 – 100.0	95.5

The percentage ‘highly annoyed’ (HA) is used to describe community response to noise. Following the scoring convention as set out in ISO/TS15666, and further described in Clark et al. (2021) three annoyance outcomes can be calculated (see Table 19).

- HA_V – For the 5-point verbal scale HA is defined by the ‘very’ and ‘extremely’ responses (so if we assigned a 1-5 scoring to the verbal responses from ‘not at all’ to ‘extremely’, this would be the top 40% of the 5-point scale (scoring 4 ‘very’ or 5 ‘extremely’).
- HA_N – For the 11-point numeric scale, HA is defined using a cut-off for the top 28% of the 11-point scale (scoring 8, 9 or 10). Hence, the 5-point and the 11-point scales have different definitions (cut-points) for HA.
- HA_{VW} – For the 5-point verbal scale it is also possible to weight the scale to provide a 28% cut-off to aid comparison with responses on the 11-point numeric scale.

For $L_{Aeq,1h}$ periods throughout the night-time (21.00-07.00) only the 5-point verbal scale was asked for each hourly period.

Table 20: Summary of scoring for ‘highly annoyed’ (reproduced from ISO 15666:2021)

Question format	Scoring ‘highly annoyed’	Outcome
11-point numeric scale	Values 8, 9, and 10	HA _N
5-point verbal scale	Values 4 and 5/‘very’ and ‘extremely’	HA _V
5-point verbal scale	Values 4 and 5/‘very’ and ‘extremely’ with ‘extremely’ counted in full, and ‘very’ weighted by a factor of 0.4	HA _{VW}

Studies vary in whether they use the 40% or the 28% cut-off to define HA. For example, the recent Federal Aviation Authority Neighborhood Environmental Survey (Miller et al., 2021) used 40% and this is also recommended by ICBEN (International Commission on Biological Effects of Noise (Fields et al., 1997). The systematic review undertaken by the WHO (Guski et al., 2017) identified papers using both cut-offs but the meta-analysis estimating the effect of aircraft noise on annoyance, which inform the guideline levels for aviation noise, was based on studies using the 28% cut-off. SoNA 2014 used a 28% cut-off (Civil Aviation Authority, 2021a).

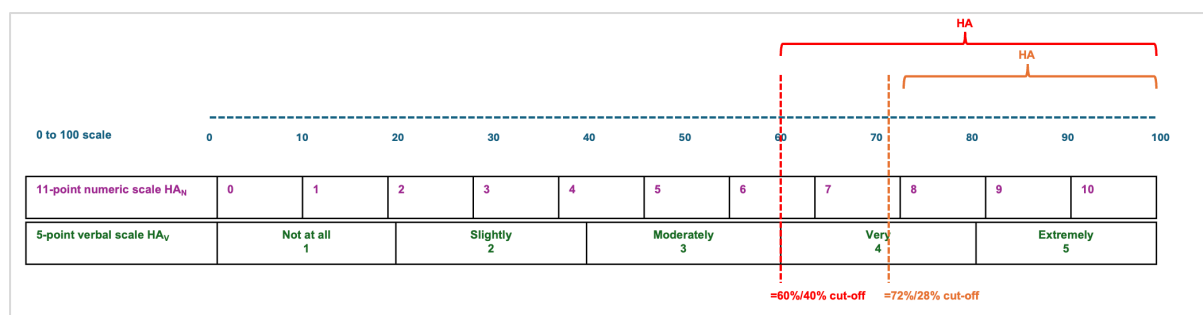
For the ANNE study, to examine a 28% cut-off, in the absence of the 11-point scale for the whole sample, HA_{VW} would have to be computed. However, to do this, it is necessary to make an assumption about where the 40% of those who scored ‘4 – very’ on the 5-point scale are distributed, as the cut-point of 28% falls within that category (see orange dotted line in Figure 3). Further, the assumptions made about how the scores are distributed within the ‘4 – very’ category influence the resulting relationship. Brink et al used statistical methods to simulate a cut-off of 28% for the 5-point verbal scale (Brink et al., 2021). For the ANNE study, we did similar, using a Monte Carlo approach to estimate a 28% cut-off for HA_{VW}. A Monte Carlo approach randomly picks 40% of the participants responding ‘very’ lots of times (e.g., 100 to 1000) to estimate the effect. The average estimate across the process is then used for the point estimate of the relationship between noise and HA. 1000 iterations were run to estimate the cut-off.

The Monte Carlo approach was chosen as it uses the available data, avoided having to make decisions about how to assign the 0.4 weighting across the sample, and was simple to understand.

A number of other approaches were considered. This included analysing the 11-point numeric data available for the sub-sample who completed the survey online. However, the existing weight for the data could not be applied to this sub-sample as it would be biased excluding and under-representing certain participants who would have completed the paper questionnaire (e.g., older, retired, homeowners, and white participants). For the same reason, a new weight could not be created for the sub-sample. Multiple imputation, a statistical procedure for handling missing data was also considered. This uses regression techniques and would employ covariates (e.g., NS-SEC, age, sex, ethnicity, attitudes, exposure level, 5-point verbal annoyance scale) to predict scores on the 11-point numeric scale. This creates estimates of the missing data over several datasets, and the imputed

data could then be analysed incorporating both the online survey and paper questionnaire data. However, multiple imputation requires data to be missing completely at random, meaning that the analyses remain likely still representative of the population. In our case, the data were systematically missing, which could bias the resulting analyses of any imputed datasets, so multiple imputation was also ruled out. There will of course, be other potential methods that could have been applied to the data.

Figure 3: Annoyance scales and cut-points (reproduced from (Brink et al., 2021))



The next section presents ERFs for the 5-point verbal scale only (HA_V). The text in the main report further describes the findings for the weighted 5-point verbal scale (HA_{VW}), with the ERFs for HA_{VW} shown in the Appendix (see Section 6.6).

Asking participants to rate annoyance for the 92-day ‘summer’ period in 2022 aligns with the 92-day timeframe for most of the noise metrics used in the analyses (e.g., $L_{Aeq,8h}$, $L_{Aeq,1h}$, N_{60} , Overflights). This alignment of the time-period for the noise metric and the annoyance question is recommended in ISO/TS15666. However, the annoyance questions do not align with the timeframe for L_{night} , which is an annual (12-month) metric reflecting exposure in January to December 2022. The timeframe difference for L_{night} also applies to the sleep disturbance questions (see Section 3.4) which ask about sleep disturbance during the 92-day period.

ISO/TS15666 requires that annoyance is not reported for participants who had not lived in their home for the time-period being asked about. We therefore excluded participants who reported living in their home for less than 6 months (unweighted $n=205$) as this would cover the 92-day summer period.

Table 21 shows that the distribution of the excluded sample by airport is similar to the distribution of the total sample by airport (see Table 3). As expected, the excluded participants were more likely to come from Heathrow and Manchester airports. Those excluded were drawn from across the range of exposure and were neither more likely to be exposed to high levels of aviation noise nor low levels of noise.

Table 21: Summary of excluded participants who had lived in their home for less than 6 months by a) airport and b) aircraft noise exposure ($L_{Aeq,8h}$)

Variable	Excluded participants (n=205)	
	N	%
(a) Airport		
BRS	4	2%
EMA	13	6%
GLA	5	2%
LHR	133	65%
LGW	6	3%
MAN	38	19%
STN	1	0.5%
LTN	5	2%
(b) Noise Exposure ($L_{Aeq,8h}$)		
<36dB	6	3%
36-<38dB	15	7%
38-<40dB	11	5%
40-<42dB	21	10%
42-<44dB	20	10%
44-<46dB	23	11%
46-<48dB	16	8%
48-<50dB	9	4%
50-<52dB	22	11%
52-<54dB	8	4%
54-<56dB	21	10%
56-<58dB	17	8%
58-<60dB	7	3%
>60dB	9	4%

b) Noise annoyance results

Participants were asked to indicate with a yes/no response which noise sources particularly bothered, disturbed, or annoyed them during the night (23.00-07.00). The noise sources were presented in a randomised order in the online survey, but this was not possible in the paper questionnaire. Whilst the question was not an ISO/TS15666 question, those who had lived in their homes for less than 6 months were excluded from the analysis, for consistency.

Table 22 shows that the top four noise sources mentioned were road traffic, aircraft, neighbours outside their homes, and neighbours inside their homes. Nearly one-third of the sample (30%) indicated that they were bothered, disturbed, or annoyed by road traffic; one quarter of the sample (24%) by aircraft/airports/airfield noise; nearly one-quarter (22%) by neighbours outside their homes; and one-seventh (14%) by neighbours inside their homes.

Table 22: Frequencies for being ‘bothered, disturbed or annoyed’ during the night-time period (23.00-07.00) for different environmental noise sources²²

Noise source	ANNE sample	
Q2	N	%
Road traffic	1212	30%
Aircraft/airports/airfields	973	24%
Neighbours (outside their homes)	894	22%
Neighbours (inside their homes)	543	14%
Building, construction, demolition, renovation, or road works	345	9%
Trains or railway stations	198	5%
Entertainment, leisure or sports facilities	128	3%
Animals	73	2%
Industrial sites	62	2%
Anti-Social Behaviour	40	1%
Crime, Drug dealers, Fly tipping etc.	34	0.9%
Fireworks	31	0.8%
Other	52	1%
Any noise annoyance	2839	68%

Table 22 shows how many of the sample reported that they were ‘bothered, disturbed or annoyed’ by environmental noise in the night-time period (23.00-07.00).

The rest of this section presents the ERFs for a range of night-time aviation noise exposure metrics and annoyance. Section 6.2 in the Appendix describes how these charts were created and how they should be interpreted.

The mean annoyance score was 1.79 (95%CI 1.76-1.83) for the 5-point verbal scale. This score indicates slight or some annoyance, given that the scale ranges from 1 to 5.

For annoyance as a binary outcome, the 5-point verbal scale (HA_V) indicated that one-tenth (9.7%) of the sample were highly annoyed by aircraft noise. In comparison, nearly one-twelfth (7.1%) of the sample reported being highly annoyed (HA_V) by road traffic noise, but it should be borne in mind that the sample were selected on aircraft noise exposure in the first instance, which may influence the findings for road traffic noise annoyance and limit comparability for annoyance ratings across the noise sources.

Table 23 shows how many of the sample reported that they were highly annoyed by aircraft noise for each hour of the night-time period (23.00-07.00) (HA_V), as well as the mean annoyance score (and confidence intervals for the estimate of the mean) for each hour.

Being highly annoyed varied over the night-time period. HA_V was highest in the hours 05.00-07.00, with one-twelfth of the sample reporting high annoyance (range 7-8%). Annoyance was also reported in the evening and first part of the night (21.00-00.00 – ~6%) and

²² This table excludes participants who lived in their home for less than 6 months (n=205).

remained at around 4% throughout the night-time period (00.00-04.00). Annoyance was reported in the hours outside of the traditional 8-hour night-time period of 23.00-07.00. Times of the night associated with the highest reports of being highly annoyed were up to midnight and from 05.00 onwards.

Table 23: Mean annoyance scores and percent highly annoyed (5-point verbal scale) for different environmental noise sources from 23.00-07.00²³

Noise source		ANNE sample								
	N	Not at all (n)	Slightly (n)	Moderately (n)	Very (n)	Extremely (n)	Mean	Lower 95% CI	Upper 95% CI	%HA _v
Road traffic (5-point) (q3)	3971	1856	1203	632	170	111	1.86	1.83	1.89	7.1%
Aircraft/airports/airfields (5-point) (q4)	3971	2243	847	497	228	156	1.79	1.76	1.83	9.7%
Aircraft/airports/airfields (5-point) (q6)										
21.00-22.00	3910	2445	839	377	145	103	1.63	1.59	1.66	6.4%
22.00-23.00	3872	2504	733	370	161	103	1.61	1.58	1.64	6.8%
23.00-00.00	3872	2752	593	300	132	95	1.51	1.48	1.54	5.9%
00.00-01.00	3869	3063	418	210	94	84	1.38	1.35	1.40	4.6%
01.00-02.00	3865	3207	335	170	92	60	1.31	1.28	1.33	4.0%
02.00-03.00	3874*	3252	334	144	83	60	1.29	1.26	1.31	3.7%
03.00-04.00	3868*	3245	327	145	81	69	1.29	1.27	1.32	3.9%
04.00-05.00	3884	3028	425	213	118	100	1.41	1.38	1.44	5.6%
05.00-06.00	3877	2729	560	296	146	146	1.56	1.53	1.59	7.5%
06.00-07.00	3875	2519	634	397	188	137	1.66	1.62	1.69	8.4%
07.00-08.00	3872	2445	713	423	171	120	1.66	1.63	1.69	7.5%

²³ Q3, Q4 and Q6 asked about annoyance during the summer period (June-September 2022). Participants completed the survey between October and December 2022. This table excludes participants who lived in their home for less than 6 months (n=205), and who may not have been living at their current address during the summer.

* There are no scheduled flights at Heathrow between 02.00-04.00, however, Heathrow participants were still asked about their experience of noise during these hours.

i. Exposure-response functions for mean annoyance

Figure 4 shows the mean annoyance scores for the 5-point verbal scale by aircraft noise exposure assessed using the $L_{Aeq,8h}$ metric. The Figure shows the observed data and the 95% confidence intervals (95%CI) (red data points and green CIs), as well as the regression line and the 95%CI for the regression line (blue line and grey shading). Statistically there were two linear sections on a log scale, with mean annoyance scores increasing with aircraft noise exposure ($L_{Aeq,8h}$). Mean scores increased from around 1 at <37dB $L_{Aeq,8h}$ to >2.5 at 51dB $L_{Aeq,8h}$ and above²⁴.

Figure 4: Plot of mean annoyance scores as a function of $L_{Aeq,8h}$ (92-day average summer night, dB) noise exposure (5-point verbal scale)

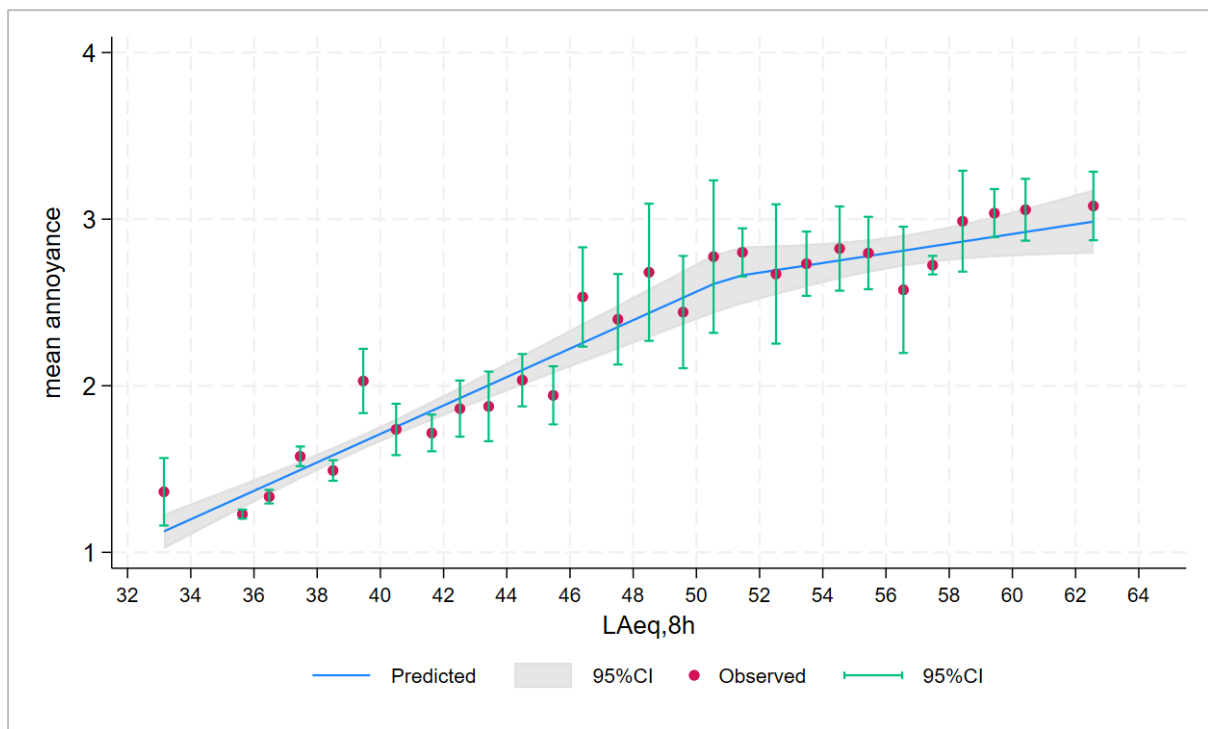


Figure 32 (see Section 6.4 in the Appendix) shows the mean annoyance score and 95% CI for the 5-point verbal scale for L_{night} ²⁵. The relationship was similar to that observed for $L_{Aeq,8h}$.

Table 24 shows the mean annoyance scores for the 5-point verbal scale for N60. Mean scores increased from ~2 for 5-<10 events and 10-<20 events, to over 2.5 for 20-<50 and ≥50 events. In terms of the annoyance observed for <1 event, having <1 event above 60dB

²⁴ Throughout the report, description in the text of the outcomes in terms of mean scores or a % for a certain noise exposure is based on the regression line rather than the data point.

²⁵ Please note that the survey asked participants to reflect on being 'bothered, disturbed or annoyed' by noise during the summer period (mid-June to mid-September 2022), whereas L_{night} is an annual measure of noise exposure in 2022.

$L_{A_{\text{max}}}$ does not preclude exposure to aircraft noise events below this level, which could be associated with an annoyance response.

Table 24: Mean annoyance by N60 noise exposure level

Mean sleep disturbance	N60					
	<1	1-<5	5-<10	10-<20	20-<50	≥50
N	79	552	280	468	1862	730
Mean	1.31	1.54	1.98	2.21	2.78	2.53
Standard error	0.09	0.06	0.11	0.17	0.06	0.12
Lower confidence interval	1.12	1.43	1.76	1.87	2.66	2.29
Upper confidence interval	1.49	1.66	2.20	2.54	2.90	2.76

Figure 5 and Figure 6 show the mean annoyance scores for each one-hour period of the night-time period ($L_{Aeq,1h}$) between 21.00 and 07.00 hours. In general, mean annoyance scores increased as aircraft noise exposure increased. However, there were differences in the steepness of the relationship across the night-time period. This means that there was variation across the one-hour periods, as indicated by lower noise thresholds for annoyance being reported and/or a stronger magnitude of relationship between increasing noise exposure and annoyance response.

The relationships for 21.00-22.00, 22.00-23.00 (evening hours) and 23.00-00.00 were similar with mean scores rising from 1 at exposures <40dB to between 2 and 3 at 51-52dB $L_{Aeq,1h}$ and above.

The relationships for 00.00-01.00, 01.00-02.00, 02.00-03.00 and 03.00-04.00 were flatter than those observed for the evening and early night-time period, indicating a lower range of mean annoyance scores ranging from 1 to 2 across the exposures.

For 04.00-05.00, the relationship was linear but the increase in mean scores flattened out at a lower exposure of 42dB. Exposures above 42dB were associated with mean scores of 2 and above, across the noise range 42->62dB.

The relationships for the morning hours (05.00-06.00, 06.00-07.00, and 07.00-08.00) were like those seen for the evening hours with mean scores rising from around 1 at <40dB to scores between 2 and 3 for the higher levels of exposure.

Table 25 to Table 28 show the mean annoyance scores for each overflight category. For overflights at 4,000ft and 7,000ft (for both the 48.5 degree and the 60 degree definitions), mean scores were above 2 for all groups. In general, the mean annoyance scores were similar for those experiencing <1, 1-<10, 10-<20, and ≥20 overflights per night. The wide confidence intervals for some estimates in these analyses are because of the low number of the ANNE sample exposed to these levels of overflights.

Figure 5: Plots of mean annoyance scores (hourly 5-point scale) as a function of $L_{Aeq,1h}$ periods from 21.00-03.00 (92-day average summer night, dB) noise exposure.

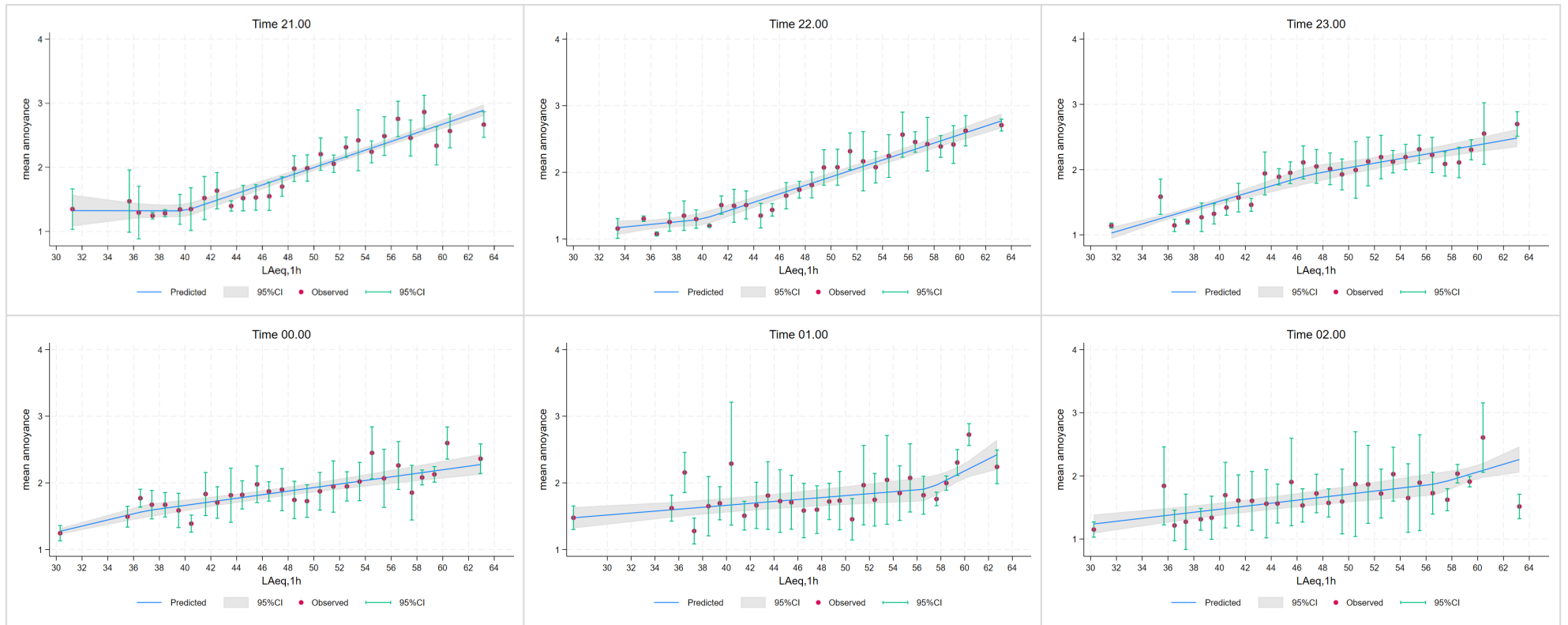


Figure 6: Plots of mean annoyance scores (hourly 5-point scale) as a function of $L_{Aeq,1h}$ periods from 03.00-08.00 (92-day average summer night, dB) noise exposure.

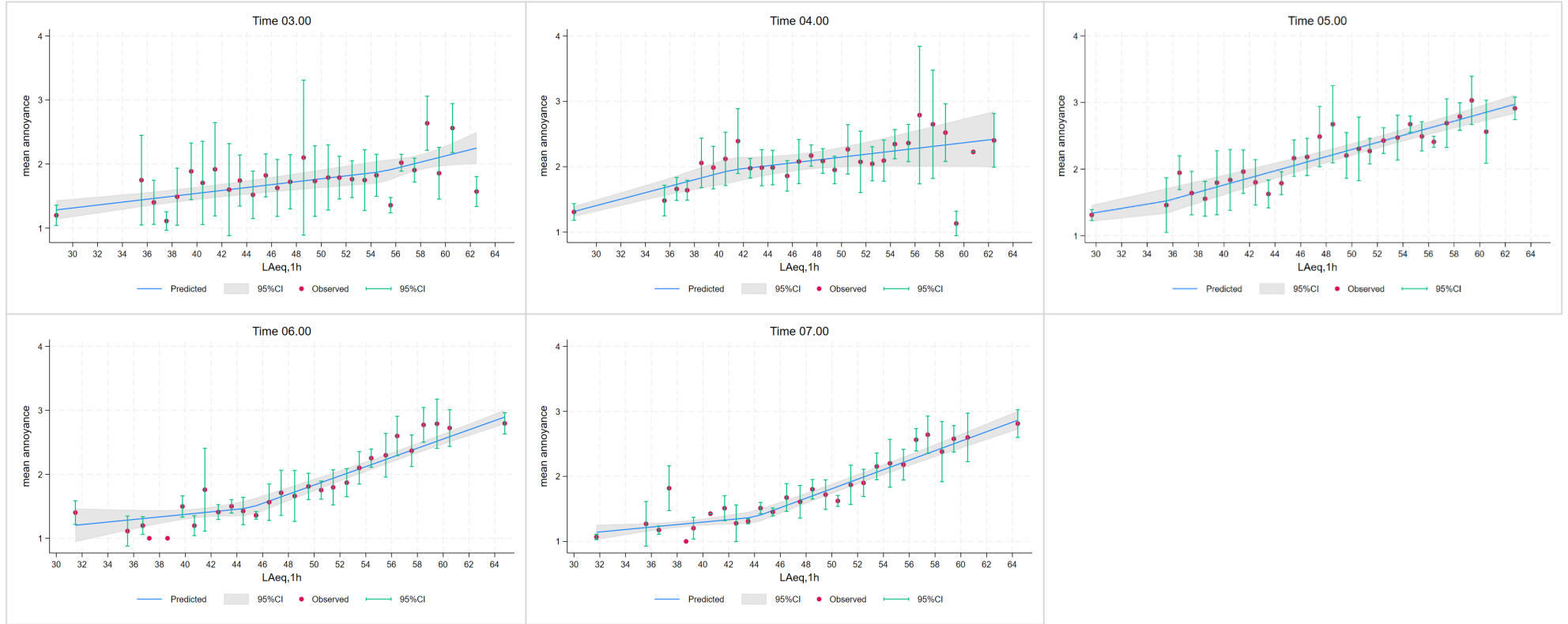


Table 25: Mean annoyance by overflights noise exposure (92 day, 4,000 ft., 60°)

Mean annoyance	Overflights (92 days, 4,000 ft., 60°)			
	<1	1-<10	10-<20	≥20
N	2264	835	608	264
Mean	2.23	2.62	2.70	2.60
Standard error	0.19	0.13	0.15	0.19
Lower confidence interval	1.86	2.36	2.41	2.22
Upper confidence interval	2.60	2.88	2.99	2.97

Table 26: Mean annoyance by overflights noise exposure (92 day, 4,000 ft., 48.5°)

Mean annoyance	Overflights (92 days, 4,000 ft., 48.5°)			
	<1	1-<10	10-<20	≥20
N	1577	982	976	436
Mean	2.05	2.58	2.75	2.56
Standard error	0.20	0.11	0.13	0.14
Lower confidence interval	1.65	2.36	2.49	2.28
Upper confidence interval	2.45	2.79	3.02	2.84

Table 27: Mean annoyance by overflights noise exposure (92 day, 7,000 ft., 60°)

Mean annoyance	Overflights (92 days, 7,000 ft., 60°)			
	<1	1-<10	10-<20	≥20
N	1682	1349	674	266
Mean	2.48	2.19	2.59	2.60
Standard error	0.08	0.27	0.16	0.19
Lower confidence interval	2.32	1.66	2.27	2.22
Upper confidence interval	2.64	2.73	2.92	2.97

Table 28: Mean annoyance by overflights noise exposure (92 day, 7,000 ft., 48.5°)

Mean annoyance	Overflights (92 days, 7,000 ft., 48.5°)			
	<1	1-<10	10-<20	≥20
N	998	1454	1065	455
Mean	2.38	2.21	2.67	2.52
Standard error	0.08	0.25	0.14	0.14
Lower confidence interval	2.21	1.70	2.38	2.24
Upper confidence interval	2.55	2.71	2.96	2.80

ii. Exposure-response functions for highly annoyed (HA)

Figure 7 shows HA (HA_V) by $L_{Aeq,8h}$. Annoyance was linearly associated with increasing aircraft noise exposure at night up to 47dB, with a further linear increase in annoyance above this noise level, bearing in mind that the study sampled up to 62dB. Very few participants reported being HA at the lowest exposure (<36dB $L_{Aeq,8h}$), with HA increasing to 10% for aircraft noise exposures of 43dB (see Table 65 in the Appendix for the proportions for Figure 7). The relationship increased sharply to 20% HA for exposure at 46dB, continuing to rise to over 30% HA for exposures >55dB. Accepting the inherent uncertainties in calculating noise exposures at lower levels, this data might support a LOAEL for high annoyance at 43B $L_{Aeq,8h}$.

Figure 7: Plot of highly annoyed (5-point scale) (HA_V) as a function of $L_{Aeq,8h}$ (92-day average summer night, dB) noise exposure

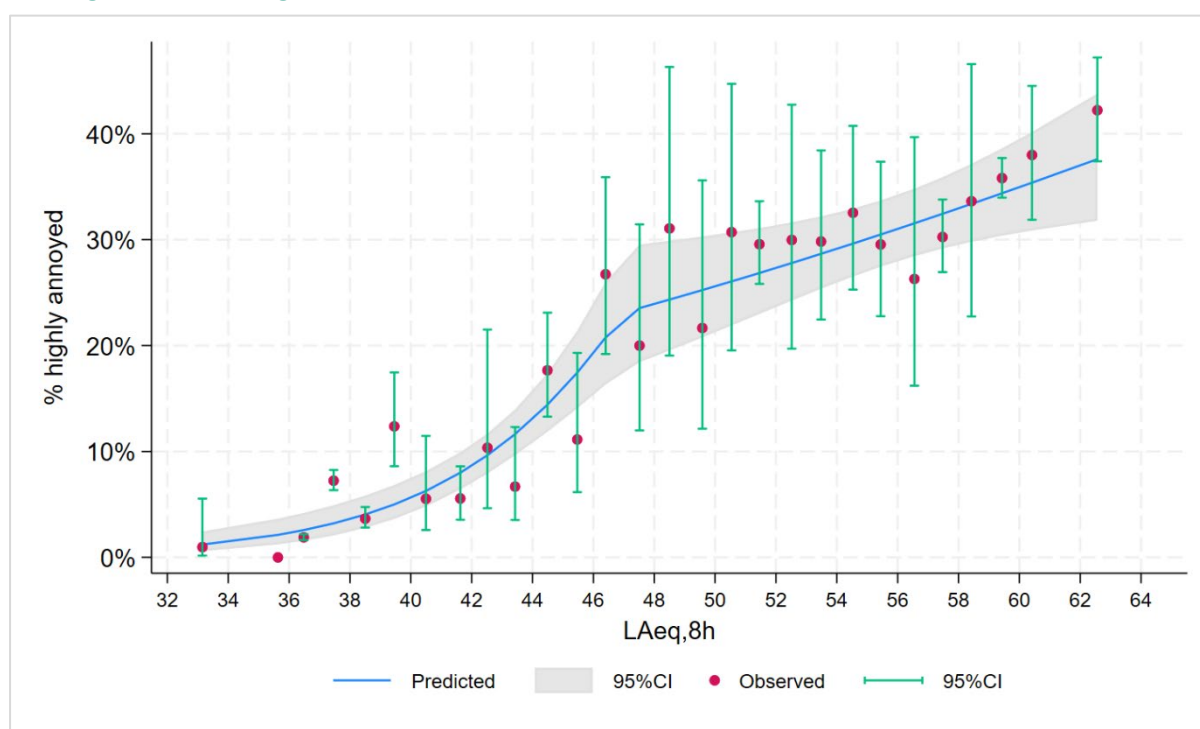


Figure 33 (see Section 6.4 in the Appendix) shows the relationships between HA and L_{night} for the 5-point verbal scale. The relationship observed for $L_{Aeq,8h}$ and L_{night} and HA_V were very similar. Annoyance was linearly associated with increasing aircraft noise exposure up to 47dB, with a shallower linear increase seen up to 62dB. Very few participants reported being HA at the lowest exposures ($<36dB L_{Aeq,8h}$), with HA increasing to 10% at 42dB. The relationship increased sharply to 20% HA at 46dB, continuing to rise to over 30% HA for exposures $>53dB$. Accepting the inherent uncertainties in calculating noise exposures at lower levels, this data might support a LOAEL for high annoyance at 42dB L_{night} .

Figure 37 (Section 6.6 in the Appendix) shows a similar relationship for the weighted 5-point verbal scale (HA_{VW}), indicating slightly lower levels of HA, as would be expected given the different cut-off for the annoyance question. HA_{VW} estimates that 10% HA is at 45dB $L_{Aeq,8h}$, compared with 43dB $L_{Aeq,8h}$ for HA_V .

Table 29 shows the proportion HA (HA_V) by N60. Annoyance increased with the number of aircraft noise events equal to or above 60dB. Less than one event was associated with 0% HA, rising to 5% for < 1 - <5 events, 11% for 5- <10 events, 17% for 10- <20 events, 32% for 20- <50 events and 23% for ≥ 50 events. This drop in HA for the highest exposure could reflect the increasing likelihood of noise insulation in the homes of those exposed above these levels or increasing likelihood of reliance on the airport in some way, e.g., for employment and economic reasons but this needs further exploration. However, the difference at the higher levels of exposure should not be thought considerable, as they are only a few percentage points and the confidence intervals overlap. Policy could additionally consider thresholds informed by N60. The same time-average exposure can be arrived at from wide variation in terms of the number and types of movements due to differences in the fleet (e.g. the noise footprint of A320 versus A380). N60 combines information about single event noise levels with number of movements, offering the potential to additionally inform policy beyond the usual time-averaged metrics. These data suggest that a LOAEL value might be identified at 5- <10 events as this is where HA is $\sim 10\%$.

Table 29: Proportion of highly annoyed by N60 noise exposure level

Highly annoyed	N60					
	<1	1-<5	5-<10	10-<20	20-<50	≥ 50
%	0.00%	5.16%	11.01%	17.31%	32.05%	23.18%
95% confidence intervals	0.00%	3.37-7.83%	7.34-16.18%	10.91-26.34%	29.02-35.23%	17.54-29.97%
N*	79	552	280	468	1862	730

*Total number of participants for each N60 category

Figure 8 and Figure 9 show the relationship between HA_V and $L_{Aeq,1h}$ for each hour between 21.00 and 07.00. The relationships varied across the one-hour periods of the night-time and were characterised by one or two linear relationships. The aircraft noise exposure associated with 10% HA moves considerably across the night-time period. To enable comparison across the night-time period, Figure 10 shows the same relationships (the regression estimates) for each hour summarised on the same plot for the hours 21.00-00.00, 00.00-04.00, and 04.00-08.00.

At 21.00-22.00 hours annoyance rose linearly from around 0% at <40dB to 10% at 49dB, 20% at 57dB and 30% at 62dB. A similar relationship was seen for 22.00-23.00 hours, albeit with slightly lower levels of HA at >60dB. At 23.00-00.00, 00.00-01.00, and 01.00-02.00 hours 10% HA was found at much lower exposure levels (43dB, respectively). At 03.00-04.00, 04.00-05.00, and 05.00-06.00 10% HA was seen at lower noise exposure levels (40dB, 36dB, and 40dB, respectively), noting the lower power in the data to examine effects given the wide-confidence intervals for some of the estimates (low number of participants with exposures in these categories between 03.00-04.00). The lowest threshold for 10% HA was at 04.00-05.00 at 36dB. At 06.00-07.00 and 07.00-08.00 the aircraft noise exposure level for 10% HSD was much higher at 50dB and 51dB, respectively. These data suggest that populations may be particularly vulnerable to the effects of aviation noise between 04.00-05.00 hours.

These patterns suggest that HA is observed at lower levels of noise exposure in the night-time than in the evening or morning hours. However, high levels of annoyance were observed across the hours of the night-time. Aircraft noise in the evening hours 21.00-23.00 was associated with high levels of annoyance, representing time-periods that are not included in the traditional night-time period of 23.00-07.00. Overall, these analyses suggest that policy should consider effects at different times of the evening and night and outside the traditional 8-hour night-time period.

Comparing the relationships of HA_V with $L_{Aeq,8h}$ versus $L_{Aeq,1hr}$ (Figure 7, Figure 8 and Figure 9) there is variability. Most of the ERFs for the one-hour periods look different compared with the 8-hour period, suggesting that annoyance levels are higher at lower exposure levels than suggested by the 8-hour exposure ERF. This would have implications for policy, as for example, there is variation across the night-time period in the exposure level at which 10% of the sample are HA.

Figure 8: Plot of highly annoyed (hourly 5-point scale) as a function of $L_{Aeq,1h}$ from periods from 21.00-03.00 (92-day average summer night, dB) noise exposure.

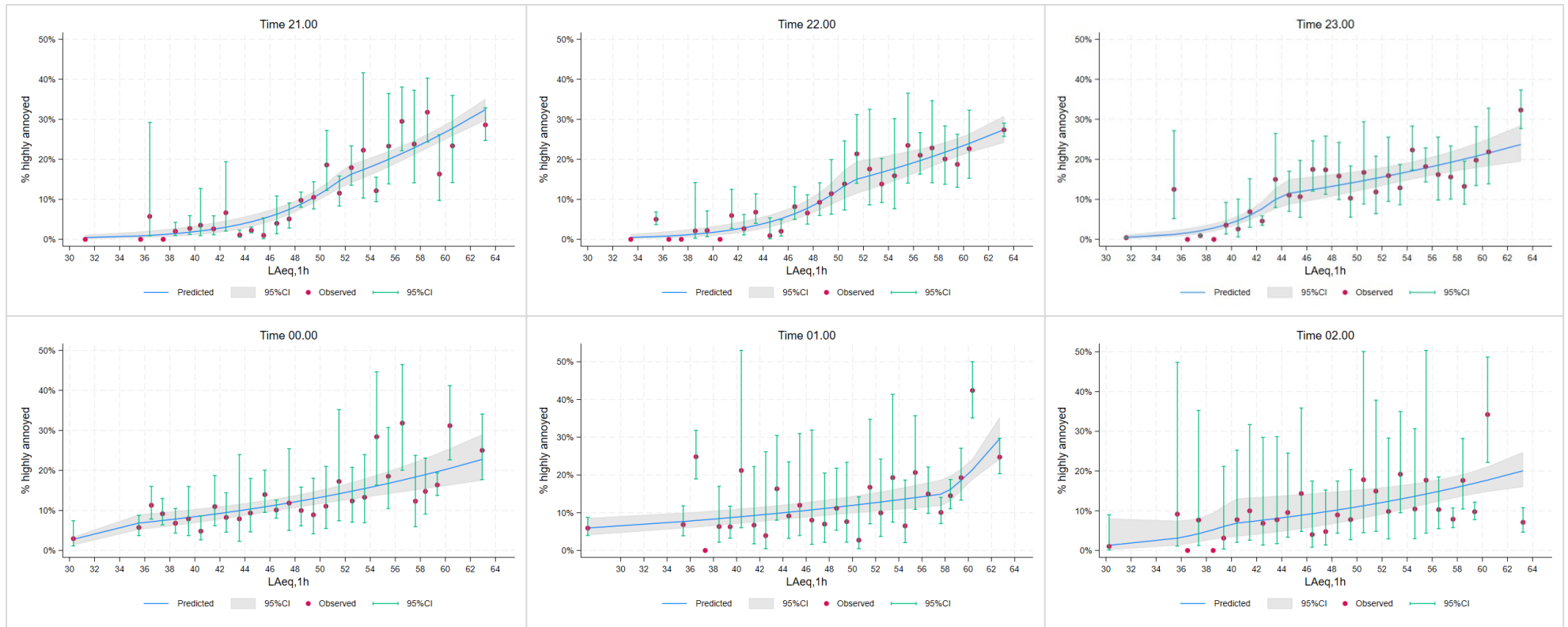


Figure 9: Plot of highly annoyed (hourly 5-point scale) as a function of $L_{Aeq,1h}$ from periods from 03.00-08.00 (92-day average summer night, dB) noise exposure.

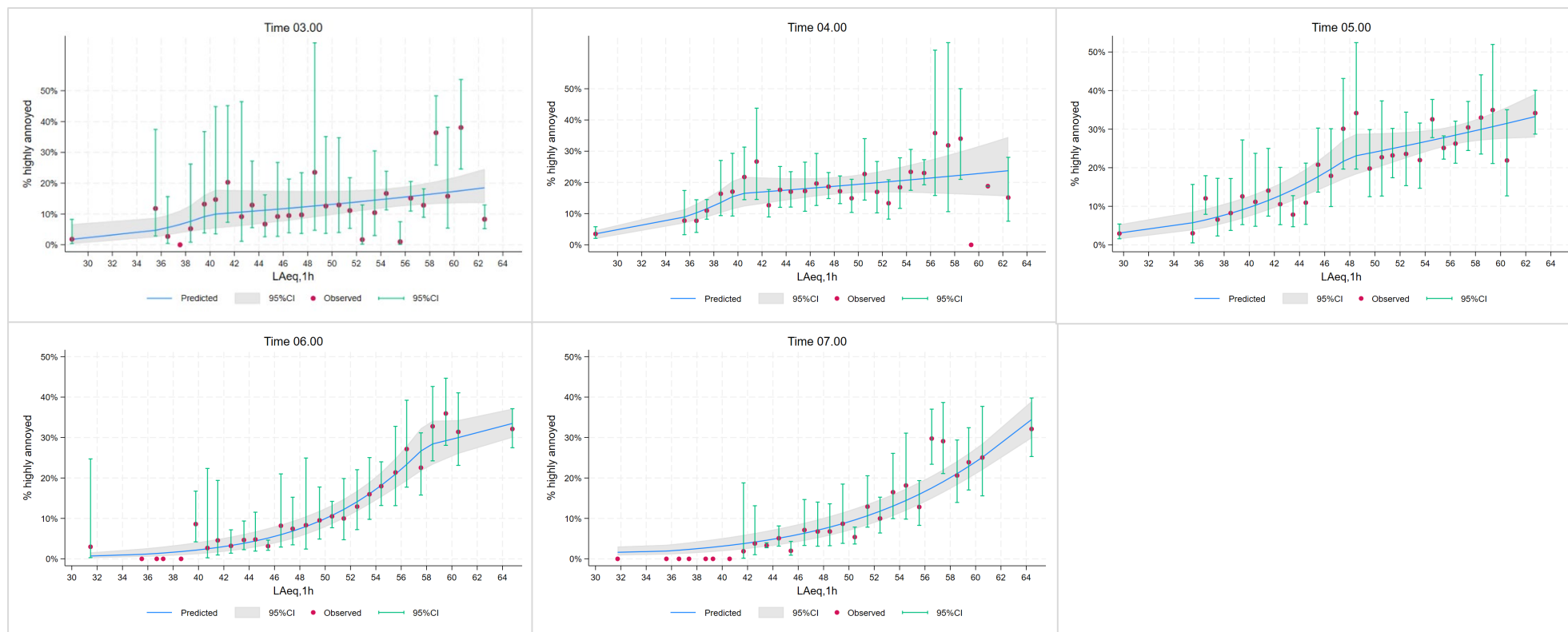


Figure 10: Plot of highly annoyed (hourly 5-point scale) as a function of $L_{Aeq,1h}$, dB, from periods from (a) 21.00-00.00, (b) 00.00-04.00, (c) 04.00-08.00.

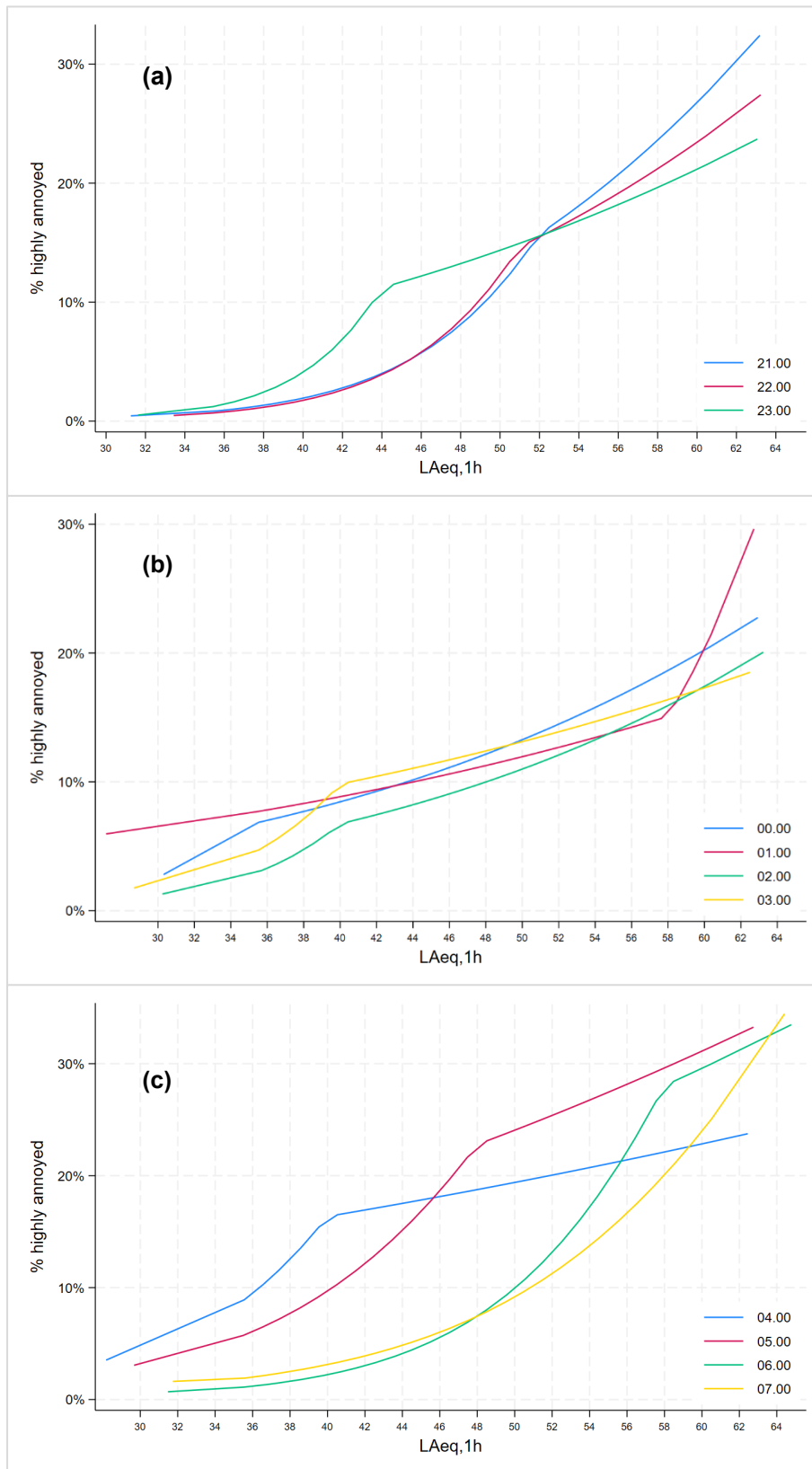


Table 30 to Table 33 show the proportion HA in relation to overflights. For overflights at 4,000ft (for both the 48.5 degree and the 60 degree definitions), <1 overflight was associated with over 10% HA (18% and 13%, respectively), and increased to 25-33% for those experiencing a greater number of overflights. For overflights at 7,000ft (for both the 48.5 degree and the 60 degree definitions), HA was reported across all the overflight groups, ranging from around 18-31%.

Table 30: Proportion of highly annoyed by overflights noise exposure (92 day, 4,000 ft., 60°)

Highly annoyed	Overflights (92 days, 4,000 ft., 60°)			
	<1	1-<10	10-<20	≥20
%	18.24%	28.00%	31.29%	26.17%
95% confidence intervals	11.89-26.95%	21.53-35.53%	24.49-39.01%	17.28-37.57%
N*	2264	835	608	264

*Total number of participants for each overflight category

Table 31: Proportion of highly annoyed by overflights noise exposure (92 day, 4,000 ft., 48.5°)

Highly annoyed	Overflights (92 days, 4,000 ft., 48.5°)			
	<1	1-<10	10-<20	≥20
%	13.78%	25.65%	33.31%	25.65%
95% confidence intervals	8.01-22.69%	20.55-31.51%	27.13-40.12%	18.19-34.86%
N*	1577	982	976	436

*Total number of participants for each overflight category

Table 32: Proportion of highly annoyed by overflights noise exposure (92 day, 7,000 ft., 60°)

Highly annoyed	Overflights (92 days, 7,000 ft., 60°)			
	<1	1-<10	10-<20	≥20
%	23.02%	18.93%	29.72%	26.33%
95% confidence intervals	19.00-27.62%	9.88-33.21%	21.33-37.43%	17.40-37.76%
N*	1682	1349	674	266

*Total number of participants for each overflight category

Table 33: Proportion of highly annoyed by overflights noise exposure (92 day, 7,000 ft., 48.5°)

Highly annoyed	Overflights (92 days, 7,000 ft., 48.5°)			
	<1	1-<10	10-<20	≥20
%	19.52%	18.39%	31.11%	24.81%
95% confidence intervals	15.18-24.75%	10.26-30.76%	24.00-38.72%	17.67-33.64%
N*	998	1454	1065	455

*Total number of participants for each overflight category

c) Summary of ANNE Survey – Annoyance

The ANNE study examined the relationship between several aviation night noise metrics and annoyance. All of the metrics examined ($L_{Aeq,8h}$, L_{night} , $L_{Aeq,1h}$) showed associations with annoyance. N60, and overflights at 4,000ft and 7,000ft were also associated with considerable proportions reporting annoyance.

A threshold of 10% of the population being ‘highly annoyed’ informed the WHO Environmental Noise Guidelines 2018 (World Health Organization, 2018), with 45dB L_{den} being the exposure level for aviation noise at which 10% of the population were HA. In the ANNE study, the exposure level at which 10% reported being HA varied throughout the night-time, acknowledging that the WHO used a metric for day-evening-night, and the ANNE study focuses on night-time exposure.

For time-averaged exposure over the 8-hour night-time period ($L_{Aeq,8h}$), very few participants reported being HA at the lowest exposure (<36dB $L_{Aeq,8h}$). 10% of the sample were ‘highly annoyed’ at 43dB $L_{Aeq,8h}$, with annoyance increasing to 20% HA at 46dB, and continuing to rise to over 30% HA for exposures >55dB $L_{Aeq,8h}$. Other night-noise metrics also showed similar patterns, for example, 10% of the sample reported being HA for 5-<10 events for N60. Any overflight (4,000ft & 7,000ft) was associated with greater than 10% HA. These data suggest that annoyance from aviation night-noise is having an impact on the health of populations living near airports exposed to night-flights, with effects beginning at fairly low levels of exposure.

The steep rise in HA from 10% at 43dB $L_{Aeq,8h}$, to 20% at 46dB $L_{Aeq,8h}$ should be noted, as a 3dB increase in exposure is associated with a doubling in the %HA. This may indicate an important threshold or sensitivity in response within the population.

This study cannot, and should not be used, to speculate on what the relationship between aviation night-noise and annoyance would look like for levels greater than 62dB, as these levels were not examined in the ANNE study and are rarely seen in the UK context.

This is the first study, to our knowledge, to examine annoyance responses for one-hour time periods of the night-time. High levels of annoyance were observed across the night-time period. Table 34 shows that the lowest aviation noise exposure thresholds for 10% HA were

found for the hours 03.00-04.00, 04.00-05.00 and 05.00-06.00, where very low levels of exposure were associated with annoyance. These data suggest that the population is particularly vulnerable to annoyance from any aviation activity during this time-period.

The analyses also showed annoyance responses outside the traditional 23.00-07.00 hour night-time period. This has relevance for how policy can protect public health during the evening and morning hours. There needs to be consideration of how noise policy can incorporate these effects.

The different thresholds for 10% HA when comparing the time-average metrics for the night-time period ($L_{Aeq,8h}$ and L_{night}) with the one-hour metrics ($L_{Aeq,1h}$) raises the question as to whether policy setting based on the time-averaged metrics for the night-time period of 8-hours would adequately account for the annoyance effects observed at different times of the night-time? As previously noted, most relationships for the one-hour periods look different to that for the 8-hour period, and for some one-hour periods annoyance levels are higher at lower exposure levels than suggested by the 8-hour exposure ERF. The analyses suggest that consideration should be given to effects at different times of the night, as well as for thresholds informed by N60.

In terms of setting a LOAEL value for exposure, questions arise about the threshold for the LOAEL, as well as for which metrics LOAEL values should or could be set. The ANNE study was designed to examine effects down to very low levels of exposure, to examine where effects might begin, informing the identification of LOAEL values defined by 10%HA. For $L_{Aeq,8h}$ this was at 43dB and for N60 this was at 5-<10 events. For overflights at 4,000ft and 7,000ft, any overflight event was associated with over 10% being HA. This suggests that overflights do not have adequate sensitivity to account for all aspects of aviation noise exposure, to inform a LOAEL value. This is not to deny that they are associated with annoyance, just that the measure lacks granularity for examining health effects.

If LOAEL values were set for each hour of the night-time, analyses suggest, based on 10% being highly annoyed, that the values would be around 49dB $L_{Aeq,1h}$ between 21.00-23.00; 43dB $L_{Aeq,1h}$ between 23.00-02.00, 48dB $L_{Aeq,1h}$ between 02.00-03.00, 36-40dB $L_{Aeq,1h}$ between 03.00-06.00; and 50-51dB $L_{Aeq,1h}$ between 06.00-08.00.

These proposed LOAEL levels would be slightly lower in some instances than those currently set by UK policy (Department for Transport, October 2017), which is 45dB $L_{Aeq,8h}$, and similar or slightly lower than the WHO Environmental Noise Guidelines for the European Region (World Health Organization, 2018), which set a value of 40dB L_{night} for aircraft noise.

SOAEL values can, and are expected to, vary across different contexts, noise sources and receptors. The Noise Policy Statement for England sets out that “It is not possible to have a single objective noise-based measure that defines SOAEL that is applicable to all sources of noise in all situations. Consequently, the SOAEL is likely to be different for different noise sources, for different receptors and at different times.” (Department for Environment Food and Rural Affairs, 2010). As previously described, there has been little discussion, either academically or practically, about how SOAEL values can be identified. To date, many UK aviation schemes have used the WHO Night Noise Guidelines interim value of 55dB L_{night} to inform a night-time SOAEL value of 55dB $L_{Aeq,8h}$ (World Health Organization, 2009).

However, a threshold lower than 55dB L_{night} could be considered, given the extent of annoyance reported in the ANNE study at levels of exposure below 55dB L_{night} .

Table 34: Summary for each noise metric for the exposure level at which it was predicted that 10% were highly annoyed (HA_V) and highly sleep disturbed (based on the regression line).

Noise metric	Level at which 10% HA (HA_V) (based on regression line)
$L_{Aeq,8h}$	43dB
L_{night}	42dB
N60	5-<10 events
Overflights (4,000ft)	<1 overflight
Overflights (7,000ft)	<1 overflight
$L_{Aeq,1h}$ 21.00-22.00	49dB
$L_{Aeq,1h}$ 22.00-23.00	49dB
$L_{Aeq,1h}$ 23.00-00.00	43dB
$L_{Aeq,1h}$ 00.00-01.00	43dB
$L_{Aeq,1h}$ 01.00-02.00	43dB
$L_{Aeq,1h}$ 02.00-03.00	48dB
$L_{Aeq,1h}$ 03.00-04.00	40dB
$L_{Aeq,1h}$ 04.00-05.00	36dB
$L_{Aeq,1h}$ 05.00-06.00	40dB
$L_{Aeq,1h}$ 06.00-07.00	50dB
$L_{Aeq,1h}$ 07.00-08.00	51dB

The study was designed and planned to analyse both the 5-point verbal and the 11-point numeric scale. Unfortunately, an error in formatting of the paper questionnaire meant that the 11-point numeric scale was not compliant with ISO/TS 15666 and was, therefore, not analysed. We have presented analyses showing both versions of scoring for the 5-point verbal scale; HA_V which defines the top 40% of the scale as being 'highly annoyed' and HA_{VW} which defines the top 28% of the scale as being 'highly annoyed'. The latter is designed to be comparable to the 11-point numeric scale. HA_{VW} estimated that 10% HA was at 45dB $L_{Aeq,8h}$, compared with 43dB $L_{Aeq,8h}$ for HA_V . As would be expected, given the higher % defining 'highly annoyed' HA_V reports slightly higher rates of annoyance in the population than HA_{VW} .

3.4 Subjective sleep disturbance

Table 35 describes the self-reported (subjective) sleep quality and sleep-related behaviours for the ANNE sample. Over half (57%) of the sample described their sleep quality as very good or fairly good and one-fifth (21%) described their sleep quality as fairly bad or very bad. Just under one-fifth (17%) had taken medication to help them sleep in the past month. Medical sleep-related disorders were low, with 3% reporting a diagnosis of insomnia and 2% a diagnosis of sleep apnoea. One-sixth of the sample (15%) reported hypertension/high blood pressure; 5% reported diabetes.

In general, national estimates of sleep quality and sleep medication use are comparable with levels reported in the ANNE study; 22% of adults described their sleep as fairly or very bad (21% in the ANNE Study) and 16% reported using sleep medication in the past month (17% in ANNE study) (Tang et al., 2017). Nationally it is estimated that 4% of men and 2% of women have a diagnosis for sleep apnoea, which is similar to the levels reported by the ANNE sample (3%) (Steier et al., 2014). The prevalence of insomnia was similar to national data, which estimates that 3-6% of the population have a diagnosis of insomnia (Calem et al., 2012). The prevalence of hypertension in the ANNE study was lower (15%) than nationally reported estimates (28%), however, the national data are based on blood pressure measurement and medication use rather than self-report, which might account for some of the differences (British Heart Foundation, 2023). The prevalence of doctor diagnosed diabetes has been estimated at 7% for the UK (NHS England, 2019), which is similar to the levels reported in the ANNE study (5%).

Across the sample the average time reported to fall asleep was 20 minutes, with an average sleep duration of 6.7 hours and two recalled awakenings per night.

Few participants slept in a room with non-openable windows. Three-quarters of the sample slept in a room with openable double-glazed windows (75%). Fewer participants had openable triple glazed windows (2%), openable secondary glazed windows (6%) or openable acoustically glazed windows (<1%). In warmer seasons over three-quarters of the sample slept with the windows partially or completely open (78%). In colder seasons, three-quarters of the sample (73%) slept with the windows closed. Just over one-quarter of the sample reported that aircraft noise interfered with sleeping with their window open (28%). One-eighth of the sample reported that aircraft noise interfered with the time they went to bed or the time that they got up (13%).

Table 35: Frequencies for sleep variables

Noise source	ANNE sample	
	N	%
During the past month or so, how would you rate your sleep quality overall? (q8)		
Very good	571	14%
Fairly good	1801	43%
Neither good nor bad	956	23%
Fairly bad	698	17%
Very bad	153	4%
Missing	5	0.1%

Noise source	ANNE sample	
Mean (SD)	2.54 (1.04)	
Median (IQR)	2 (2-3)	
During the past month, how often have you taken medicine (prescribed or “over the counter”) to help you sleep? (q9)		
Not during the past month	3485	83%
Less than once a week	279	7%
Once or twice a week	179	4%
Three or more times a week	227	5%
Missing	14	0.3%
Have you ever been diagnosed by a health professional with any of the following sleep disorders? (q10) (tick all that apply)		
Sleep apnoea	76	2%
Narcolepsy	2	0.04%
Restless leg syndrome	75	2%
Period limb movement syndrome	6	0.2%
Insomnia	139	3%
Is there someone living in your home that frequently requires your care during the night? (q12)²⁶		
Yes	366	9%
No	3808	91%
Missing	9	0.2%
Have you ever been diagnosed by a health professional with any of the following conditions? (q11) (tick all that apply)		
Hypertension / high blood pressure	631	15%
Arrhythmia/irregular heartbeat	137	3%
Heart disease	85	2%
Diabetes	215	5%
Cancer	208	5%
During the past month, how long has it usually taken you to fall asleep each night? (minutes) (q13)		
Median (IQR)	20 (10-40)	
Range	0-540 ²⁷	
During the past month, how many hours of actual sleep did you get a night (hours) (q14)		
Mean (sd)	6.7 (1.28)	
Range	0-24	
During the past month, how often did you wake up during the night? (q15)		
Median (IQR)	2 (1-3)	
Range	0-99	

²⁶ This item was included in the survey because it is a screening question for participation in the next phase of the study.

²⁷ This data is presented as reported by the sample; no outliers have been removed from the dataset.

Noise source	ANNE sample	
In warmer seasons do you usually sleep with the windows...(q16)		
Closed	886	21%
Partially open	2508	60%
Completely open	771	18%
Sleep in room with no windows	14	0.3%
Missing	4	0.1%
In colder seasons do you usually sleep with the windows...(q17)		
Closed	3036	73%
Partially open	1074	26%
Completely open	51	1%
Sleep in room with no windows	15	0.4%
Missing	7	0.2%
What kinds of windows do you have in the room where you sleep? (q18)		
Openable		
Single glazed	532	13%
Secondary glazed	237	6%
Double glazed	3128	75%
Triple glazed	68	2%
Acoustic Glazed	20	0.5%
Don't know glazing	199	5%
Non-openable		
Single glazed	13	0.3%
Secondary glazed	7	0.2%
Double glazed	22	0.5%
Triple glazed	1	0.02%
Acoustic Glazed	0	0%
Don't know glazing	7	0.2%
Sleep in room with no windows	10	0.2%
Does noise from aircraft, airfields or airports interfere with your sleeping patterns such as the time you go to bed or the time you get up? (q21)		
Yes	524	13%
No	3655	87%
Missing	5	0.1%
Does noise from aircraft, airfields or airports interfere with sleeping with your windows open? (q22)		
Yes	1151	28%
No	3017	72%
Sleep in room with no windows	9	0.2%
Missing	6	0.1%

Sleep disturbance was assessed by a question which has been applied in international studies (Smith et al., 2022). Following the format of the 5-point annoyance verbal scale, the question asks 'Thinking about this summer, when you were here at home, how much does noise from aircraft, airports or airfields disturb your sleep during the night (11pm to 7am)?', with responses rated on a 5-point verbal scale 'not at all (1)', 'slightly (2)', 'moderately (3)', 'very (4)', 'extremely (5)'. The 'percentage highly sleep disturbed' (HSD) is defined by indicating 'very' or 'extremely' as opposed to 'not at all', 'slightly' and 'moderately'. This matches the 40% cut-point used for HA_v. Following the approach taken for annoyance, we excluded participants who had lived in their home for less than 6 months from the analyses of sleep disturbance outcomes.

Table 36 shows the mean sleep disturbance score and HSD for the sample. The mean sleep disturbance score was 1.68 (95%CI 1.62-1.71), indicating slight sleep disturbance. HSD was reported by 7.7%.

Table 36 also shows the mean sleep disturbance score and the HSD for each hour of the night-time period (21.00-07.00). HSD was highest in the later hours of the night (05.00-07.00), with 7% of the sample reporting high sleep disturbance (range 7.2-7.5%). However, HSD was also reported in the evening and early hours of the night with 4 to 6% of the sample reporting HSD. HSD remained at ~3% throughout the night-time period (01.00-04.00). Overall, these data show that sleep disturbance was reported in the hours outside of the traditional 8-hour night-time period of 23.00-07.00. Times of the night associated with the highest reports of being sleep disturbed were up to 01.00 and from 04.00 onwards. This could reflect the effect of noise on times when people are trying to get to sleep in the early night-time, and when it is more difficult to fall back to sleep if woken, in the later hours of the night-time. This may also reflect the fewer flights, and therefore lower exposure for some participants between the hours of 01.00-04.00. Compared with the same analyses for HA, the HSD show similar temporal patterns.

Table 36: Mean sleep disturbance scores for different environmental noise sources 23.00-07.00²⁸

Noise source	ANNE sample										
	N	Not at all (n)	Slightly (n)	Moderately (n)	Very (n)	Extremely (n)	Do not usually sleep at this time (n)	Mean ²⁹	Lower 95% CI	Upper 95% CI	%HSD ³⁰
Aircraft/airports/airfields (5-point) (q19)	3971	2404	883	377	178	128		1.68	1.62	1.71	7.7%
Aircraft/airports/airfields (5-point) (q20)											
21.00-22.00	3857	2549	643	271	76	86	225	1.48	1.45	1.51	4.1%
22.00-23.00	3826	2621	591	263	119	105	121	1.51	1.48	1.54	5.7%
23.00-00.00	3823	2751	577	236	120	104	34	1.48	1.45	1.51	5.7%
00.00-01.00	3818	3025	426	183	90	88	7	1.37	1.34	1.40	4.5%
01.00-02.00	3805	3172	317	164	73	58	18	1.28	1.27	1.31	3.4%
02.00-03.00	3813	3217	293	166	61	64	11	1.28	1.26	1.30	3.2%
03.00-04.00	3811	3185	305	165	74	68	9	1.30	1.27	1.32	3.6%
04.00-05.00	3831	2986	418	216	98	101	10	1.41	1.38	1.43	5.1%
05.00-06.00	3844	2742	544	262	131	153	10	1.54	1.51	1.57	7.2%
06.00-07.00	3850	2566	598	352	157	139	38	1.61	1.57	1.64	7.5%
07.00-08.00	3827	2555	590	320	118	111	130	1.55	1.52	1.58	5.8%

²⁸ This table excludes participants who lived in their home for less than 6 months (n=205).

²⁹ Means have been calculated based on responses 1 (not at all) to 5 (extremely). Participants responding “do not usually sleep at this time” have been excluded.

³⁰ Q19 (first row of data) covers the full 8-hour period and did not include the response option “do not usually sleep at this time” as it is based on the ISO/TS 15666 format for the annoyance questions. For the hourly time-periods (q20), participants responding “do not usually sleep at this time” have been excluded from the means and % highly sleep disturbed.

i. Exposure-response functions for mean sleep disturbance

Figure 11 shows mean sleep disturbance scores by aircraft noise exposure assessed using the $L_{Aeq,8h}$ metric. The Figure shows the observed data and the 95% confidence intervals (95%CI) (red data points and green CIs), as well as the regression line and its 95%CI plotted (blue line and grey shading). Statistically two linear relationships were found. Sleep disturbance was linearly associated with increasing aircraft noise exposure ($L_{Aeq,8h}$) up to 50dB, followed by a flatter line above this level, bearing in mind the study sampled up to ~62dB. Mean sleep disturbance scores rose from just above 1 for >36dB up to above 2 at 46dB. Exposures >50dB were associated with scores ~2.5.

Figure 34 (Section 6.3 in the Appendix) shows a similar pattern of results for mean sleep disturbance scores and the L_{night} aircraft noise exposure metric.

Figure 11: Plot of mean sleep disturbance scores as a function of $L_{Aeq,8h}$ (92-day average summer night, dB) noise exposure.

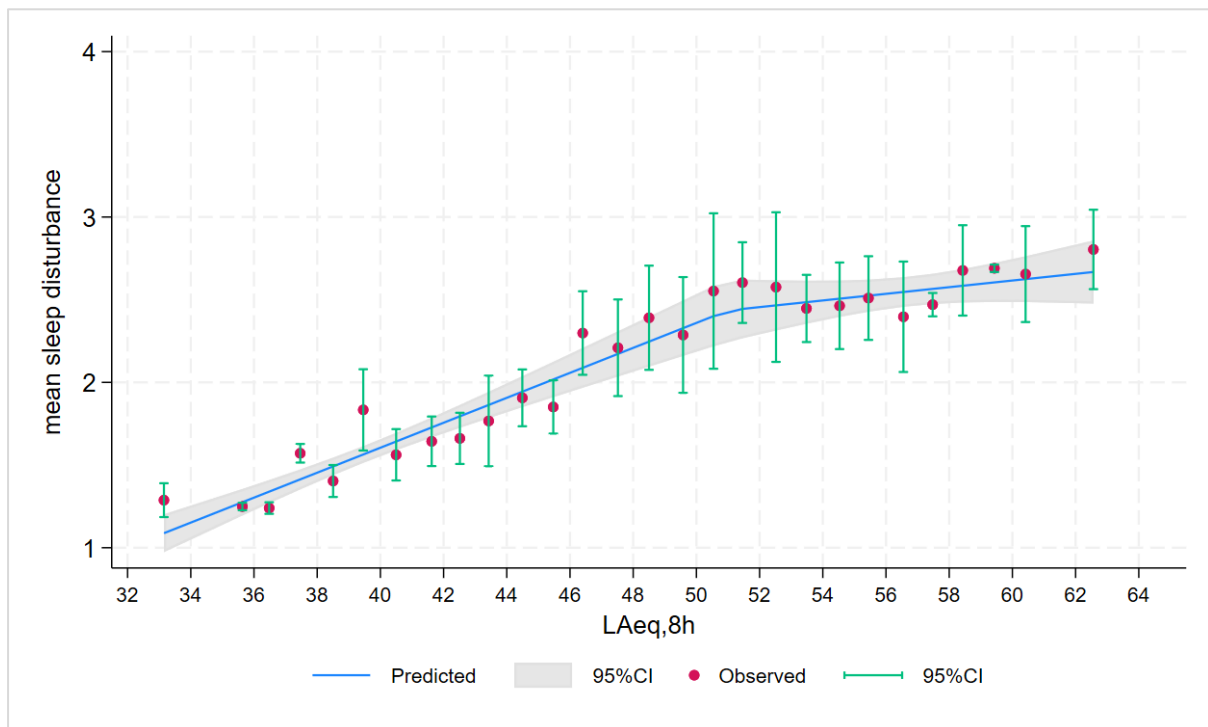


Table 37 shows the mean sleep disturbance score by N60 exposure. Mean sleep disturbance increased with increasing number of events equal to or above 60dB. Mean scores increased from just above 1 at <1 event, to above 2 for 10-<20, 20-<50 events, and ≥50. 20-<50 events per night had a similar effect on mean sleep disturbance scores as ≥50 events.

Table 37: Mean sleep disturbance by N60 noise exposure level

Mean sleep disturbance	N60					
	<1	1-<5	5-<10	10-<20	20-<50	≥50
N	79	552	283	469	1858	730
Mean	1.24	1.46	1.80	2.05	2.55	2.27
Standard error	0.06	0.05	0.07	0.15	0.05	0.11
Lower confidence interval	1.13	1.36	1.66	1.76	2.44	2.06
Upper confidence interval	1.36	1.55	1.94	2.35	2.65	2.48

Figure 12 and Figure 13 show the mean sleep disturbance score for each one-hour period of the night, as assessed by the $L_{Aeq,1h}$ metric. The data for each individual hour showed two linear relationships, with mean sleep disturbance scores increasing with an increase in noise exposure, with effects either starting at different noise exposure thresholds or flattening out at certain noise exposure levels. The relationships for the middle hours of the night e.g., the individual hours between 02.00-06.00 suggest higher mean sleep disturbance scores at lower exposures (>36dB), compared with the earliest and latest one-hour periods of the night-time. Overall, the range of mean scores seen across the one-hour periods was similar across the night-time period, but slightly wider in the evening and latest night-time hours in terms of lowest and highest score.

Table 38 to Table 41 show the mean sleep disturbance scores for the overflight metrics for the sample. In general, for overflights at 4,000ft and at 7,000ft (for both the 48.5 degree and the 60 degree definitions), mean sleep disturbance scores above 2 were reported across the categories. The scores did not show increases with increasing number of overflights, but more generally indicated higher mean annoyance scores.

Figure 12: Plot of mean sleep disturbance scores as a function of $L_{Aeq,1h}$ periods from 21.00-03.00 (92-day average summer night, dB) noise exposure.

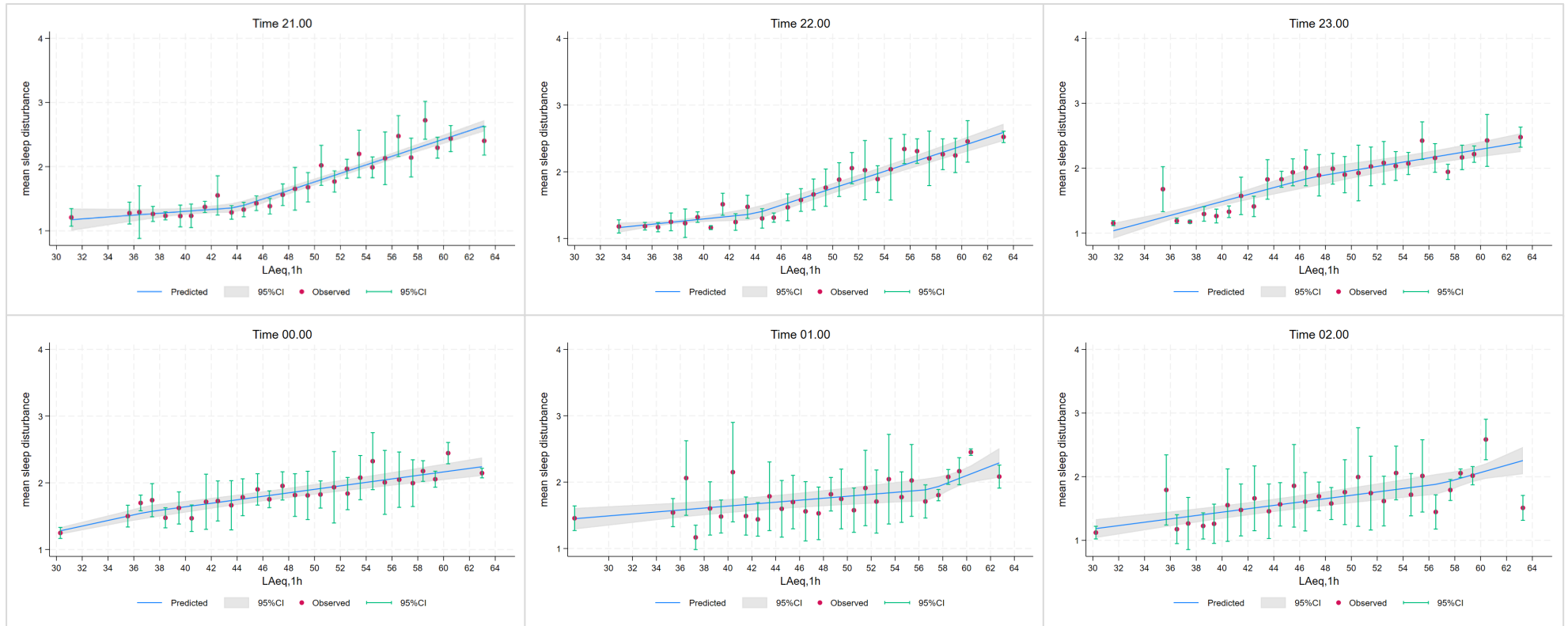


Figure 13: Plot of mean sleep disturbance scores as a function of $L_{Aeq,1h}$ periods from 03.00-08.00 (92-day average summer night, dB) noise exposure.

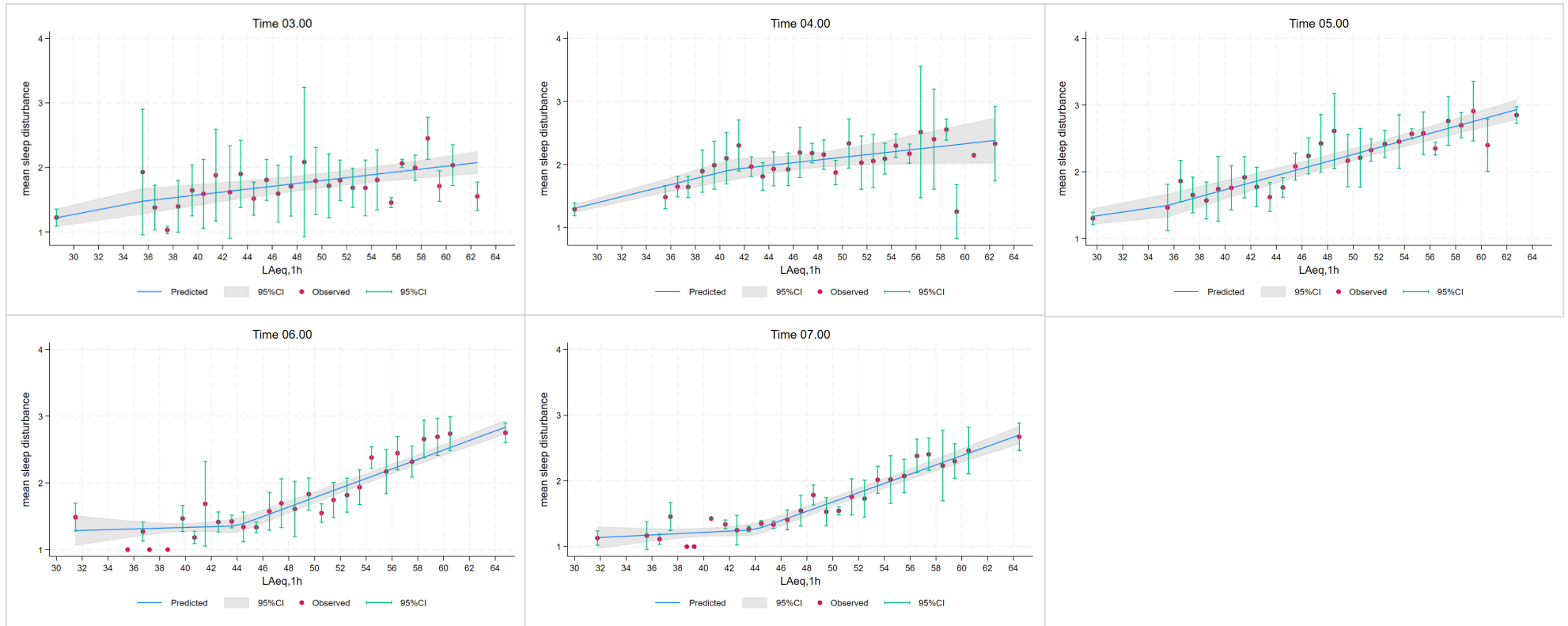


Table 38: Mean sleep disturbance by overflights noise exposure (92 day, 4,000 ft., 60°)

Mean sleep disturbance	Overflights (92 days, 4,000 ft., 60°)			
	<1	1-<10	10-<20	≥20
N	2267	833	608	264
Mean	2.05	2.40	2.45	2.35
Standard error	0.16	0.11	0.12	0.17
Lower confidence interval	1.74	2.17	2.20	2.02
Upper confidence interval	2.37	2.62	2.70	2.68

Table 39: Mean sleep disturbance by overflights noise exposure (92 day, 4,000 ft., 48.5°)

Mean sleep disturbance	Overflights (92 days, 4,000 ft., 48.5°)			
	<1	1-<10	10-<20	≥20
N	1578	983	974	436
Mean	1.91	2.35	2.50	2.31
Standard error	0.18	0.09	0.11	0.13
Lower confidence interval	1.56	2.16	2.27	2.05
Upper confidence interval	2.26	2.53	2.72	2.57

Table 40: Mean sleep disturbance by overflights noise exposure (92 day, 7,000 ft., 60°)

Mean sleep disturbance	Overflights (92 days, 7,000 ft., 60°)			
	<1	1-<10	10-<20	≥20
N	1685	1346	674	266
Mean	2.27	2.02	2.36	2.36
Standard error	0.07	0.23	0.14	0.17
Lower confidence interval	2.12	1.56	2.09	2.02
Upper confidence interval	2.41	2.48	2.64	2.69

Table 41: Mean sleep disturbance by overflights noise exposure (92 day, 7,000 ft., 48.5°)

Mean sleep disturbance	Overflights (92 days, 7,000 ft., 48.5°)			
	<1	1-<10	10-<20	≥20
N	999	1454	1063	454
Mean	2.19	2.04	2.42	2.28
Standard error	0.08	0.22	0.12	0.13
Lower confidence interval	2.03	1.60	2.18	2.03
Upper confidence interval	2.35	2.48	2.66	2.53

ii. Exposure-response functions for percent highly sleep disturbed (HSD)

Figure 14 shows HSD by $L_{Aeq,8h}$ exposure. HSD was linearly associated with increasing aircraft noise exposure ($L_{Aeq,8h}$) up to 47dB, with a further shallower linear increase above this level, bearing in mind the study sampled up to ~62dB. HSD was ~0% at <36dB, rising to 10% at 44dB. HSD increased to 20% at 49dB, where the regression line flattened out but still increased with increasing exposure, remaining at around 20-28% $L_{Aeq,8h}$. These data suggest that 44dB $L_{Aeq,8h}$ could be a LOAEL for HSD, as this is where the relationship is 10% HSD (see Table 65 for the proportions in Figure 14).

Figure 14: Plot of highly sleep disturbed as a function of $L_{Aeq,8h}$ (92-day average summer night, dB) noise exposure.

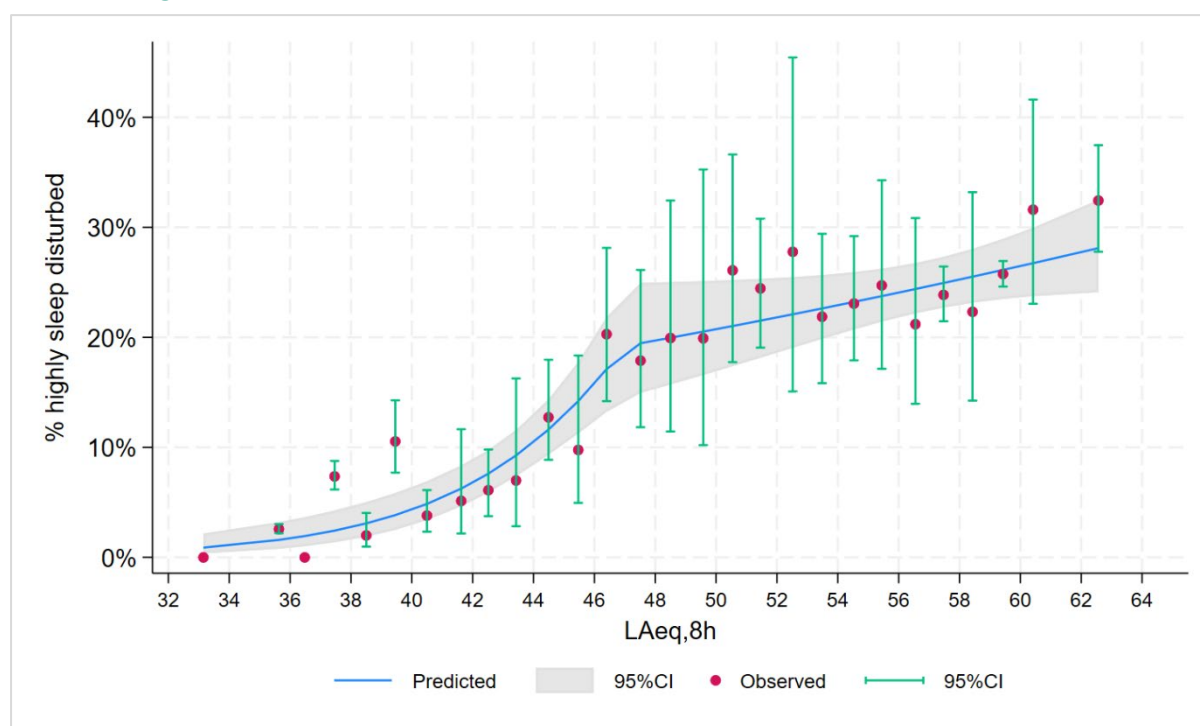


Figure 35 (Section 6.4 in the Appendix) shows the relationship between being highly sleep disturbed (HSD) and L_{night} , which was similar to the linear relationships seen for $L_{\text{Aeq},8\text{h}}$, as described above. The relationships for HSD and $L_{\text{Aeq},8\text{h}}$ and L_{night} are very similar to those observed for HA (see Figure 7 and Figure 33), although the responses were a few percentage points higher for annoyance than sleep disturbance across the noise exposure bands. Post-hoc analysis found that the correlation between the continuous annoyance and sleep disturbance responses was 0.850, indicating a strong correlation. However, the two concepts are not exact proxies for each other: some participants do report annoyance and not sleep disturbance, and vice versa. A correlation of 0.850 suggests that around 72% of the variance between the two measures is shared.

Table 42 shows the proportion HSD by N60 noise exposure. HSD increased with the number of aircraft noise events equal to or above 60dB. Less than one event was associated with no HSD (0%), rising to 4% for 1-<5 events, 8.5% for 5-<10 events, 13.5% for 10-<20 events, 25% for 20-<50 events and 18% for ≥ 50 events. These data suggest that policy could consider thresholds informed by N60. The data suggest that a LOAEL value could be identified between 5-<10 events and 10-<20 events as this is where HSD is ~10%.

Table 42: Proportion of highly sleep disturbed by N60 noise exposure level

Highly sleep disturbed	N60					
	<1	1-<5	5-<10	10-<20	20-<50	≥ 50
%	0.00%	3.96%	8.50%	13.55%	25.26%	17.87%
95% CIs	0.00%	2.74-5.70%	6.18-11.57%	8.58-20.75%	23.08-27.58%	12.75-24.46%
N*	79	552	283	469	1858	730

*Total number of participants in each N60 category

Figure 15 and Figure 16 show HSD for each hour of the night, using the $L_{\text{Aeq},1\text{h}}$ metric. The relationships varied across the one-hour periods of the night-time and were characterised by one or two linear relationships. The aircraft noise exposure associated with 10% HSD moves considerably across the night-time period. To enable comparison across the night-time period, Figure 17 shows the same relationships (the regression estimates) for each hour summarised on the same plot for the hours 21.00-00.00, 00.00-04.00, and 04.00-08.00.

At 21.00-22.00 HSD rose linearly from around 0% at <36dB to 10% at 52dB and 20% at 57dB. A similar relationship was seen for 22.00-23.00. At 23.00-00.00 and 00.00-01.00 10% HSD was found at much lower exposure levels (43dB and 42dB, respectively), with 10% HSD being in the 40-50dB range for 01.00-02.00, 02.00-03.00, 03.00-04.00, and 05.00-06.00, respectively, noting the lower power in the data to examine effects given the wide-confidence intervals for some of the estimates (low number of participants with exposures in these categories between 03.00-04.00). The lowest threshold for 10% HSD was at 04.00-05.00 at 37dB. At 06.00-07.00 and 07.00-08.00 the aircraft noise exposure level for 10% HSD was higher at 51dB and 53dB.

These patterns suggest that HSD is observed at lower levels of noise exposure in the night-time than in the evening or morning hours. High levels of sleep disturbance were observed

across the hours of the night-time. Overall, these analyses suggest that policy should consider effects at different times of the night.

Comparing Figure 14 to Figure 15 and Figure 16 there are some differences. The $L_{Aeq,8h}$ results found 10%HSD at 44dB, and as discussed above, the 10%HSD varied widely when examined throughout the night-time period. However, the $L_{Aeq,1h}$ results generally support the findings of the $L_{Aeq,8h}$ results which suggested that 44dB could be a LOAEL for HSD, as this is where the relationship is 10% HSD. The data suggest that if using the $L_{Aeq,1h}$ results that the LOAEL for HSD could be lower than 44dB for some time-periods where 10% HSD is at lower exposure levels, although this must be weighed against the larger confidence intervals and lower statistical power for these analyses, as well as uncertainties in noise modelling at lower levels.

Figure 15: Plot of highly sleep disturbed as a function of $L_{Aeq,1h}$ periods from 21.00-03.00 (92-day average summer night, dB) noise exposure.

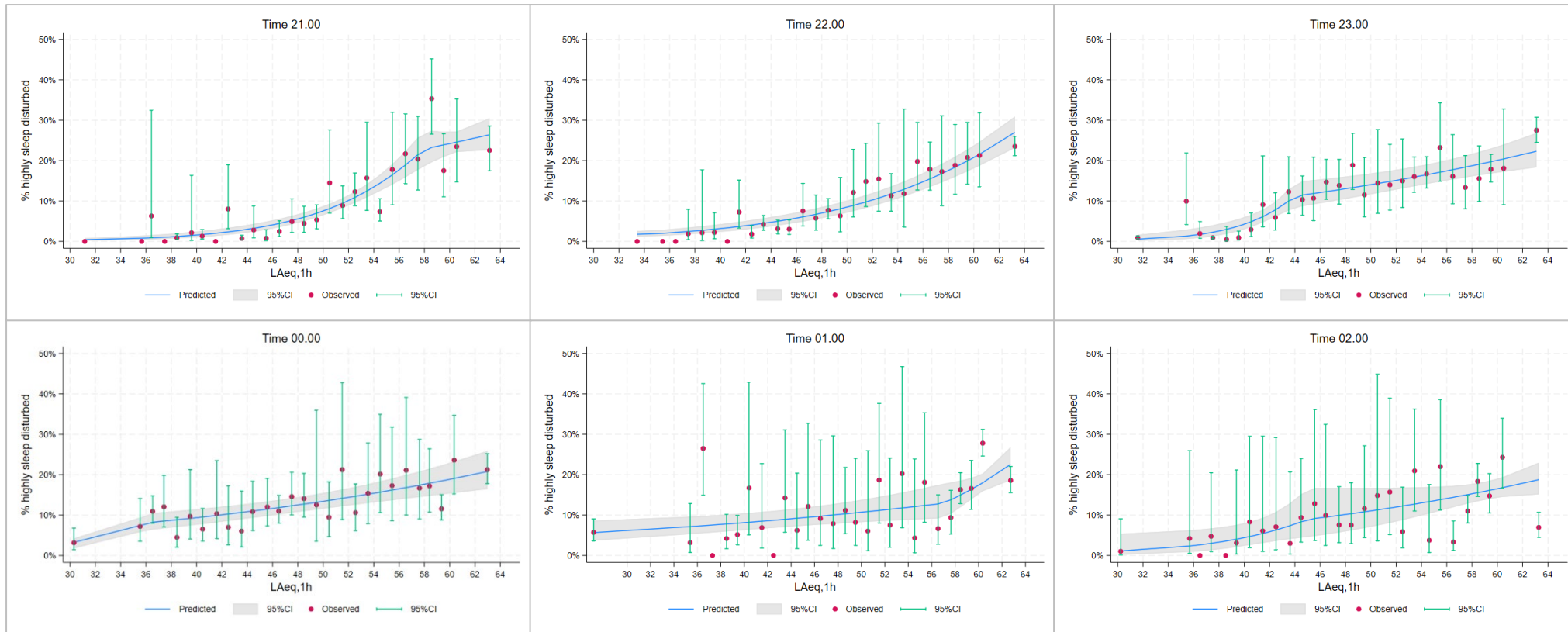


Figure 16: Plot of highly sleep disturbed as a function of $L_{Aeq,1h}$ periods from 03.00-08.00 (92-day average summer night, dB) noise exposure.

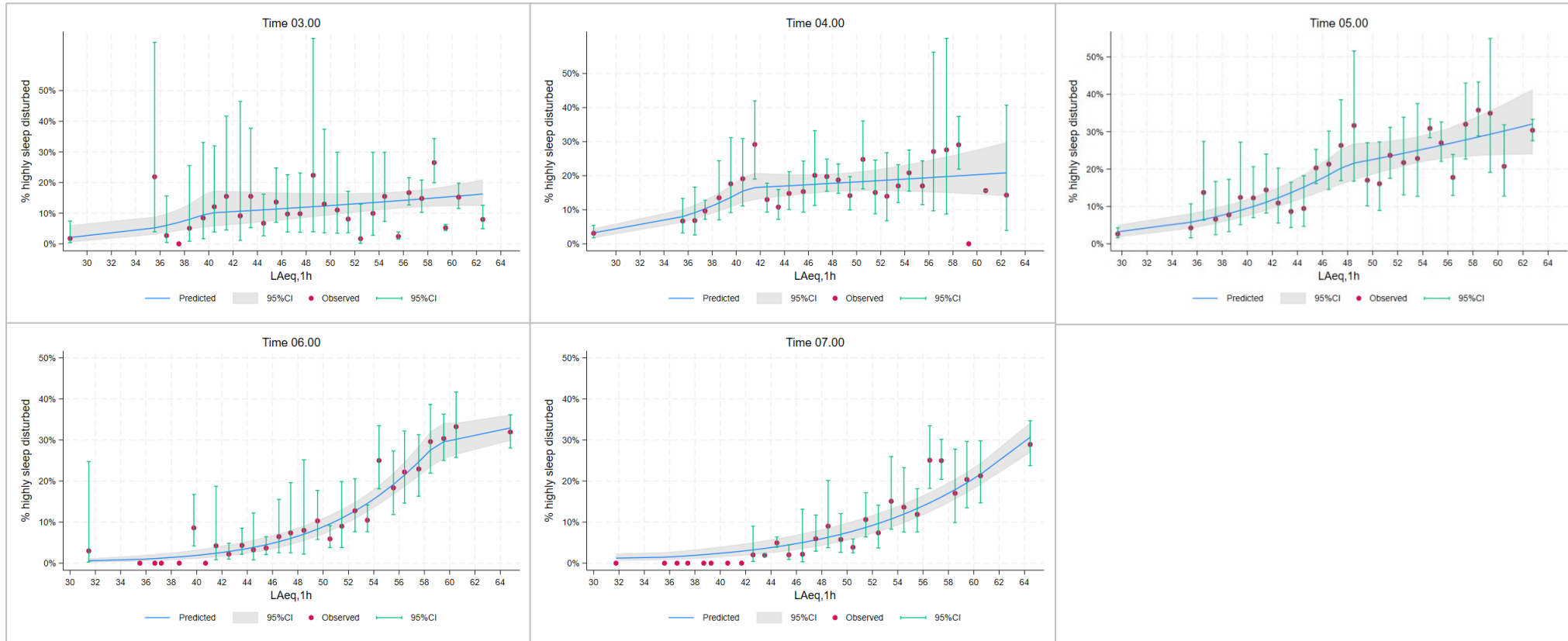


Figure 17: Plot of highly sleep disturbed as a function of $L_{Aeq,1h}$, dB, from periods from (a) 21.00-00.00, (b) 00.00-04.00, (c) 04.00-08.00.

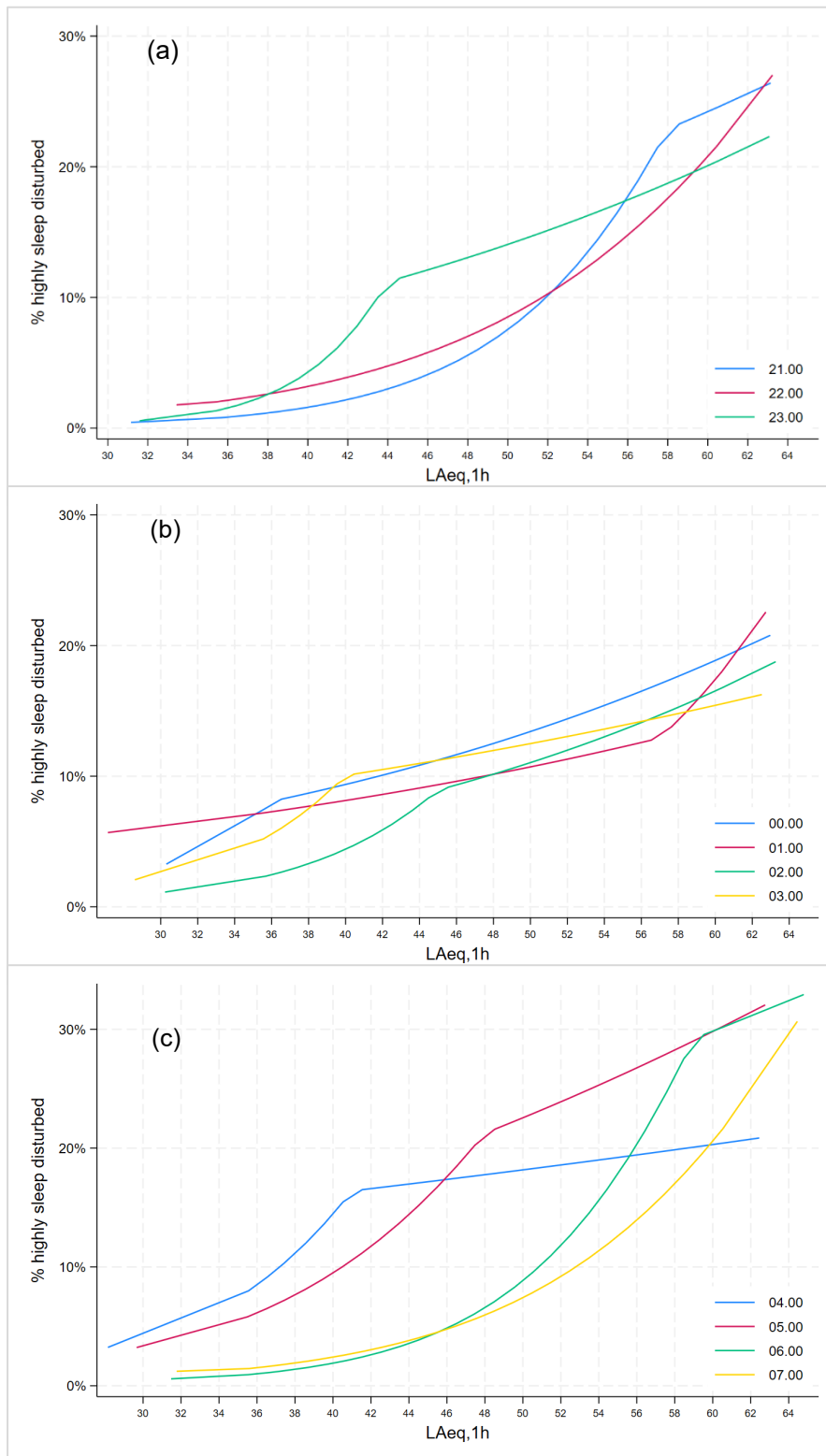


Table 43: Proportion of highly sleep disturbed by overflights noise exposure (92 day, 4,000 ft., 60°)

Highly sleep disturbed	Overflights (92 days, 4,000 ft., 60°)			
	<1	1-<10	10-<20	≥20
%	14.16%	22.45%	24.22%	20.57%
95% confidence intervals	9.36-20.85%	17.56-28.25%	19.13-30.15%	12.84-31.27%
N*	2267	833	608	264

*Total number of participants in each overflight category

Table 44: Proportion of highly sleep disturbed by overflights noise exposure (92 day, 4,000 ft., 48.5°)

Highly sleep disturbed	Overflights (92 days, 4,000 ft., 48.5°)			
	<1	1-<10	10-<20	≥20
%	11.43%	19.63%	25.42%	20.27%
95% confidence intervals	6.42-19.53%	16.38-23.34%	20.94-30.94%	14.08-28.28%
N*	1578	983	974	436

*Total number of participants in each overflight category

Table 45: Proportion of highly sleep disturbed by overflights noise exposure (92 day, 7,000 ft., 60°)

Highly sleep disturbed	Overflights (92 days, 7,000 ft., 60°)			
	<1	1-<10	10-<20	≥20
%	17.79%	15.18%	22.24%	20.77%
95% confidence intervals	14.61-21.49%	8.18-26.45%	16.72-28.95%	13.04-31.44%
N*	1685	1346	674	266

*Total number of participants in each overflight category

Table 46: Proportion of highly sleep disturbed by overflights noise exposure (92 day, 7,000 ft., 48.5°)

Highly sleep disturbed	Overflights (92 days, 7,000 ft., 48.5°)			
	<1	1-<10	10-<20	≥20
%	15.86%	14.36%	23.86%	19.45%
95% confidence intervals	12.20-20.37%	8.28-23.74%	19.06-29.43%	13.49-27.22%
N*	999	1454	1063	454

*Total number of participants in each overflight category

Table 43 to Table 46 show the analyses of the overflight data in relation to HSD for the sample. For overflights at 4,000ft (for both the 48.5 degree and the 60 degree definitions), HSD increased from around 11%-15% for <1 overflight to 20-25%% for those experiencing a greater number of overflights. For overflights at 7,000ft (for both the 48.5 degree and the 60 degree definitions), similar levels of HSD were reported across the <1 overflight and 10-<20 overflights (15-18%) groups, and reports were similar for the 20-<50 and >50 groups (19 to 24%).

a) Summary of ANNE Survey - Subjective sleep disturbance

In noise and health research, two different and distinct types of sleep disturbance have been examined. Subjective (self-reported) sleep disturbance linked to external time-average noise metrics, and objective sleep disturbance assessed by changes in biophysiological signals (e.g., awakenings, body movements) that occur during sleep, linked to either internal or external individual noise events, as well as time-average metrics. The social survey of the ANNE study examines self-reported – ‘subjective’ sleep disturbance. A separate ANNE study is assessing associations between aviation night-noise and ‘objective’ sleep disturbance. The ANNE objective sleep study is expected to be completed in 2025. This will enable a comparison of findings across the subjective and objectively assessed sleep disturbance studies.

The ANNE study examined the relationship between several aviation night noise metrics and sleep disturbance, with all the metrics, $L_{Aeq,8h}$, L_{night} , and $L_{Aeq,1h}$, showing associations with sleep disturbance. N60, as well as overflights at 4,000ft and 7,000ft were associated with increasing proportions reporting sleep disturbance.

For time-averaged exposure over the 8-hour night-time period ($L_{Aeq,8h}$), very few participants reported being HSD at <36dB. 10% of the sample were highly sleep disturbed at 44dB $L_{Aeq,8h}$, with sleep disturbance increasing with exposure, and reaching around 20-28% HSD for exposures in the 49-60dB range. Similar patterns were seen for other night noise metrics: 10% of the sample reported being HSD for 5-<10 events / 10-<20 events for N60. Any overflight event was associated with over 10% being HSD. This suggests that overflights do not have adequate sensitivity to account for all aspects of aviation noise exposure, to inform a LOAEL value. This is not to deny that they are associated with subjective sleep

disturbance, just that the current measure lacks granularity and sensitivity in relation to health.

These data suggest that sleep disturbance from aviation night-noise is having an impact on the health of populations exposed to aviation noise at night, with effects beginning at fairly low levels of exposure. These levels could inform LOAEL values.

This study cannot, and should not, be used to speculate on what the relationship between aviation night-noise and sleep disturbance would look like for levels higher than 62dB $L_{Aeq,8h}$, as these levels were not examined in the ANNE study and are rarely seen in the UK context.

High levels of sleep disturbance were observed across the night-time period. As seen for annoyance, there was variation across the individual night-time hours in sleep disturbance. The exposure level at which 10% reported being HSD varied. Table 47 shows that the lowest aviation noise exposure threshold for 10% HSD was found for 04.00-05.00, but that in general the threshold was lower between 00.00-06.00 than for 21.00-00.00 and 06.00-08.00. HSD was observed at lower levels of noise exposure in the night-time than in the evening or morning hours. For some hours of the night very low levels of exposure were associated with HSD. These data suggest that the population is particularly vulnerable to HSD from aviation activity during these time periods.

Table 47: Summary for each noise metric for the exposure level at which it was predicted that 10% were highly sleep disturbed (based on the regression line).

Noise metric	Level at which 10% HSD (based on regression line)
$L_{Aeq,8h}$	44dB
L_{night}	43dB
N60	5-<10 events / 10-<20 events
Overflights (4,000ft)	<1 overflight
Overflights (7,000ft)	<1 overflight
$L_{Aeq,1h}$ 21.00-22.00	52dB
$L_{Aeq,1h}$ 22.00-23.00	52dB
$L_{Aeq,1h}$ 23.00-00.00	43dB
$L_{Aeq,1h}$ 00.00-01.00	42dB
$L_{Aeq,1h}$ 01.00-02.00	47dB
$L_{Aeq,1h}$ 02.00-03.00	47dB
$L_{Aeq,1h}$ 03.00-04.00	40dB
$L_{Aeq,1h}$ 04.00-05.00	37dB
$L_{Aeq,1h}$ 05.00-06.00	40dB
$L_{Aeq,1h}$ 06.00-07.00	51dB
$L_{Aeq,1h}$ 07.00-08.00	53dB

Fewer people in the population are likely to be trying to sleep in the evening and morning hours, which could account for lower reports of sleep disturbance: conversely, most people would be trying to sleep between 00.00-06.00, which could account for higher reports of sleep disturbance. Further, if you are disturbed by aircraft noise in the later part of the night, e.g., 04.00 onwards, physiologically individuals will be less tired and therefore less likely to fall back to sleep, which could increase reports of sleep disturbance. Aircraft noise in the early part of the night, when individuals are most fatigued, may have less of an impact, as biologically they have a higher chance of falling asleep. The objective sleep study being conducted as part of the ANNE study will be able to further examine the impact of aircraft noise events during different times of the night, using physiologically assessed sleep disturbance outcomes. This will enable a comparison of effects across subjective and objectively assessed sleep disturbance.

As seen for annoyance, sleep disturbance occurred outside the traditional 23.00-07.00 hour night-time period which has relevance for how policy can protect public health during the evening and morning hours.

The different thresholds for 10% HSD when comparing the time-average metrics for the night-time period ($L_{Aeq,8h}$ and L_{night}) with the one-hour metrics ($L_{Aeq,1h}$) raises the question as to whether policy setting based on the time-averaged metrics for the night-time period of 8-hours would adequately account for the sleep disturbance effects observed at different times of the night-time? In fact, whilst some relationships for the one-hour periods look similar to that for the 8-hour period or have a slightly higher threshold for 10%, for some one-hour periods during the night, e.g. those between 01.00-02.00 and 03.00-06.00 sleep disturbance is higher at lower exposure levels than suggested by the 8-hour exposure ERF. The analyses suggest that consideration should be given to effects at different times of the night, as well as for thresholds informed by N60.

Few studies, to date, have assessed the effects of aviation noise on both annoyance and sleep disturbance. There has long been debate about which concept best reflects the impact of night-time aviation noise on public health. This study suggests that night-time aviation noise exposure is associated with both annoyance and sleep disturbance. The shape of the relationship between noise exposure was similar for both outcomes, albeit, with slightly higher proportions reporting being highly annoyed than highly sleep disturbed for the same noise exposure level. The findings for annoyance and sleep disturbance were similar for all of the noise metrics. The slightly higher proportions reported for annoyance compared with sleep disturbance could reflect non-acoustic factors, such as attitudes to aviation and other personal, social and demographic factors which influence response. Although, these factors could also potentially influence self-reported sleep disturbance.

3.5 Comparison of ANNE ERFs for annoyance and sleep disturbance with ERFs from recent studies

This section compares the ERFs from the ANNE study for annoyance and sleep disturbance with those from recent studies. All the studies considered here provide exposure-response functions for noise and health either from national studies or meta-analyses which combine the findings of several studies. The studies included will vary in terms of the population of interest, the sampling framework, the exposure range, and assessment method including the metrics considered, and data collection methodologies of the study or studies included in the analyses (e.g. face-to-face, online, postal).

Figure 18 plots recent estimates of the effect of aircraft noise exposure at night with HA and Figure 19 for HSD, alongside the estimates from the ANNE study. These figures include the following relationships:

- WHO ENG 2018 relationship for HA (Guski et al., 2017);
- WHO ENG 2018 relationship for HSD (Basner and McGuire, 2018);
- SoNA 2014 relationship for HA³¹ (Civil Aviation Authority, 2021c); and
- Updated WHO ENG 2022 relationship for HSD (Smith et al., 2022).

These studies report the relationships for $L_{Aeq,8h}$ or L_{night} , except for the WHO ENG 2018 relationship for HA which reports L_{den} . The figures plot the range of noise exposures sampled for each study (e.g., SoNA 2014, ANNE) or plotted in the regression analyses carried out for the analyses (e.g., WHO). The annoyance relationships for the WHO ENG 2018 and SoNA 2014 use a 28% cut-off for HA: the annoyance relationships for ANNE use a 40% cut-off for HA. We are unable to include the Monte Carlo estimates of the 28% cut-off from the ANNE study in Figure 18 given the different statistical approach of plotting the median of the estimates.

Figure 18 shows that the ANNE study estimates for aircraft noise at night and HA are higher at lower exposures than the WHO ENG 2018 and SoNA 2014 estimates. The ANNE study shows steeper increase in annoyance than previous ERFs up to 47dB. This might be explained by the fact that the ANNE study sampled on aircraft noise exposure at night, in comparison to SoNA 2014 and some of the studies included in the WHO ENG 2018 which selected samples based on day-time exposure or exposure over the day, evening, night-time period. The ANNE study also sampled at lower noise exposures than many or most previous studies, which could increase the precision of the estimates at this lower end of exposure.

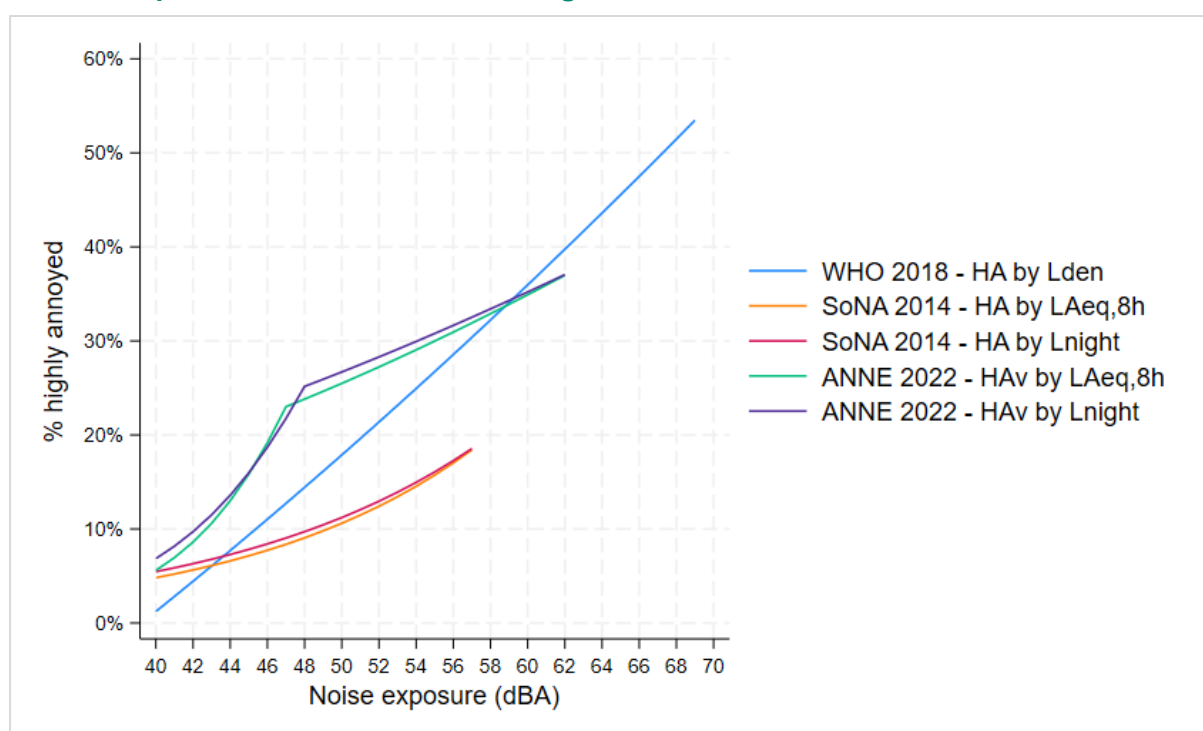
The ANNE study estimates remain higher than the WHO ENG 2018 and SoNA 2014 estimates >47dB, with the ANNE and WHO ENG 2018 suggesting similar level of annoyance at ~60dB. We cannot speculate on the similarity of these ERFs at higher levels as the ANNE study did not examine higher exposures. Such exposures do not reflect the UK context. The

³¹ Referred to in CAP2161 as HSD but it is a HA measure based on an annoyance question not a sleep disturbance question. We therefore compare the CAP2161 analyses to the ANNE annoyance analyses and not the ANNE sleep disturbance analyses.

difference between ANNE and the other ERFs could reflect the fact that the ANNE analyses account for the sigmoid (s-shaped) relationship of the data for exposure and HA observed.

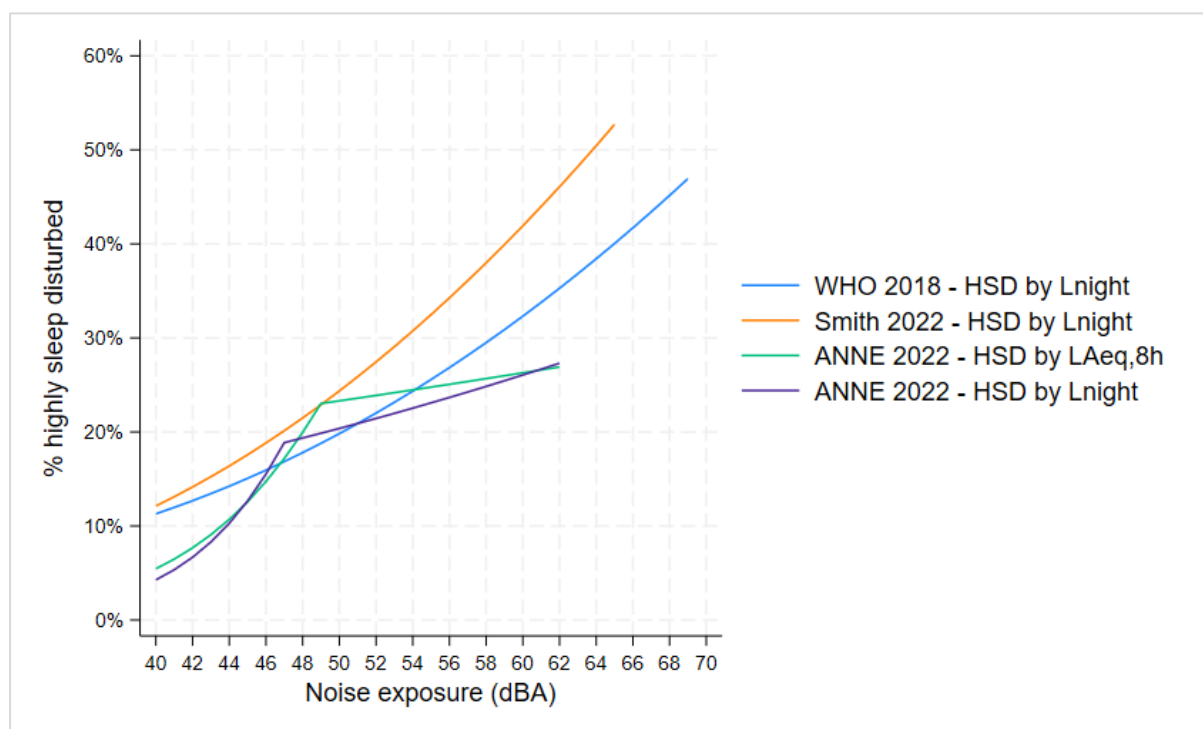
Figure 19 shows that the ANNE study estimates for aircraft noise at night and HSD. The ANNE study estimates are lower at low aircraft noise exposures than the WHO ENG 2018 and updated WHO ENG 2022 estimates. The ANNE study estimates also differ at higher exposures, showing a levelling-off of effect at around 47-48dB, depending on the noise metric, albeit with a substantial ~25% of the population HSD. As discussed above, the sampling framework of the ANNE study and the analyses accounting for the sigmoid shape of the relationship between exposure and HSD could explain these differences.

Figure 18: Plot comparing the ANNE study findings with other recent estimates of the relationship between aircraft noise at night and HA



NB: in considering the data in Figure 18 it should be remembered that the WHO 2018 and SoNA 2014 use the 28% cut-off for HA, whilst ANNE 2022 uses the 40% cut-off for HA.

Figure 19: Plot comparing the ANNE study findings with other recent estimates of the relationship between aircraft noise at night and HSD



The ERFs of the ANNE study differ in some ways from those derived from previous WHO meta-analyses or from analyses of SoNA 2014. The ANNE analyses suggest higher rates of annoyance than the WHO or SoNA 2014, but slightly lower rates of sleep disturbance. The ANNE analyses also suggest that the effects for sleep disturbance ‘level out’ albeit, at levels showing substantial effects on health.

There are several reasons for these differences. Firstly, relationships are likely to vary across contexts and time, with the World Health Organization (World Health Organization, 2018) recommending the use of local data to estimate effects, where available.

“data and exposure–response curves derived in a local context should be applied whenever possible to assess the specific relationship between noise and annoyance in a given situation. If, however, local data are not available, general exposure–response relationships can be applied, assuming that the local annoyance follows the generalized average annoyance.” (Section 5.5, page 109) (WHO, 2018).

In comparing ANNE with SoNA 2014, it should be noted that the studies sampled different populations (exposed to aviation noise at night versus during the day) and were conducted eight years apart. Further, ANNE examined both annoyance and sleep disturbance, whereas SoNA 2014 examined night-noise exposure in relation to annoyance (although, named this sleep disturbance). The findings of the ANNE study suggest that the SoNA 2014 analyses of night-time aviation noise exposure may have underestimated effects on sleep disturbance by using the annoyance measure as a proxy for sleep disturbance (Comparing SoNA 2014 HA in Figure 18 with ANNE HSD in Figure 19).

In comparing ANNE with the WHO analyses, it should be noted that the statistical analyses in the two studies differ considerably. The ANNE study is a primary research study, where the data has been analysed to produce the regression line. The WHO analyses come from meta-analyses of primary research studies, where the estimates of the relationships between noise and health are used to produce the regression line. Meta-analyses have the advantage of being able to assess the relationship across a body of evidence (e.g., all studies of aviation noise exposure and annoyance published within a specific time-period), but the lack of primary data can limit the information that can be analysed. Further, the WHO relationships potentially plot the regression line up to very high exposures, based on fewer data points. Studies also vary in the shape of the regression line fitted.

Whilst differences between previous annoyance surveys have led to debate (Independent Commission on Civil Aviation Noise, 2019), it should be remembered that there is no 'ultimate' truth about the strength of relationships found between noise exposure and health. ANNE delivers ERFs between aviation night-noise and health to inform UK policy. It will be for future studies to examine for how long the ANNE relationships remain representative.

3.6 Health & Wellbeing

This section describes key outcome data relating to the ANNE participants' self-reported health and wellbeing. Self-reported health was assessed using a question with five response categories, ranging from very good (1) to very bad (5). So, a lower score indicates better health. Table 48 shows that three-quarters (78%) of the sample reported very good or good health: 4% reported bad or very bad health. The ANNE sample rated themselves as being healthy.

Table 48: Frequencies for health variables

Noise source	ANNE sample	
How is your health in general? (q7)	N	%
Very good (1)	1309	31%
Good (2)	1964	47%
Fair (3)	741	18%
Bad (4)	141	3%
Very bad (5)	22	0.5%
Missing	5	0.1%
Mean (SD)	1.95 (0.81)	
Median (IQR)	2 (1-3)	
Body Mass Index (q43-48)³²	N	%
Underweight (<18.5)	107	3%
Healthy range (18.5-24.9)	1650	39%
Overweight (25-29.9)	999	24%
Obesity, class 1 (30-34.9)	281	7%
Obesity, class 2 (35-39.9)	89	2%
Obesity, class 3 (≥40)	41	1%
Missing	1016	24%

Participants also self-reported their wellbeing, using the Short Warwick Edinburgh Mental Wellbeing Scale (SWEMWBS). The SWEMWBS asks about feelings and thoughts over the past fortnight, so does not directly align with the 'summer period' for most of the noise metrics. For this reason, to maximise the data, participants who had lived in their home for less than 6 months were not removed from analyses of the SWEMWBS. Table 49 shows the responses to the SWEMWBS questions. A total score is also reported, made from adding the individual question responses, with total scores on the scale ranging from 7 to 35. Higher scores indicate higher or better wellbeing. National data report wellbeing scores with a

³² This item was calculated based on participants responses to self-reported height and weight questions in the survey. These items were included as screening questions for participation in the next phase of the study.

median of 23.21 (standard deviation 3.90)³³. A change of 1 to 3 points was found to be statistically important in a clinical sample (Shah et al., 2018). In the ANNE study, the median score was similar to the national norm, with a median score of 22.36 and a standard deviation of 3.91. This means that the levels of wellbeing reported in the ANNE sample are like those observed nationally in England³⁴. The ANNE sample does not have poorer wellbeing than would be expected.

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https://warwick.ac.uk/fac/sci/med/research/platform/wemwbs/using/howto/wemwbs_population_norms_in_health_survey_for_england_data_2011.pdf

³⁴ The norm data is from the Health Survey for England, whilst the ANNE sample includes participants from England and Scotland.

Table 49: Frequencies for Wellbeing (SWEMWBS) items and overall total score

Noise source	ANNE sample							
	N	None of the time (1)	Rarely (2)	Some of the time (3)	Often (4)	All of the time (5)	Mean	SD
Over the last 2 weeks.... (q23 to q29)								
I've been feeling optimistic about the future	4180	6%	17%	41%	27%	8%	3.14	1.01
I've been feeling useful	4180	3%	8%	37%	39%	13%	3.53	0.91
I've been feeling relaxed	4177	4%	18%	46%	27%	5%	3.11	0.90
I've been dealing with problems well	4175	2%	8%	41%	39%	10%	3.48	0.85
I've been thinking clearly	4177	1%	6%	32%	43%	18%	3.71	0.87
I've been feeling close to other people	4178	3%	10%	31%	39%	17%	3.57	0.97
I've been able to make up my own mind about things	4179	1%	4%	21%	45%	28%	3.97	0.86
Total Score (NB: raw score gets transformed)							22.36	3.91

<https://www.corc.uk.net/outcome-experience-measures/short-warwick-edinburgh-mental-wellbeing-scale-swemwbs/>

Figure 20 shows the relationship between SWEMWBS and $L_{Aeq,8h}$. Statistically the relationship was characterised by two linear lines, with higher aircraft noise exposure being associated with a shallow decrease in wellbeing up to 48dB $L_{Aeq,8h}$, and steeper decline above this level, bearing in mind the study sampled up to ~62dB. In general, however, the decrease was fairly small in magnitude across the range of noise exposure. At lower levels of aircraft noise exposure, wellbeing was slightly below the national norm, with scores decreasing by around 1 point in comparison for those with exposures above 60dB $L_{Aeq,8h}$. So, across a range of ~25 dB the change in wellbeing score was 1, suggesting that noise could be having a small but clinically significant effect on wellbeing, comparing the change from lowest to highest noise exposure.

Figure 20: Plot of SWEMWBS as a function of $L_{Aeq,8h}$ (92-day average summer night, dB) noise exposure

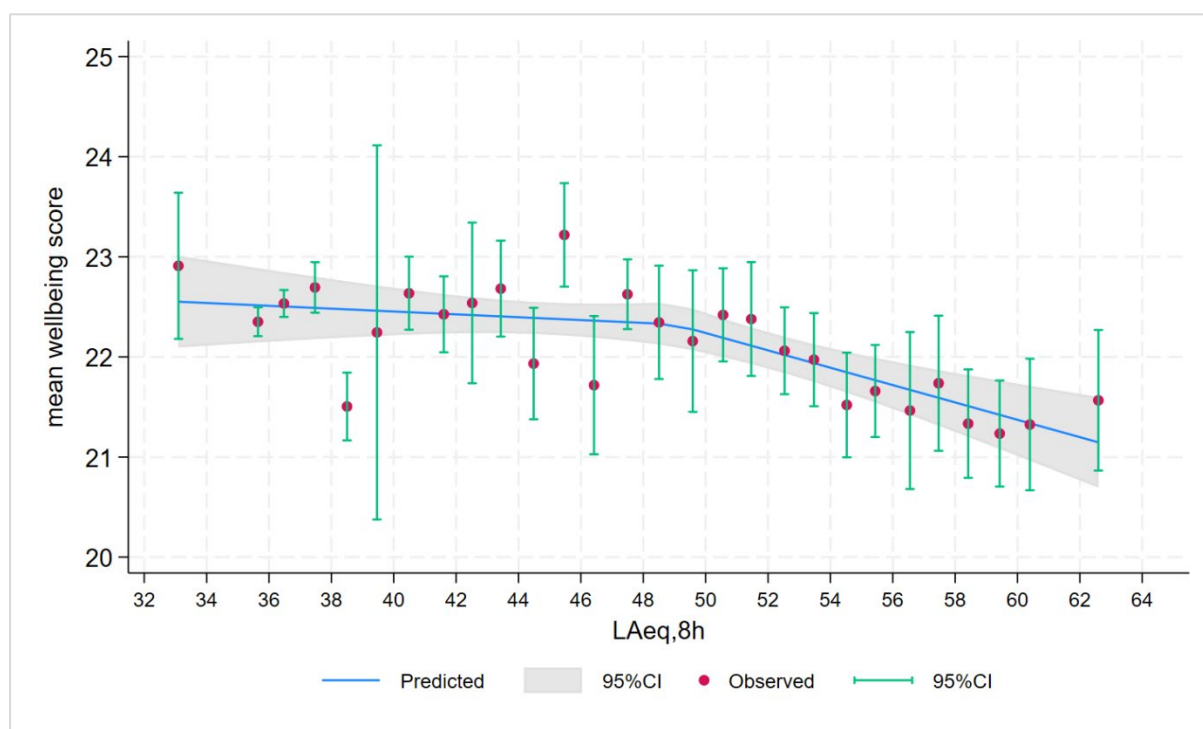


Figure 36 (section 6.4 in the Appendix) shows the relationship between SWEMWBS and L_{night} , which showed a similar linear relation to that described above for $L_{Aeq,8h}$.

Table 50 shows the mean wellbeing score for the N60 metric, which decreased slightly with increasing N60. As seen for other noise metrics, the reduction in wellbeing across the range of exposures was around 1 point across the range of noise events examined (mean score <1 event 22.75: mean score for ≥ 50 events 21.93) which could suggest a small but clinically significant effect on wellbeing, comparing the change from lowest to highest noise exposure.

Table 50: Mean wellbeing score by N60 noise exposure level

Mean wellbeing score	N60					
	<1	1-<5	5-<10	10-<20	20-<50	≥50
N	67	519	317	539	1736	773
Mean	22.75	22.32	22.42	22.44	21.75	21.93
Standard error	0.46	0.06	0.31	0.14	0.22	0.15
Lower confidence interval	21.83	22.20	21.79	22.15	21.31	21.63
Upper confidence interval	23.67	22.45	23.04	22.73	22.19	22.22

Figure 21 and Figure 22 show the relationship between wellbeing (SWEMWBS) scores and the one-hourly aircraft noise exposure metrics ($L_{Aeq,1hr}$). Statistically the relationships were characterised by two linear associations, with wellbeing decreasing with increasing aircraft noise in the one-hourly periods of the night-time. There was little variation in the relationship observed across the one-hour periods, although the relationships for some hours of the night-time were slightly flatter. As seen for other noise metrics, the reduction in wellbeing was around 1 point across the exposures, which could indicate a small but clinically significant effect, comparing the change from lowest to highest noise exposure.

Table 51 to Table 54 show the relationship between the overflight metrics and wellbeing. There was little difference in wellbeing for overflights at 4,000ft or 7,000ft (for both the 48.5 degree and the 60 degree definitions) but the scores are below the national mean for the wellbeing scale and below the mean score for the ANNE sample, suggesting slightly lower wellbeing for all categories of overflights. Given the number of categories available for overflights it was not possible to further plot or statistically test the association.

Figure 21: Plot of SWEMWBS as a function of $L_{Aeq,1h}$ periods from 21.00-03.00 (92-day average summer night, dB) noise exposure.

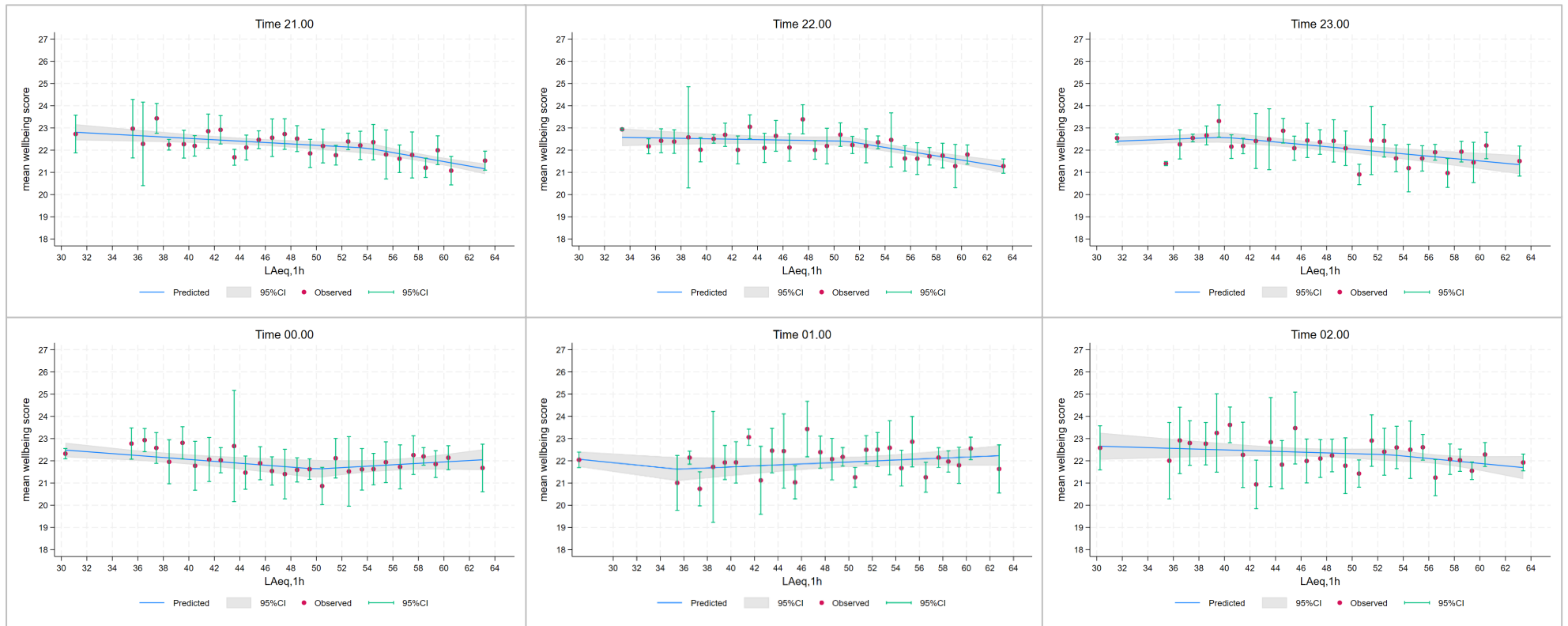


Figure 22: Plot of SWEMWBS as a function of $L_{Aeq,1h}$ periods, from 03.00-08.00 (92-day average summer night, dB) noise exposure.

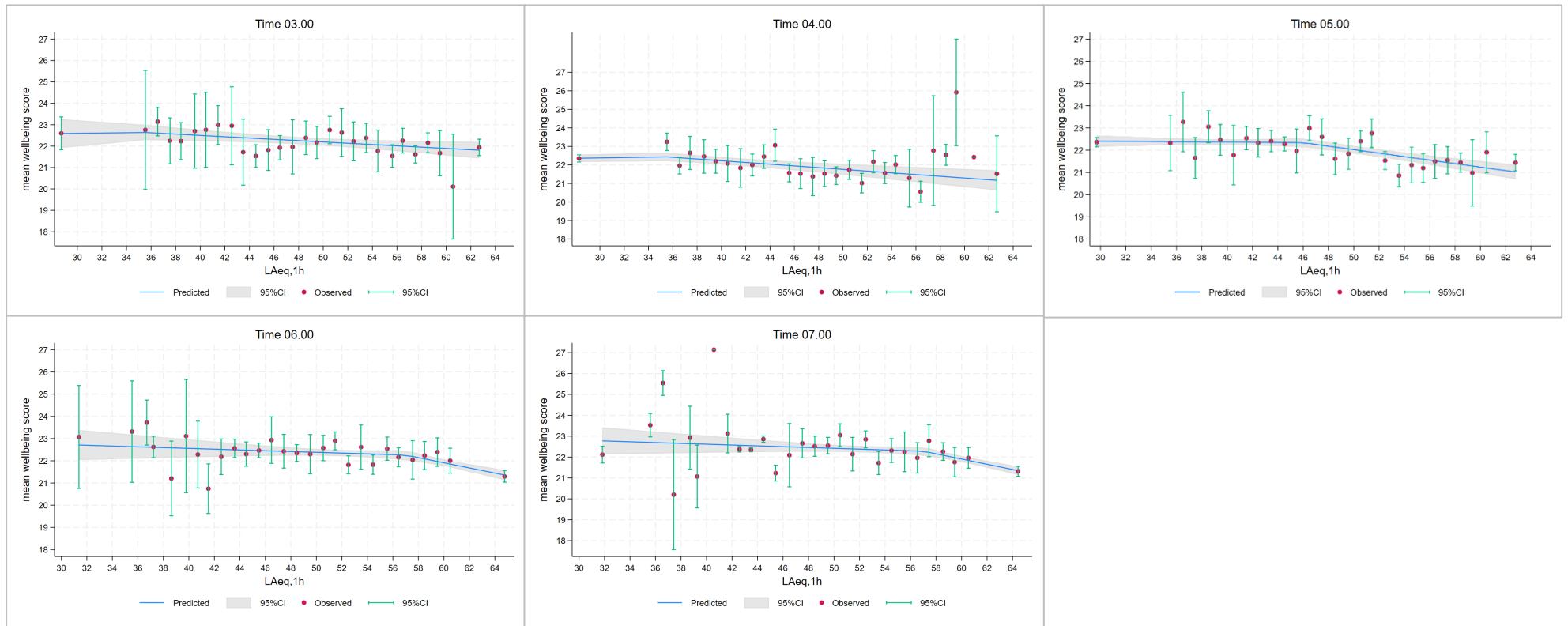


Table 51: Mean wellbeing score by overflights noise exposure (92 day, 4,000 ft., 60°)

Mean wellbeing score	Overflights (92 days, 4,000 ft., 60°)			
	<1	1-<10	10-<20	≥20
N	2189	884	600	278
Mean	22.03	21.86	22.05	22.29
Standard error	0.15	0.26	0.16	0.26
Lower confidence interval	21.73	21.33	21.72	21.76
Upper confidence interval	22.32	22.38	22.38	22.81

Table 52: Mean wellbeing score by overflights noise exposure (92 day, 4,000 ft., 48.5°)

Mean wellbeing score	Overflights (92 days, 4,000 ft., 48.5°)			
	<1	1-<10	10-<20	≥20
N	1514	998	985	454
Mean	22.11	21.91	21.86	22.22
Standard error	0.14	0.23	0.26	0.21
Lower confidence interval	21.84	21.45	21.35	21.80
Upper confidence interval	22.39	22.37	22.37	22.64

Table 53: Mean wellbeing score by overflights noise exposure (92 day, 7,000 ft., 60°)

Mean wellbeing score	Overflights (92 days, 7,000 ft., 60°)			
	<1	1-<10	10-<20	≥20
N	1640	1356	674	281
Mean	21.90	22.09	22.04	22.28
Standard error	0.19	0.21	0.15	0.26
Lower confidence interval	21.53	21.67	21.75	21.77
Upper confidence interval	22.28	22.50	22.33	22.80

Table 54: Mean wellbeing score by overflights noise exposure (92 day, 7,000 ft., 48.5°)

Mean wellbeing score	Overflights (92 days, 7,000 ft., 48.5°)			
	<1	1-<10	10-<20	≥20
N	961	1434	1084	472
Mean	21.99	22.05	21.90	22.22
Standard error	0.20	0.19	0.24	0.20
Lower confidence interval	21.58	21.67	21.42	21.82
Upper confidence interval	22.39	22.42	22.39	22.63

To our knowledge, the ANNE study is the first to examine exposure to noise as assessed by the overflight metric in relation to health outcomes. The study found that overflights at 4,000ft and 7,000ft (for both the 48.5 degree and the 60 degree definitions) were associated with annoyance (mean scores and HA) and sleep disturbance (mean scores and HSD): wellbeing scores were also lower. Altitude based priorities, as set out in UK policy state that:

“Noise from aircraft flying at or above 4,000 feet is less likely to affect the key noise metrics used for determining adverse effects and as aircraft continue to climb above this altitude their noise impact reduces.” (Department for Transport, October 2017).

The findings from this study in relation to overflights at 4,000ft and 7,000ft could support this proposition being extended to 7,000ft. However, the overflight metric, per se, estimates exposure for only a small proportion of the population. Most of the ANNE participants have no overflights, making it less suitable for studying population health. Relying on overflights alone would underestimate the public health effects of aviation night-noise.

3.7 Non-acoustic factors

Table 55 summarises attitudes to aviation for the ANNE sample. Participants were asked a number of questions, where each attitude was rated on a scale ranging from 1 (strongly disagree) to 5 (Strongly agree). Overall, a range of positive and negative attitudes to aviation were reported across the sample. Nearly three-quarters of the sample thought that aviation was harmful to the environment (72%). One-quarter of participants felt that having an airport in the area made their home less valuable (24%). Two-fifths felt that noise from aeroplanes was bad for their own health or that of those in their household (39%), and for children’s education at the local schools (38%). However, the ANNE sample were not overwhelmingly negative about aviation, with convenience and the economic benefits of aviation acknowledged. Two-thirds felt that it was convenient to have an airport in the area (64%) and three-fifths that having an airport in the area was good for the local economy (57%). Taken as a whole, the data show that attitudes to aviation in the ANNE sample were varied, with both positive and negative impacts being recognised.

Table 55: Frequencies for attitudes to aviation

Noise source	ANNE sample						
To what extent do you agree or disagree with the following statements? (q30) ³⁵	Strongly disagree (1)	Disagree (2)	Not sure (3)	Agree (4)	Strongly agree (5)	Mean	SD
Noise from aeroplanes is bad for the health of myself or my household	16%	22%	22%	28%	11%	2.96	1.27
Noise from aeroplanes is bad for children's education at the local schools	13%	20%	29%	26%	12%	3.04	1.21
Noise from aeroplanes makes my home less valuable	13%	18%	25%	30%	13%	3.11	1.24
Having an airport in the area is good for the local economy	6%	9%	28%	43%	14%	3.50	1.03
I worry about plane crashes around here	45%	29%	12%	10%	3%	1.96	1.12
Having an airport in the area makes my home more valuable	11%	22%	46%	16%	4%	2.80	0.97
It is convenient to have an airport in the area	7%	10%	18%	46%	18%	3.58	1.11
Air travel harms the environment	4%	6%	18%	40%	32%	3.90	1.05
I like flying	5%	15%	16%	44%	19%	3.58	1.12
Having an airport in the area makes my home less valuable	8%	21%	47%	17%	7%	2.93	0.98
I worry about more land being taken over by the airport	13%	25%	29%	21%	11%	2.92	1.19
I like watching the aeroplanes	14%	26%	18%	33%	8%	2.97	1.22

³⁵ Missing data ranges from 19 to 36 participants per item (0.5%-0.9%)

Table 56 summarises aviation consumer behaviour within the ANNE sample. Two-thirds (66%) had taken a flight from a UK airport within the past 12 months, with a further one-fifth (20%) having taken a flight from a UK airport within the past one to four years. National data from the UK Aviation Consumer Survey found in 2019, prior to the COVID pandemic and subsequent impact on aviation, that 57% of the population had flown in the past 12 months; post-COVID, in 2022, 45% had flown in the past 12 months (Civil Aviation Authority, 2022). This suggests that the ANNE sample were slightly more likely to be aviation consumers, which is probably explained by the higher number of participants from higher managerial, administrative, and professional socioeconomic groups, with greater income and who may also travel more frequently for work. Most participants who had taken a flight in the past 12 months had taken one to two trips (37%). These data show that the ANNE sample were engaged with aviation as consumers. Only 1% reported having never flown from a UK airport and 4% having not flown within the last 10 years.

Table 56: Aviation consumer

Use of aviation	ANNE sample	
	N	%
When was the last time you flew from a UK airport? (q31)		
Within the last 12 months	2750	66%
Longer than 1 year ago, up to 2 years ago	184	4%
Longer than 2 years ago, up to 4 years ago	669	16%
Longer than 4 years ago, up to 10 years ago	329	8%
More than 10 years ago	182	4%
Never	60	1%
Missing	10	0.2%
How many trips by air have you made in the past 12 months? (q32)		
Not eligible to answer question (only those who say within last 12 months above answer this question)	1433	34%
1	783	19%
2	748	18%
3	471	11%
4	272	7%
5	72	2%
Over 5	395	9%
Missing	9	0.2%

Table 57 describes the coping behaviours that participants reported they had engaged with in response to noise between 23.00-07.00. Two thirds of the sample reported none of the coping behaviours (66%), with one-third reporting engaging in some coping behaviour (34%). The most reported behaviour was closing windows which was reported by over one-quarter of the sample (29%). One-tenth (10%) reported using ear plugs or headphones to avoid hearing the sound, and 6% reported making noise by playing music or white noise. Few participants reported that they had installed secondary, double, triple, or acoustic

glazing³⁶ (3%), or slept in a different room in the home (3%) or started, signed, or participated in a campaign, protest, or petition (2%). These data show that whilst most of the ANNE sample did not report engaging in these coping behaviours, a number did engage in behaviours to try and cope with aviation noise at night.

Table 57: Coping behaviours

Coping behaviours	ANNE sample	
	N	%
Which of these things, if any, have you or anyone else in your household done about noise from aircraft, airfields and airports during the night-time (23.00-07.00) within the last 12 months? (q33) (n=4183)		
Made our own noise (e.g., playing music/white noise) so that we could not hear the noise	260	6%
Used earplugs or headphones to avoid hearing the noise	439	10%
Keep windows closed	1230	29%
Started, signed or participated in a campaign, protest, or petition	77	2%
Took advice, e.g., from Citizen's Advice Bureau, another advice or Legal organisation	16	0.4%
Slept in a different room in the home	143	3%
Installed secondary, double, triple or acoustic glazing	123	3%
None of the above	2763	66%

Table 58 shows how many of the sample reported that they had made a complaint about noise from aircraft, airfields, and airports during the night-time (23.00-07.00) within the past year. Only 4% of the sample had made a complaint. The most reported behaviours were complaining to an airport, airport owner, airport operator or airport consultative committee (1%); a resident's association (1%), to a councillor (0.7%) or a Member of Parliament (MP) (0.5%); or to a newspaper or TV/Radio Station (0.5%). The data show that within the ANNE sample it was not common to make a complaint about aviation noise at night. Of those who made a complaint, nearly three-quarters complained to one party (71%), one-sixth to two parties (15%), and one-sixth to three or more parties (16%).

³⁶ Acoustic glazing is specifically treated to disrupt soundwaves. Double or triple glazing comprises two or three panes of glass with a gap typically containing argon gas but are not specifically treated to disrupt soundwaves.

Table 58: Complaint behaviours

Complaint behaviours	ANNE sample	
	N	%
Did you complain, write or speak to any of the following about the noise from aircraft, airfields and airports during the night-time (23.00-07.00) within the last 12 months? (q34)		
An airport, airport owner, airport operator or airport consultative committee	59	1%
A resident's association	49	1%
A councillor	30	0.7%
A Member of Parliament	22	0.5%
A newspaper or TV/Radio Station	21	0.5%
The Civil Aviation Authority	17	0.4%
One or more airlines	15	0.4%
The Environmental Health Department in the Local Authority (Council)	14	0.3%
Another Local Authority (Council) Department	10	0.2%
A government department	4	0.1%
The police	1	0.02%
Other	4	0.1%
None of the above	4012	96%
Any complaint made	153	4%
(Of those who complained) Number of parties participants complained to		
1	108	71%
2	23	15%
3	7	5%
4	7	5%
5	6	4%
6	1	0.7%
7	1	0.7%

Table 59 shows the changes to dwellings by airport noise insulation schemes. This was a multiple-choice question, where participants could tick multiple options. 6% of the sample reported that they had had changes made to their dwelling as part of an airport noise insulation scheme, with 3% reporting double or triple glazing, 1% reporting secondary glazing, 1% insulation for roofs, lofts, doors, or windows and 1% changes to the walls (e.g., soundproofing). Just over half the sample (56%) reported that no changes to their dwelling had been made as part of a noise insulation scheme. One-fifth of the sample (21%) did not know if their dwelling had been part of a noise insulation scheme, which may influence the reliability of the percentages reported for this question.

Table 59: Changes to dwelling by airport noise insulation scheme

Changes	ANNE sample	
	N	%
Has your home had any of the following changes made to it as part of a noise insulation scheme run by an airport? (q35)		
Double or triple glazing	145	3%
Secondary glazing	42	1%
Changes to the walls (e.g., soundproofing)	27	0.6%
Insulation for roofs, lofts, doors, or windows	24	0.6%
Ventilation units (to allow fresh air into your home without opening windows and doors)	16	0.4%
Replacement external doors	11	0.3%
Acoustic glazing	10	0.2%
Changes to the ceiling (e.g., overboarding/soundproofing)	4	0.1%
Other	8	0.2%
No changes have been made to my home as part of a noise insulation scheme run by an airport	2349	56%
Don't know	860	21%
Any change made	231	6%

a) Exposure-response functions for highly annoyed (HA_v) (5-point verbal scale) and L_{Aeq,8h} by non-acoustic factors³⁷

This section reports a number of ERFs L_{Aeq,8h} and HA for sub-groups of the ANNE sample. For some of the non-acoustic factors examined, the sub-samples are small when considered by noise exposure, and hence, the findings are, and should be, considered preliminary, rather than definitive.

The non-acoustic factors examined included:

- Noise sensitivity;
- Attitudes to whether living near an airport is good for the local economy;
- Home insulation;
- Household related aviation;
- NS-SEC (socioeconomic classification);
- Ethnicity;
- Age;
- Health; and
- Length of time living in the home.

These were identified a priori from previous literature as likely to influence annoyance responses but represent only a small proportion of the data available within the survey. Further work examining non-acoustic factors could be undertaken.

The analyses in this section examine whether participants in the different sub-groups have different reactions to aircraft noise across noise exposure. For example, are noise sensitive people generally more annoyed across noise exposure (examining whether the “intercept” terms in the regression models are different). This involves including both noise and the sub-group as main effects in the regression model. If the main effect for the sub-group is statistically ($p < 0.05$) or borderline significant ($p < 0.10$), the relationships are plotted and narratively described. If the main effect for the sub-group is not statistically or borderline significant, the relationship is not plotted or described.

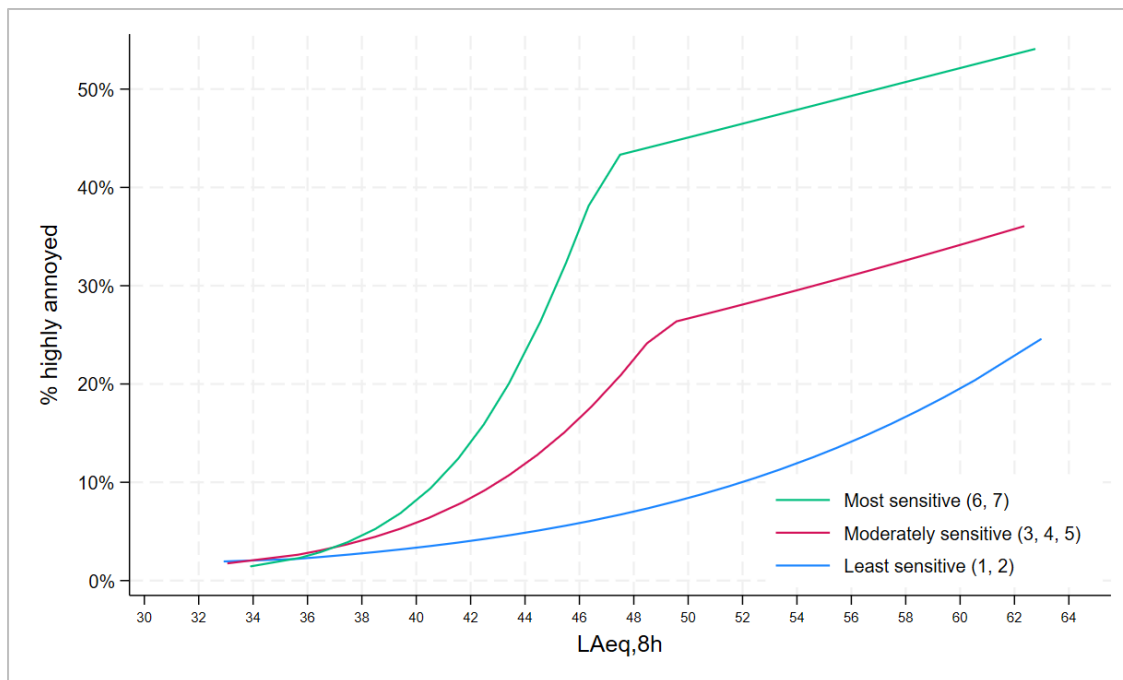
i. Noise sensitivity

Figure 23 shows the ERF between L_{Aeq,8h} and HA for the sample, by noise sensitivity (q50). Noise sensitivity was collapsed into tertiles for analysis, grouping the ‘least noise sensitive’ (scores of 1 and 2; $n=854/22\%$), the ‘moderately noise sensitive’ (scores of 3, 4 and 5; $n=2,289/58\%$) and the ‘most noise sensitive’ (scores of 6 and 7, $n=810/20\%$). Being moderately or most noise sensitive was associated with statistically significantly higher levels of HA, compared with being least noise sensitive ($p < 0.001$, respectively).

³⁷ In this section the number/% of participants in each category will differ to previous tables (e.g., in section 3.1). This is because the statistical weight used for these analyses gives even weights across noise exposure groups to enable stronger comparisons across them, whereas the weight used for the descriptive analyses gives participants in low noise areas much higher weight, so that they reflect the population.

The Figure shows that noise sensitivity increases the reports of being highly annoyed. The least noise sensitive sub-sample report lower rates of annoyance, followed by the moderately noise sensitive sub-sample, and then the most noise sensitive sub-sample, across all noise exposures, except the lowest <36dB $L_{Aeq,8h}$. These differences are substantial at the higher exposures (e.g., above 47dB $L_{Aeq,8h}$), with there being >20% difference in the percentages between the most noise sensitive and the moderately noise sensitive sub-groups, and the moderately noise sensitive and the least noise sensitive, respectively. The difference in the percentages is over 30% comparing the most and least noise sensitive sub-groups exposed above 47dB $L_{Aeq,8h}$.

Figure 23: Plot of highly annoyed (HA_V) as a function of $L_{Aeq,8h}$, dB, by noise sensitivity



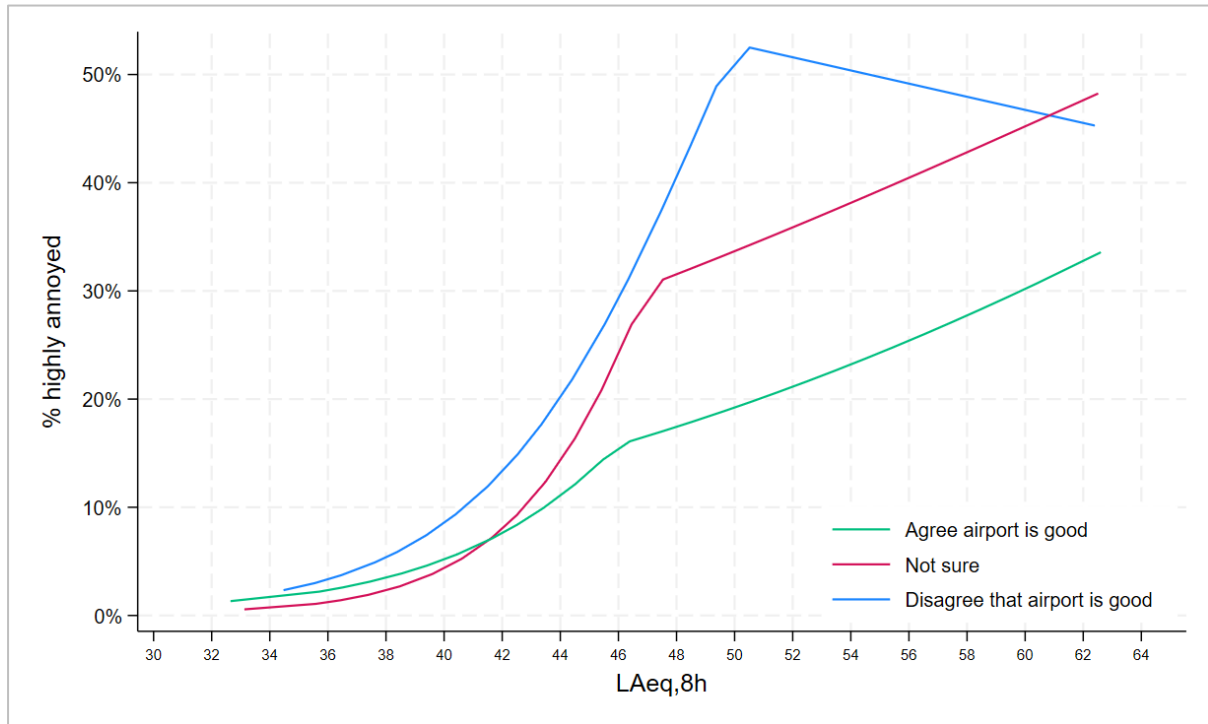
ii. Attitudes

Figure 24 shows the ERF between $L_{Aeq,8h}$ and HA for the sample, by attitude to the airport (q30; attitude 3). Responses to the question 'having an airport in the area is good for the local economy' were collapsed for analysis into 'Strongly Disagree/Disagree' (most negative attitude) (n=454/12%), 'neutral/not sure' (n=965/24%), and 'Strongly Agree/Agree' (most positive attitude) (n=2,523/64%). The most negative attitude to the airport was statistically associated with higher levels of HA, compared to the most positive attitude sub-group ($p < 0.001$). Neutral attitudes were borderline statistically significantly associated with higher levels of HA, compared to the most positive attitude sub-group ($p = 0.057$).

The Figure shows that negative attitudes to the airport increases the reports of being highly annoyed. The sub-sample with more positive attitudes to the airport report lower rates of annoyance, followed by the sub-sample with neutral attitudes, and then the sub-sample with negative attitudes, across all noise exposures, except the lowest <36dB $L_{Aeq,8h}$. These differences are substantial at the higher exposures (e.g., above 47dB $L_{Aeq,8h}$), with there being more than a 10% difference in the percentages between the negative attitude and the neutral attitude sub-groups. A similar magnitude of difference was observed between the

neutral attitude and positive attitude sub-groups up to $\sim 56\text{dB } L_{Aeq,8h}$, with the differences diminishing at higher exposures, which might be due to low power in the data. The ERF for the sub-group with the most positive attitudes is similar to the ERF for the whole sample, indicating that high levels of annoyance are observed even for those with more positive attitudes. Neutral and negative attitudes seem to increase annoyance further.

Figure 24: Plot of highly annoyed (HA_V) as a function of $L_{Aeq,8h}$, dB, by attitude to the airport

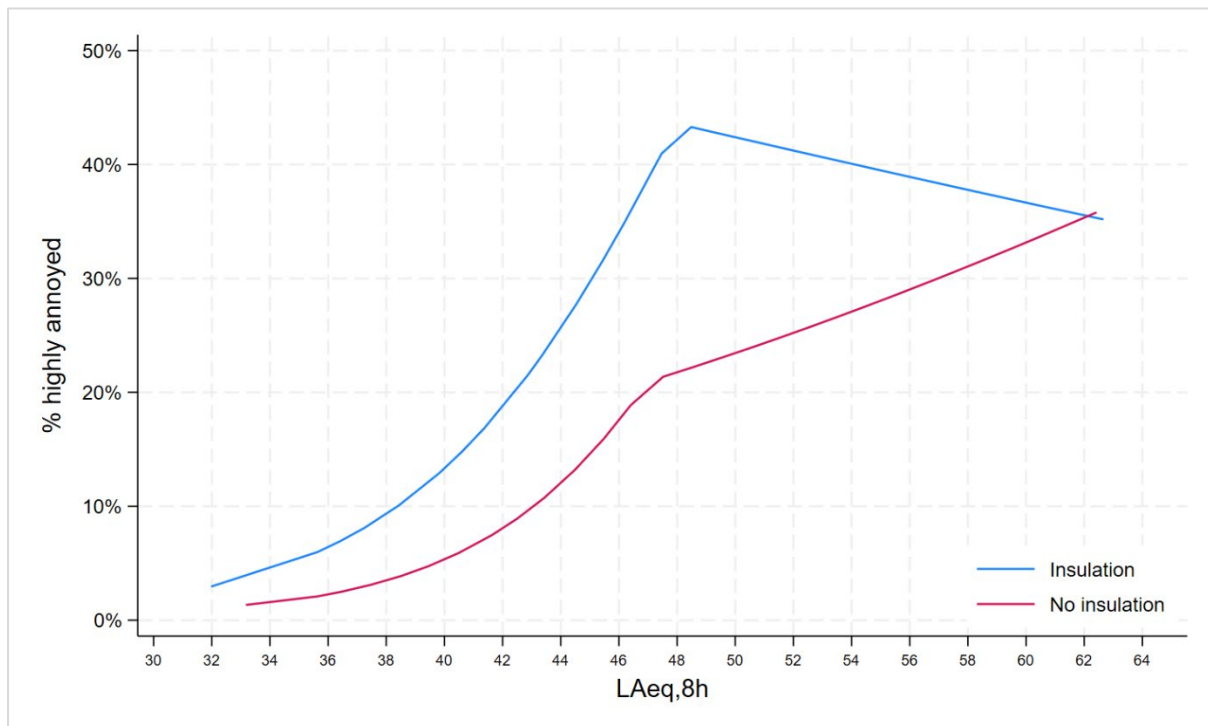


iii. Insulation

Figure 25 shows the ERF between $L_{Aeq,8h}$ and HA for the sample, by whether the participants reported having had any insulation work undertaken at the home as part of an Airport Noise Insulation Scheme (q35). The question on noise insulation was collapsed for analysis into having received 'any insulation' ($n=702/18\%$) and 'no insulation' which included don't know or missing data ($n=3,276/82\%$). Having no noise insulation was statistically significantly associated with lower rates of HA, compared to those with noise insulation ($p=0.011$).

As previously reported, many participants were unaware of whether or not their home had been part of such a scheme: these data are analysed here within the 'no insulation' group³⁸. The figure shows that insulation was associated with higher reports of being highly annoyed. Unexpectedly, the sub-sample reporting insulation had higher rates of annoyance, than the sub-sample reporting not having insulation, across all $L_{Aeq,8h}$ exposures, except 62dB $L_{Aeq,8h}$. These differences were greater for the mid-exposures, than for the highest exposures.

Figure 25: Plot of highly annoyed (HA_V) as a function of $L_{Aeq,8h}$, dB, by insulation

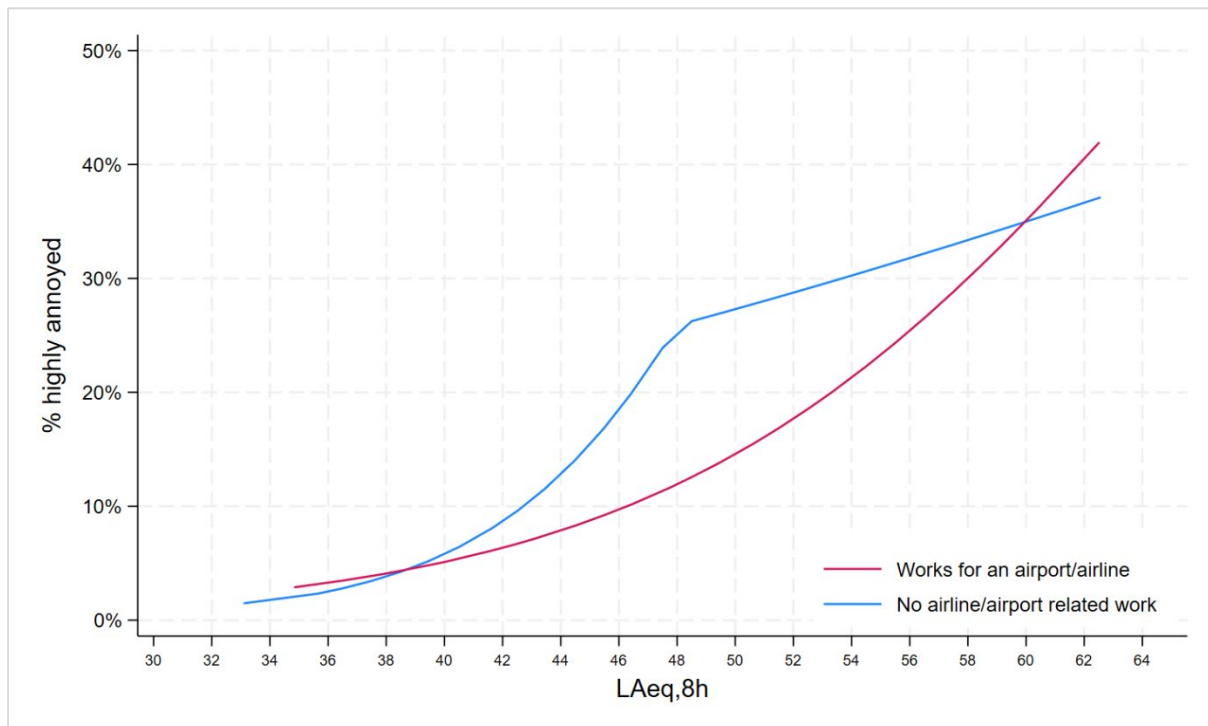


³⁸ The data were analysed as reported. Insulation schemes are typically offered to those living in dwellings with relatively high noise exposure levels. A few participants with lower levels of noise exposure reported being part of an insulation scheme. So, these participants are unlikely to have been part of an airport insulation scheme but we cannot rule out that they may have undertaken their own insulation works, or that those who are noise sensitive may have undertaken their own insulation works.

iv. *Household member's employment related to aviation*

Figure 26 shows the ERF between $L_{Aeq,8h}$ and HA for the sample, by household aviation employment (q59). The question on aviation employment was collapsed into 'any aviation related employment' (n=386/10%) and no aviation related employment which included missing data (n=3,592/90%). Having household related employment in aviation was borderline statistically significantly associated with lower rates of HA, compared to those with no household related employment in aviation ($p < 0.055$). The ERFs were similar at lower levels of exposure ($< 42\text{dB } L_{Aeq,8h}$) and at the highest exposures ($> 60\text{dB } L_{Aeq,8h}$) but reports of annoyance were much higher for those with no aviation related employment in the household between 44-60dB $L_{Aeq,8h}$.

Figure 26: Plot of highly annoyed (HA_v) as a function of $L_{Aeq,8h}$, dB, by household aviation employment



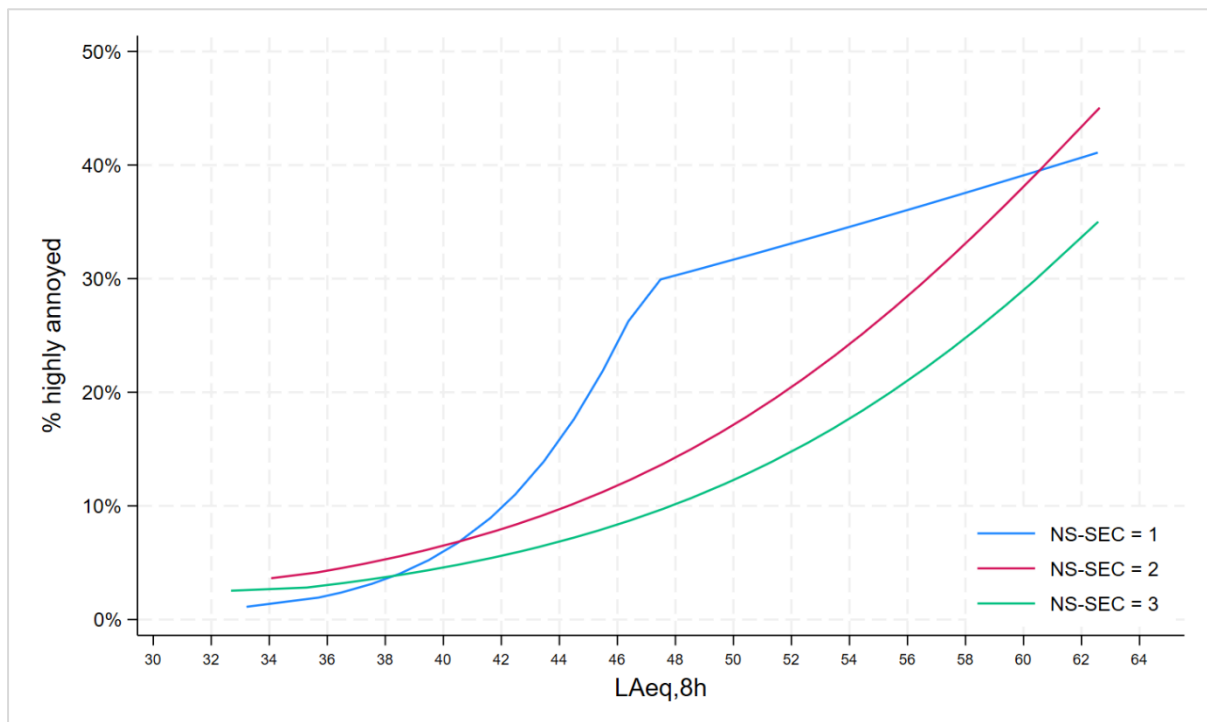
v. NS-SEC

Figure 27 shows the relationship between $L_{Aeq,8h}$ and HA for the sample, split by NS-SEC. The five NS-SEC groups (see Table 9) were collapsed into three groups for the analysis:

- (1) 'Higher managerial, administrative, and professional occupations' (n=2,304/63%),
- (2) 'Intermediate occupations' (n=639/17%) which includes 'Intermediate occupations' and 'Small employers and own account workers', and
- (3) 'Routine and manual occupations' (n=728/20%) which includes 'Lower supervisory and technical occupations' and 'Semi-routine and routine occupations'.

'Intermediate occupation' and 'Routine and manual occupation' were both statistically significantly associated with lower rates of HA, compared to those with 'Higher managerial, administrative, and professional occupations' ($p < 0.001$, respectively). From $>42\text{dB } L_{Aeq,8h}$ there are differences in the reports of HA between the NS-SEC groups. Annoyance is highest for the 'Higher managerial, administrative and professional occupations', followed by the 'Intermediate occupations', then the 'Routine and manual occupations'. At the highest exposure ($>60\text{dB } L_{Aeq,8h}$) the 'Higher managerial, administrative and professional occupations' and the 'Intermediate occupations' groups have a similar response. These differences by NS-SEC are substantial for some exposures, indicating a 10-20% difference in reports of annoyance.

Figure 27: Plot of highly annoyed (HA_V) as a function of $L_{Aeq,8h}$, dB, by NS-SEC

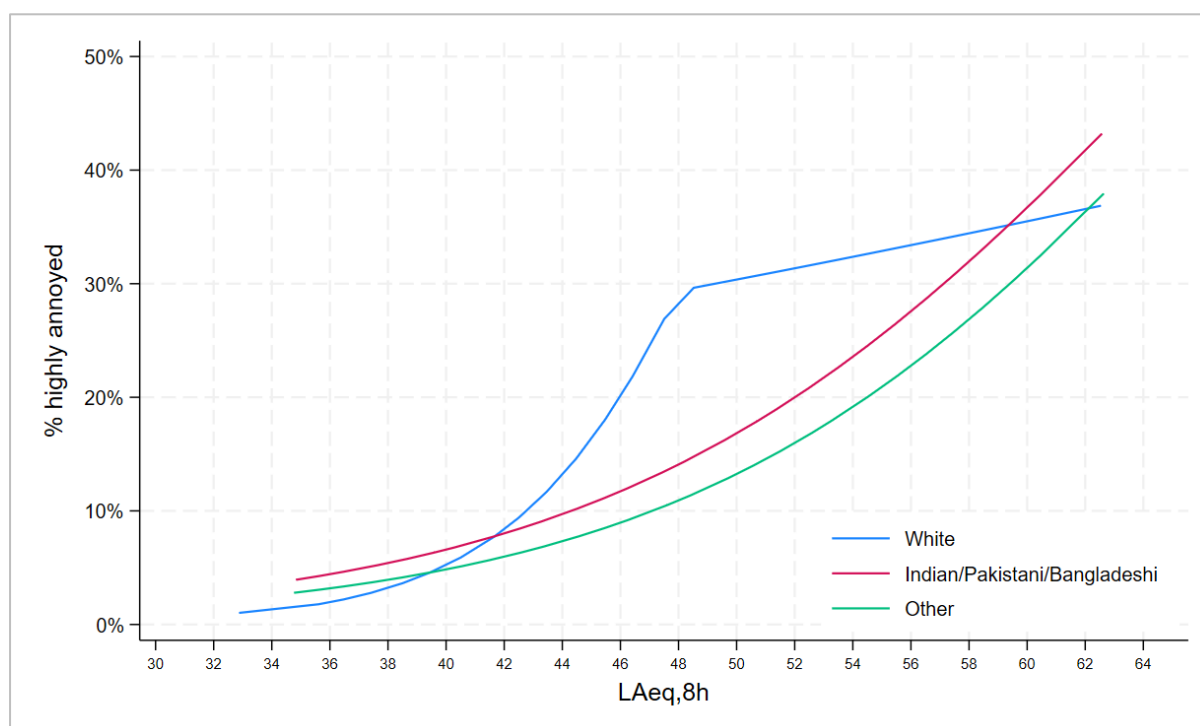


vi. Ethnicity

Figure 28 shows the relationship between $L_{Aeq,8h}$ and HA by ethnicity. The ethnic groups were collapsed for analysis into 'White' (n=2,574/65%), 'Asian' (Bangladeshi/Indian/Pakistani) (n=838/21%), and 'Other' (n=535/14%). 'Asian' ethnic group was associated with statistically significantly lower rate of HA, compared to the 'White' ethnic group ($p<0.001$). 'Other' ethnic group was associated with a borderline statistically significantly lower rate of HA, compared to the 'White' ethnic group ($p<0.055$).

The figure shows that the ERFs were very similar for the 'Asian' and the 'Other' groups across all the exposure groups. Annoyance was similar at lower exposures across all three ethnic groups (below 44dB $L_{Aeq,8h}$) but the 'White' ethnic group reported markedly higher annoyance for exposures between 44dB-<58dB. This might be accounted for by the relatively lower proportion of population exposed to these levels of noise for the 'Asian' and 'Other' ethnic groups compared with the 'White' ethnic group in the ANNE sample.

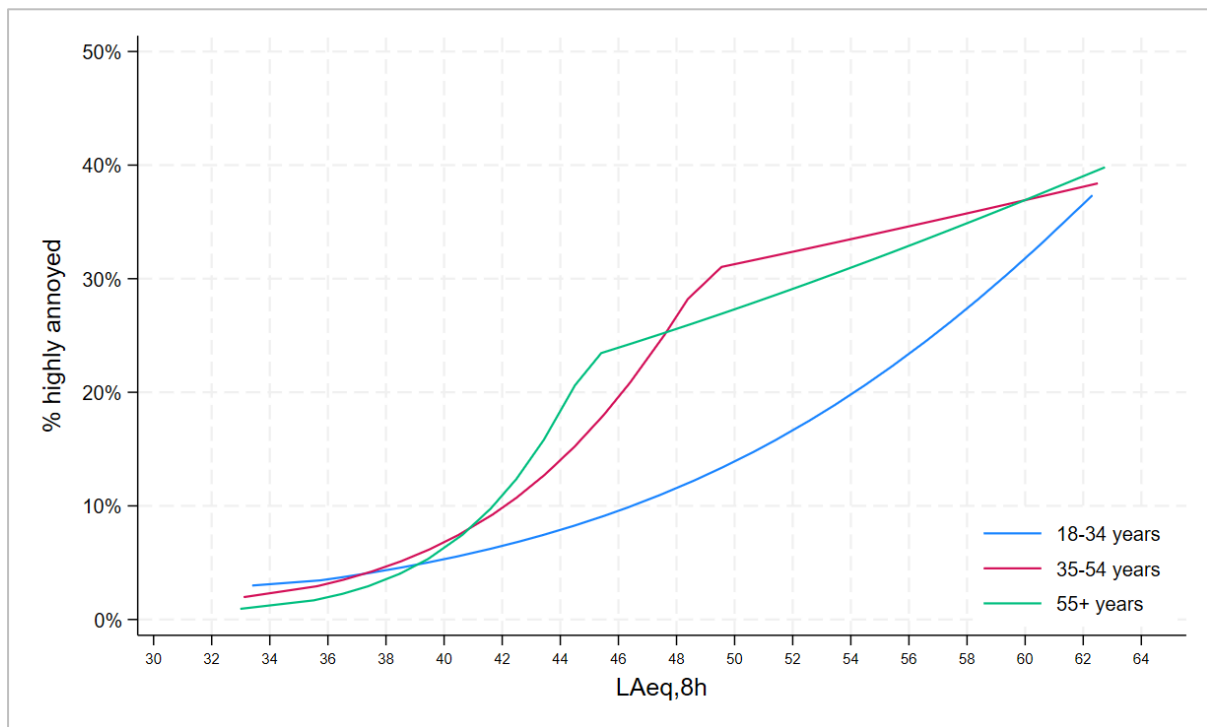
Figure 28: Plot of highly annoyed (HA_V) as a function of $L_{Aeq,8h}$, dB, by ethnicity



vii. Age

Figure 29 shows the relationship between $L_{Aeq,8h}$ and HA by age. The age groups were collapsed for analysis into '18-34 years' (n=1,121/28%), '35-54 years' (n=1,495/38%), and '≥55 years' (n=1,345/34%). Being '35-54 years' and '≥55 years' was associated with statistically significantly higher rates of HA, compared to the '18-34 years' group ($p < 0.001$, respectively). The figure suggests that the 18-34-year-old group report lower annoyance than those aged '35-54 years' and '≥55 years', except at the lowest and highest exposures. The ERFs were fairly similar for the '35-54 years' and the '≥55 year' age groups across all exposures, with responses differing most for the mid-range of noise exposure. From 43dB $L_{Aeq,8h}$ the %HA for the younger age group is over 10% lower than that observed for the two older age groups.

Figure 29: Plot of highly annoyed (HA_V) as a function of $L_{Aeq,8h}$, dB, by age



viii. Health

For analysis, self-reported health, was collapsed into 'very good or 'good' health (n=2,950/74%) and 'fair, bad, or very bad' health (n=1,019/26%). Poorer health was not statistically significantly associated with higher or lower rates of HA, compared to those in better health ($p=0.261$), so no further data is presented.

ix. Length of time in current home

The length of time participants lived in their current home (q62) was collapsed into 'up to 2 years' (n=631/16%), '2 to 10 years' (n=1,371/35%), and 'over 10 years' (n=1,963/50%) for analysis. However, length of time in the home was not statistically significantly associated with higher or lower rates of HA, so no further data is presented ($p=0.584$ and $p=0.893$, respectively). These findings suggest that it isn't the case that people who have lived in their homes for longer are less annoyed or have got 'used to the noise' or that they have adapted or habituated to the environmental conditions.

b) Summary of ANNE survey - non-acoustic factors

Non-acoustic factors are factors other than the noise level, per se, which can influence noise annoyance. These can include personal factors such as noise sensitivity, coping, control; tangible factors such as a quiet façade to the home; and psychosocial factors such as attitudes to the noise maker, perceived fairness, perceived benefits (Fenech et al., 2021, Riedel et al., 2021).

Previous studies have also suggested that certain groups in society may be more vulnerable to the effects of aircraft noise on annoyance or health outcomes including the elderly, shift workers, children, those with pre-existing ill-health, and those who are noise sensitive (European Environment Agency, 2020, Tarnopolsky et al., 1980, van Kamp and Davies, 2013). Vulnerability can be considered in terms of whether the same noise exposure has a greater health impact for these groups.

Analyses of non-acoustic factors demonstrate that the ERF between $L_{Aeq,8h}$ and being highly annoyed differ for a number of non-acoustic factors. Higher annoyance was reported by those who are noise sensitive; had received insulation; and from 'Higher managerial, administrative, and professional occupations'. Lower annoyance was reported for those who had household members in aviation-related employment; and who were younger (18-34 years). There was little influence of self-reported health status, or the number of years lived in the home on the association between aviation noise at night and annoyance. However, these results have to be considered indicative and not definitive, in light of the numbers available for analyses within some of the sub-groups examined.

SoNA 2014 previously reported that the association between day-time aviation noise ($L_{Aeq,16h}$) and being highly annoyed differed by noise sensitivity and expectations of change at the airport. It is clear from SoNA 2014 and the ANNE study that noise sensitivity is an important modifier of annoyance responses.

The ANNE study sampled a higher proportion of participants from 'higher managerial, administrative, and professional occupations', than found in the general population. The higher ERF between $L_{Aeq,8h}$ and being highly annoyed for this group, suggests that the ERF estimated in the ANNE study between $L_{Aeq,8h}$ and being highly annoyed may over-estimate the true level of annoyance in the population.

The ANNE study asked participants to indicate if their home had been part of a noise insulation scheme run by an airport. It might be expected that noise insulation, as a result of lowering noise exposure within the home, might be associated with lower annoyance responses. Unexpectedly, the ERF between $L_{Aeq,8h}$ and being highly annoyed was higher for those whose homes had received insulation than for those who had not. There are several possible explanations for this finding.

There might be issues with the accuracy of the participants' reports for this particular question, as there were a high level of "don't know" responses, and participants may have difficulty recalling which specific changes may have been made to their home or may not know whether their home has historically been part of a scheme before they moved in. Further, participants who are not eligible for a scheme may undertake and have reported their own insulation activities. Participants who have received insulation will be exposed to

higher levels of aviation noise than those who would not be eligible for a noise insulation scheme run by an airport and are likely to still experience noise outside of their home. Whilst the ANNE study is focused on night-time exposure, it is possible that noise is still heard within the home, even for those with insulation; and that attitudes about noise exposure outside of their home, during the daytime and/or evening may also be influencing the reports of annoyance during the night-time. Future surveys should consider further developing the questions on insulation to improve accuracy and detail of reporting.

Length of time living in the home did not alter the strength of the ERF between $L_{Aeq,8h}$ and being highly annoyed. This suggests that people do not 'get used to the noise' or adapt to having noise exposure during the night-time. Conversely, self-rated health did not alter the strength of the ERF between $L_{Aeq,8h}$ and being highly annoyed. It has been hypothesised that ill-health might be a vulnerability factor for noise effects on health (European Environment Agency, 2020). The ANNE study used a standard question to assess health, but future studies may additionally consider collecting self-reports of a number of health conditions to explore this issue further.

4 Equations

To enable others to use the relationships from the ANNE study to estimate effects for annoyance, sleep disturbance and wellbeing we provide the regression equations below.

a) Highly annoyed (HA_v) by L_{Aeq,8h}

$$HA_v = \frac{100}{1 + e^{12.065 - 0.2312*Z - 0.0446*Y}} \text{ where } Z = \min(L_{Aeq,8h}, 47), Y = \max(0, L_{Aeq,8h} - 47)$$

b) Highly annoyed (HA_v) by L_{night}

$$HA_v = \frac{100}{1 + e^{10.210 - 0.1902*Z - 0.0405*Y}} \text{ where } Z = \min(L_{night}, 48), Y = \max(0, L_{night} - 48)$$

c) Highly sleep disturbed by L_{Aeq,8h}

$$HSD = \frac{100}{1 + e^{12.551 - 0.2365*Z - 0.0320*Y}} \text{ where } Z = \min(L_{Aeq,8h}, 47), Y = \max(0, L_{Aeq,8h} - 47)$$

d) Highly sleep disturbed by L_{night}

$$HSD = \frac{100}{1 + e^{10.174 - 0.1827*Z - 0.0162*Y}} \text{ where } Z = \min(L_{night}, 49), Y = \max(0, L_{night} - 49)$$

5 Discussion

5.1 Introduction

The aims of the ANNE study were:

1. To estimate the association of night aviation noise on subjective sleep disturbance and annoyance for a sample of residents living near UK airports using a range of time-average metrics ($L_{Aeq,8h}$, L_{night} , N60, overflights) and for different hourly periods between 21.00-08.00 hours using the $L_{Aeq,1h}$ metric.
2. To examine if the effects of night aviation noise on annoyance differ by age, ethnicity, noise sensitivity, and pre-existing illness.
3. To examine how the effects of night aviation noise on annoyance differ by non-acoustic factors.

The study was designed to examine annoyance and sleep disturbance in a national sample exposed to aviation noise during the night-time. This differs from the SoNA 2014 survey, where the sample was selected based on daytime aviation noise exposure, with post-hoc analyses subsequently analysing night-time aviation noise exposure. This research was also designed to be a snapshot of people's attitudes, reflecting people's views on annoyance and sleep disturbance at the time of completing the survey. As a result, the findings from this study are indicative, rather than conclusive.

Key strengths of the ANNE study include sampling down to low levels of aviation night-noise exposure, as well as analyses that statistically test and reflect the shape of the relationships between aviation night noise and the outcomes.

Findings should be considered in the light of small number of the sample exposed to higher levels of aviation noise at night; small numbers for some sub-group analyses examining non-acoustic factors; and that any estimate of noise exposure will carry some uncertainty (estimated at +/- 1dB for this study (See Appendix Section 6.4.)). Small differences in terms of dB exposure between some findings should not be unduly emphasised in terms of potential effect or importance. Further, there are greater uncertainties in estimating lower levels of exposure. Also, indoor noise is attenuated to an unknown degree in the study, as it is dependent on building characteristics (window type and glazing, building skin, indoor reverberations), as well as on behaviours including window opening and other coping behaviours.

The ANNE study is the first UK study focused on the effects of aviation night-noise since the 1992 UK Sleep Study funded by the Department for Transport which used actimeters (sensors which track movement) to monitor sleep in a representative sample of 400 residents from around London Heathrow, London Gatwick, London Stansted, and Manchester airports (Ollerhead et al., 1992). As that study focused on objective sleep disturbance it is a better comparator for the ongoing ANNE objective sleep disturbance study, than for the ANNE survey analyses in this report.

This section summarises the findings of the ANNE survey for each study aim.

5.2 Aim 1

To estimate the association of night aviation noise on subjective sleep disturbance and annoyance for a sample of residents living near UK airports using a range of time-average metrics ($L_{Aeq,8h}$, L_{night} , N60, overflights) and for different hourly periods between 21.00-08.00 hours using the $L_{Aeq,1h}$ metric.

All of the noise metrics examined ($L_{Aeq,8h}$, L_{night} , $L_{Aeq,1h}$, N60 and overflights at 4,000ft and 7,000ft) showed associations with annoyance and sleep disturbance. These could be statistically tested for $L_{Aeq,8h}$, L_{night} , $L_{Aeq,1h}$ but not for N60 and overflights at 4,000ft and 7,000ft.

Focusing on the standard 8-hour night-time period (23.00-07.00) the ANNE study found for time-averaged exposure over the 8-hour night-time period ($L_{Aeq,8h}$) that very few participants reported being HA at the lowest exposure (<36dB $L_{Aeq,8h}$). 10% of the sample were 'highly annoyed' at 43dB $L_{Aeq,8h}$, with annoyance increasing with exposure, until levelling out at around 30% HA for exposures in the 55-60dB $L_{Aeq,8h}$ range. Similar patterns were seen for other night noise metrics, with 10% of the sample being HA for 5-<10 events for N60; and for <1 overflight (4,000ft & 7,000ft). Similarly, very few participants reported being HSD at <36dB $L_{Aeq,8h}$. 10% of the sample were highly sleep disturbed at 44dB $L_{Aeq,8h}$, with sleep disturbance increasing with exposure, and levelling out at around 20-25% HSD for exposures in the 50-60dB $L_{Aeq,8h}$ range. Similar patterns were seen for other night noise metrics, with 10% of the sample being HSD for 5-<10 events / 10-<20 events for N60; and for <1 overflight (4,000ft).

The analyses also found annoyance and sleep disturbance effects outside the traditional 23.00-07.00 hour night-time period. Whilst some relationships for annoyance for the one-hour periods look similar to that for the 8-hour period, quite a few of the relationships suggest that annoyance levels are higher at lower exposure levels than suggested by the 8-hour exposure ERF. The lowest aviation noise exposure thresholds for 10% HA were found for 03.00-04.00, 04.00-05.00 and 05.00-06.00 hours, where very low levels of exposure were associated with annoyance (40dB, 36dB, and 40dB, respectively).

The exposure level at which 10% reported being HSD also varied. The lowest aviation noise exposure threshold for 10% HSD was found for 04.00-05.00 hours (37dB), and the hours with the lowest thresholds were similar to those observed for HA, being the hours between 03.00 and 06.00. In general, the threshold was lower between 00.00-06.00 (ranging between 37-47dB) than for 21.00-00.00 and 06.00-08.00 (ranging between 51-<53dB).

It should be remembered that the ANNE study cannot, and should not, be used to speculate on what the relationship between aviation night-noise and health would look like for exposure levels higher than ~60dB, as these levels were not examined in the ANNE study and are rarely seen in the UK context.

5.3 Aim 2

To examine if the effects of night aviation noise on annoyance differ by age, ethnicity, noise sensitivity, and pre-existing illness.

The ANNE study found that higher annoyance was reported by those who are noise sensitive, had received insulation, and those from 'higher managerial, administrative, and professional occupations'. Lower annoyance was reported by younger participants (18-34 years). There was little influence of self-reported health status, or the number of years lived in the home on the association between aviation noise at night and annoyance. This suggests that people do not 'get used to' the exposure or adapt or habituate. There were few differences in annoyance by ethnicity, with the exception that the 'White' ethnic group reported markedly higher annoyance for exposures between 44dB-<58dB compared with the 'Asian' and 'Other' ethnic groups. However, this could be explained by low numbers of 'Asian' and 'Other' ethnic groups exposed at these noise levels.

5.4 Aim 3

To examine how the effects of night aviation noise on annoyance differ by non-acoustic factors.

The ANNE study found that higher annoyance was reported by those holding negative attitudes about airports: differences of ~20% in HA were observed between the negative attitude and positive attitude sub-groups for some exposures $\geq 50\text{dB } L_{Aeq,8h}$. Annoyance was lower for those with aviation related employment in the household.

5.5 Next steps

This report presents initial analyses focused on the aims outlined above. Further analyses could be undertaken given the breadth of survey data available. This section summarises potential further uses of the data, with the caveat that the ANNE sample may lack statistical power to examine all these factors or research questions robustly (i.e., some outcomes or variables may be reported by only a few participants within the sample, and/or across noise exposures, limiting their use).

A small number of non-acoustic factors have been examined in relation to annoyance in this report. Further non-acoustic factors could be examined in relation to annoyance, including examination of how attitudes to aviation influence response, as well as how engagement with the aviation industry (e.g., employment or flying behaviour) influence response. It would be possible to use data reduction techniques (e.g., principal components analysis) to derive scales to assess attitudes to aviation for use in further analyses. It would also be interesting to examine window-opening behaviour. There is interest from many stakeholders in examining how being a member of a campaign group influences responses. However, only $n=34$ (0.8%) of the sample reported being a member of a campaign group (see Table 7): this is too small for further analysis.

This report has focused on the subjective sleep disturbance outcome of HSD, yet additional questions about subjective sleep disturbance were collected and could be analysed including sleep quality and use of sleep medication. It would also be possible to explore in more detail the role of potential moderators of associations between aviation night-noise and sleep disturbance and quality including health status and window-opening behaviour.

This report has not examined non-acoustic factors in relation to sleep disturbance. It would be interesting to see if the same relationships were found for HSD as for HA, and also whether any particular non-acoustic factors were more important for HSD compared with HA, and vice versa. Given similarities in the report between findings for HA and HSD they are likely to be similar, but this should be examined.

It may also be possible to add further noise exposure data to the ANNE data, for example, data from the Environmental Noise Regulations noise mapping. This would enable exploration of the role of ambient background noise and co-exposure to other environmental noise sources, e.g., road traffic or railway noise on the associations between aviation night-noise and annoyance and sleep disturbance.

The ANNE survey has examined a range of time-averaged A-weighted metrics to characterise aircraft noise exposure in relation to annoyance and subjective sleep disturbance. It has not been able, nor was it an aim, to examine the association between individual aircraft noise events and sleep disturbance. These relationships can and will be examined in the ANNE objective sleep disturbance study, which will examine the effect of individual aircraft noise events on physiologically assessed awakenings. The study will also collect sound level measurements in participants' bedrooms, enabling the examination of the relationship of internal and external aviation noise exposure on awakenings. The ANNE survey has examined some noise exposure metrics over the 8-hour night-time period (23.00-07.00) with subjective sleep disturbance and annoyance. Whilst we have explored additional one-hour periods outside and within the 8-hour night-time period, the objective sleep disturbance study will additionally examine time-averaged metrics for the period participants are asleep. After successful completion of a feasibility study in 2022-2023, the ANNE objective sleep disturbance study is expected to report in 2026.

6 Appendix

6.1 Choosing the regression models for the ANNE survey analyses

One of the aims of the ANNE survey was to generate a national ERF for aviation night-noise and being highly annoyed (HA) and highly sleep disturbed (HSD). There is a long history of these types of relationships in the field of noise and health (Miedema and Vos, 2007, Schultz, 1978, Fidell, 2003, Guski et al., 2017, Basner and McGuire, 2018, Smith et al., 2022).

ERFs are established by:

1. Plotting the data points (e.g., HA) for each noise exposure (e.g., $L_{Aeq,8h}$)
2. Using statistical analyses, in the form of a regression to establish a line between the data points, indicating the ERF.

The shape of the line will vary according to which type of regression (i.e., the underlying mathematical approach) is used, and whether the health outcome is continuous or categorical (e.g., annoyance scored on a continuous scale from 1 to 5, versus annoyance scored as being 'HA' - yes or no). Noise exposure can be plotted continuously on a 1dB scale, or in 'noise bands' which categorise a few 1dB bands together, e.g. 46->48dB, 48->50dB etc. Further, typically, the regressions which inform ERFs are unadjusted: they do not include any other factors which might influence either the exposure or the annoyance or sleep disturbance outcome (e.g., age, gender, socioeconomic factors, etc).

The regressions use the individual data from each participant, e.g. whether that particular individual was highly annoyed given their exposure estimated at e.g., 45dB $L_{Aeq,8h}$ but to illustrate the fit of the models the aggregated response across individuals with the same noise exposure (e.g., 45dB) is plotted.

For the ANNE study, the fit of a number of different regression models were compared to determine the most appropriate shape of the line that gets drawn between the data points. To enable a wide range of models to be considered, the exploratory models were fitted to the ANNE data with exposure defined using continuous $L_{Aeq,8h}$ plotted in 1dB bands for both HA and HSD.

The types of models examined were:

- a. Logistic regression with 1/noise
- b. Logistic regression with $\ln(\text{noise})$
- c. Logistic regression with $\exp(\text{noise})$
- d. Logistic regression with noise
- e. Logistic regression with noise and noise²
- f. Logistic regression with noise noise² noise³
- g. Logistic regression with noise noise² noise³ noise⁴
- h. Complementary log log regression with noise
- i. Complementary log log regression with noise noise² noise³ noise⁴
- j. Probit regression with noise noise² noise³ noise⁴

- k. Logistic function (symmetric sigmoid with intercept) on unweighted data
- l. Logistic function (symmetric sigmoid with no intercept) on unweighted data
- m. Gompertz function (asymmetric sigmoid with intercept) on unweighted data
- n. Gompertz function (asymmetric sigmoid with no intercept) on unweighted data
- o. Logistic regression with best knot at 47 and slope after knot
- p. Logistic regression with level slope after knot and best knot at 50

The models were appraised visually initially, as it is difficult to compare the different types of models statistically (e.g., logistic versus probit, sigmoid, etc).

There were no discernible differences between the logistic (d, g) versus the probit (j) or complementary log-log regression models (h, i), therefore logistic regression models were preferred as the results can be interpreted in terms of the log(odds). Similarly, the sigmoidal models (k, l, m, n) did not improve the fit of the data sufficiently to justify the added complexity of fitting them and interpreting their results.

In comparing the logistic regression models, the cubic (f) and quartic (g) regression models overfitted the data (i.e., fitting individual quirks (points) in the data rather than the population as a whole). This was particularly true when examining annoyance/sleep deprivation over individual hours of the night.

The quadratic regression (e) had a statistically significant better fit than the linear logistic regression (d) but one of the characteristics of a quadratic model is that the end of the curve at high noise values will often be predicted as decreasing despite there being no such trend in the data.

The logistic regression with 1 knot model fits two linear regression lines (on a log scale) to the data, which meet at a single point (the “knot”) (o and p). For these models, the best position of the knot has to be determined. To determine the best position of the knot it was assumed that the knot occurred at each 1dB noise level in turn and then the best fitting model was chosen. The largest Bayesian Information Criteria (BIC) was chosen as the automatic selection criteria (Kuha, 2004). The BIC is an accepted measure of how well the line fits the data and is based on summing up the distances of each point from the line and considering how complicated the model being fitted is, with large values of the BIC being good.

As well as identifying the best position for the knot, based on the data points for HA and HSD, we explored whether the regression line after the knot would best fit the data by either having a slope after the knot (i.e., continuing to show that an increase in noise exposure was associated with an increase in annoyance or sleep disturbance) (o) or by not having a slope after the knot (i.e., the first regression line shows that increasing noise exposure was associated with an increase in annoyance or sleep disturbance, which did not increase further after the knot with continuing increases in noise exposure) (p).

Following visual appraisal of the models, which ruled out many of the models, it was possible to compare the logistic regression models with each other using measures of model fit and statistical significance. Four models were considered:

- Linear Logistic regression (d) (as used in SoNA 2014)
- Quadratic logistic regression (e)

- Logistic regression with best knot at 47 and slope after knot (o)
- Logistic regression with level slope after knot and best knot at 50 (p)

These four models were also examined for $L_{Aeq,1h}$.

Table 60 shows the relative fits of the different models. The best fitting model is defined by the largest BIC (i.e., the least negative BIC) or the smallest AIC, deviance, or dispersion. All four measures agree for these models, with the model with one knot and a varying slope after the knot being the best fit (o). Note that the differences between the logistic regression model with just a linear term (d) is much larger than the differences between the other three models, with any of these three models being reasonable to adopt (e, o, p). Consideration was also given to interpretability. The model with the quadratic term (e) had the decreasing tendency at the highest noise values and so was not a preferred model.

To further inform decision making, a sensitivity analysis was undertaken, estimating the percentage HA and HSD for of these models. This showed that the type of regression model employed made subtle differences to the percentage HA and HSD for most exposures, (e.g., 41dB to 58dB), where the % difference was around 2% across the different models). At lower exposure (e.g. 33dB to 40dB) the % difference ranged 3 to 4% across the models. At higher exposure, the % difference ranged 5 to 9% across the models, indicating the lower power in the data at higher levels and slightly greater uncertainty in the estimates.

In summary, the statistical comparison of these logistic regression models suggest:

- The logistic regression models (e, o, p) tested fitted the ANNE data better than the logistic linear regression (d).
- There were not large differences between the models (e, o, p) in terms of the model fit parameters, or the estimated %HA or %HSD.
- The logistic regression with the quadratic term (e) was less favoured, due to the decreasing tendency for annoyance or sleep disturbance at the highest noise values.
- The logistic regression models with a knot were therefore favoured.
- The logistic regression line with a slope after the knot was viewed as making the most of the available data (i.e., allowing the possibility for %HA or %HSD to continue to increase with increasing noise exposure beyond the knot, regardless of whether the increase was statistically significant).
- The analysis of the $L_{Aeq,1h}$ data showed that the position of the knot moved considerably through the night-time period, so the final models also allowed for this.

Table 60: Comparison of the fit of proposed models for $L_{Aeq,8h}$ and HA

Model	Fit of Models	Position Knot	Intercept	SE (intercept)	First slope/ linear term	SE (first slope)	Second slope / quadratic term	SE (second slope)	AIC	Deviance	Dispersion	BIC
1 (d)	Logistic regression: Linear	-	-1.364	0.105	0.933	0.130	-	-	0.793	3144	0.792	-29746
2 (e)	Logistic regression: Linear and Quadratic	-	-1.141	0.120	0.984	0.090	-0.486	0.125	0.787	3118	0.786	-29764
3 (o)	Logistic regression with knot and two slopes	47dB	-12.065	1.485	0.231	0.034	0.045	0.016	0.784	3109	0.783	-29773
4 (p)	Logistic regression with knot and level after knot	50dB	-10.626	0.746	0.197	0.016	-	-	0.786	3118	0.786	-29772

Note: The parameters for models 1 and 2 were fitted to a standardised noise of (dB-50)/10 so the parameter estimates cannot be directly compared to those of models 3 and 4.

6.2 Description of the statistical analyses

This report presents a number of exposure-response functions (ERFs) which plot a noise exposure metric on the x-axis (horizontal axis) and a health outcome (e.g., mean annoyance score, the percentage highly annoyed (HA)) on the y-axis (vertical axis).

These data are then statistically analysed using generalised linear models (regression models), which plot the best-fit relationship between the noise exposure metric and the health outcome. To test the shape of the relationships, for binary outcomes (such as highly annoyed or not) logistic regression models with linear splines with 1 or 2 knots were fitted. The Bayesian Information Criteria (BIC) was used to identify the models with the best fit. Similarly for continuous outcomes linear regression models were fitted with splines including 1 or 2 knots.

Each plot contains the following data:

Table 61: Definitions and interpretations of the data in the ERFs

Feature of the ERF	Definition	Example of interpretation from Figure 30
Data point (red dot)	The health outcome estimate for the noise exposure band for the survey sample	At 43dB $L_{Aeq,8h}$ exposure, ~10% of the sample report being highly annoyed
Data point 95% confidence interval (green lines)	The range of the 'true' estimate for data point for which we have 95% confidence that the actual data point lies	We have 95% confidence that the % highly annoyed at 43dB $L_{Aeq,8h}$ exposure ranges from 5% - 21%.
Regression line(s) (blue line)	Statistically fitted <i>prediction</i> of the relationship between noise exposure and the health outcome represents the best straight line relationship across a set of data points (it does not simply join up the data points, per se). Where there appears to be two different relationships over the range of noise exposure, separate regression lines can be fitted to the data points.	Shows two regression lines have been fitted to the data points. Being highly annoyed increases with increasing $L_{Aeq,8h}$ up to around 47dB. At 43dB $L_{Aeq,8h}$ exposure, 10% of the sample are predicted to be highly annoyed (see Table 65). Above 50dB, a second regression line is fitted, as the health outcome has a different increase with increasing noise. From 55dB $L_{Aeq,8h}$ exposure, over 30% of the sample are predicted to be highly annoyed (see Table 65).

Feature of the ERF	Definition	Example of interpretation from Figure 30
Regression line 95% confidence intervals (grey shaded area around the blue line)	The range of the 'true' <i>predicted</i> estimates for the regression line for which we have 95% confidence that the actual estimates lie	At 43 $L_{Aeq,8h}$, we have 95% confidence that the % highly annoyed ranges from 9-12%.

Figure 30 and Figure 31 both plot the same data to show the relationship between noise exposure and being highly annoyed – for example 10% of people at 43dB are annoyed in both figures.

The figures look different because the scale they are plotted on is different. In Figure 30 it is the usual “arithmetic” scale in which the distance from 10 to 20% is the same as the distance from 20 to 30%. In Figure 31, a “logarithmic” scale is used, which means that the distance from 10 to 20% (a doubling) is equal to the distance from 20% to 40% (another doubling). The statistical models are fitted on this log scale, because otherwise points with very low percentages appear to be much more accurate than points with much larger percentages, which is not correct as similar numbers of people are in all the noise categories.

Figure 31 shows that the model fitted is a simple combination of two straight lines and that this fits well as most of the points are close to the lines. Figure 31 can also easily be interpreted as it shows that for each increase in 4dB up to 50dB almost twice as many people will be annoyed (e.g., 10% annoyed at 43dB and 20% at 47dB).

We have presented the approach shown in Figure 30 throughout the report as it is easier to read the percentages of people highly annoyed directly from the Figure as the percentages are equally spaced on the axis, but it does not clearly demonstrate the model fitted, which Figure 31 does. However, in Figure 31 it is harder to determine the exact percentages annoyed corresponding to each point as the values are not equally spaced out.

In summary, in this sample of people, 10% of them reported being highly annoyed at noise levels of 43dB (red dot). However, if we take into account the proportions being annoyed at both lower and higher noise levels our best estimates are that in a general population, around 10% of people (blue line) would be annoyed and that if we repeated this study, we would expect the percentage highly annoyed to lie between 9-12% (grey shaded area).

The % for HA estimated by the regression line are shown in Table 65.

Figure 30: Plot of highly annoyed (5-point scale) (HA_V) as a function of $L_{Aeq,8h}$ (92-day) noise exposure (dB). (Figure 11 from main report)

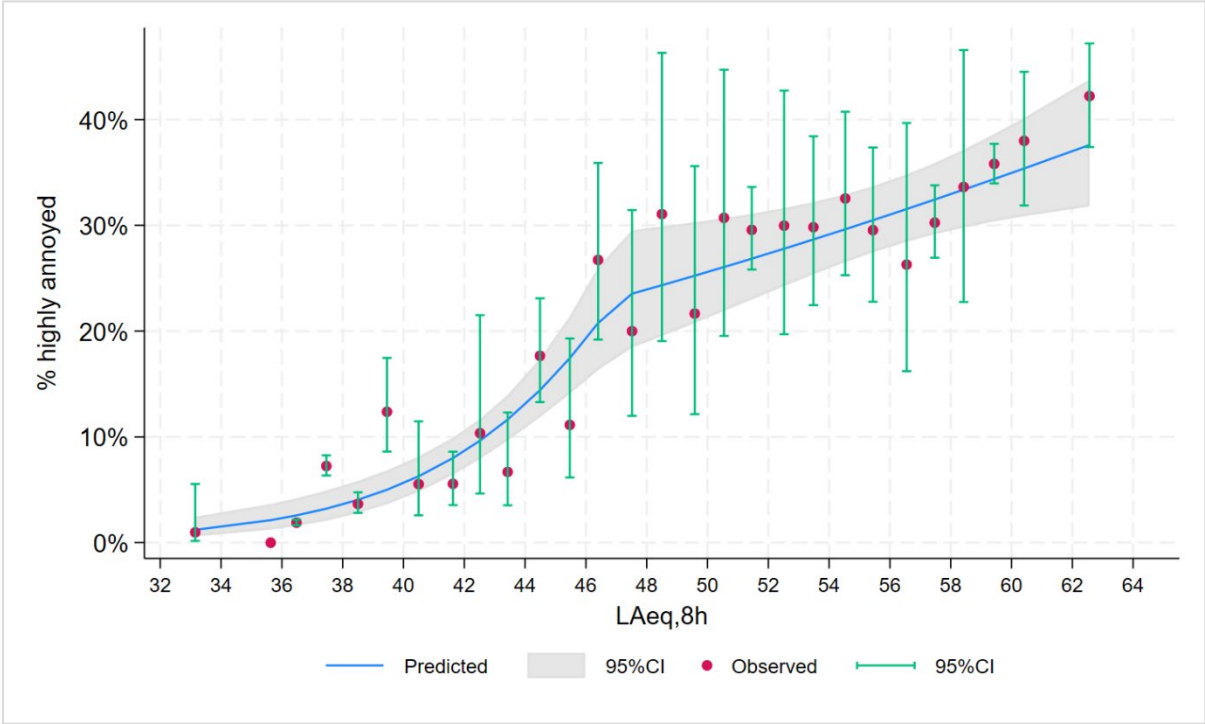
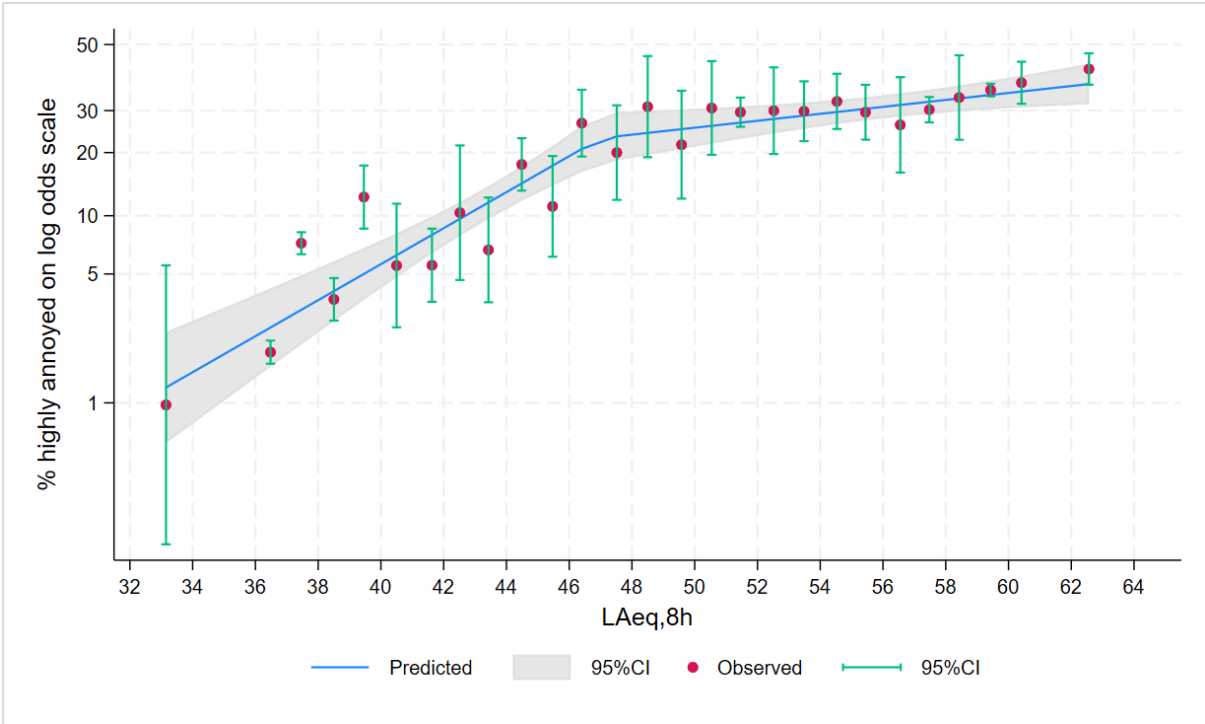


Figure 31: Plot of highly annoyed (5-point scale) (HA_V) as a function of $L_{Aeq,8h}$ (92-day) noise exposure (dB) on a log odds scale



6.3 Sensitivity analyses for percent highly annoyed

a) Example of sensitivity analysis for percent highly annoyed and $L_{Aeq,8h}$ noise exposure

As described in Section 2.5 sensitivity analyses were run additionally adjusting the exposure-response function analyses for airport and household clustering using multilevel modelling.

The table below shows the coefficients from the statistical analyses of $L_{Aeq,8h}$ and being highly annoyed unadjusted for airport and household clustering, and then adjusted for airport and additionally household clustering. The coefficients showed little change in the relationship between aviation noise exposure and being highly annoyed when these factors were taken into account. This was also true for sensitivity analyses on the sleep disturbance and wellbeing outcomes.

Table 62: Mixed-effects generalised linear model results for the association between highly annoyed (5-point verbal scale) and $L_{Aeq,8h}$ noise exposure, adjusting for airport and household

Model		Coefficient	LCI	UCI
Unadjusted	Slope 1st section	0.231	0.163	0.300
	Slope 2nd section	0.045	0.012	0.077
	Intercept	-12.065	-15.034	-9.096
Adjusted by airport	Slope 1st section	0.241	0.169	0.313
	Slope 2nd section	0.051	0.015	0.087
	Intercept	-12.460	-15.431	-9.489
Adjusted by airport and household	Slope 1st section	0.250	0.176	0.324
	Slope 2nd section	0.063	0.013	0.112
	Intercept	-13.067	-15.959	-10.176

b) Sensitivity analysis for percent highly annoyed and $L_{Aeq,1h}$ noise exposure

Sensitivity analyses were also run to examine the potential impact of the larger samples in the ANNE study from London Heathrow and Manchester airports on the findings. For example, London Heathrow which has specific operations from 04.30 onwards, could be influencing the HA findings for specific one-hour time periods (04.00-05.00 and 05.00-06.00). Table 63 shows the coefficients from the statistical analyses of $L_{Aeq,1h}$ for 04.00-05.00 and 05.00-06.00 and being highly annoyed unadjusted for airport and household clustering, and then individually adjusted for airport and then additionally household clustering. The

coefficients showed little change in the relationship between aviation noise exposure and being highly annoyed when these factors were taken into account, suggesting that the findings were not being influenced by the London Heathrow airport sample, specifically.

Table 63: Mixed effects generalised linear model results for the association between highly annoyed (5-point verbal scale) and $L_{Aeq,1h}$ noise exposure (04.00-06.00), adjusting for airport and household

Model		Coefficient	LCI	UCI
04.00-05.00				
Unadjusted	Slope 1st section	0.124	0.076	0.171
	Slope 2nd section	0.029	-0.002	0.060
	Intercept	-6.071	-7.791	-4.351
Adjusted by airport	Slope 1st section	0.124	0.097	0.152
	Slope 2nd section	0.051	0.034	0.068
	Intercept	-6.137	-6.958	-5.317
Adjusted by airport and household	Slope 1st section	0.132	0.098	0.166
	Slope 2nd section	0.060	0.034	0.086
	Intercept	-6.602	-7.588	-5.616
05.00-06.00				
Unadjusted	Slope 1st section	0.099	0.063	0.136
	Slope 2nd section	0.046	0.011	0.080
	Intercept	-5.834	-7.463	-4.205
Adjusted by airport	Slope 1st section	0.109	0.084	0.133
	Slope 2nd section	0.047	0.028	0.065
	Intercept	-5.954	-6.794	-5.114
Adjusted by airport and household	Slope 1st section	0.116	0.085	0.147
	Slope 2nd section	0.055	0.028	0.081
	Intercept	-6.378	-7.427	-5.329

6.4 Reporting checklist for social and socio-acoustic surveys (ISO/TS15666)

Table 64: Minimum specifications for reporting core information from social and socio-acoustical surveys in scientific reports

Topic area	Item	Topic	Required information
Overall design	1	Survey date	28 October 2022 to 3 January 2023
	2	Site location	United Kingdom: London Heathrow airport; London Stansted airport; Glasgow airport; London Luton airport; London Gatwick airport; East Midlands airport; Bristol airport; Manchester airport.
	3	Site selection	A range of airport sites were purposively sampled, to provide a sample with a range of night-flights characteristics (flights between 21.00-08.00). The sample includes airports undertaking freight and/or passenger flights, some of which had night-flight restrictions, or were part of a government quota scheme, or operated voluntary restrictions. Airports were selected to have different ambient background noise, and populations (urban/rural).
	4	Site size	N=4,000 individuals living near 8 UK airports which had night-flights.
	5	Study purpose	1. To estimate the association of night aviation noise on subjective sleep disturbance and annoyance for a sample of residents living near UK airports using a range of time-average metrics ($L_{Aeq,8h}$, L_{night}, N60, overflights) and for different hourly periods between 21.00-08.00 using the $L_{Aeq,1h}$ metric. 2. To examine if the effects of night aviation noise on annoyance differ by age, ethnicity, noise sensitivity, and pre-existing illness. 3. To examine how the effects of night aviation noise on annoyance differ by non-acoustic factors. Participants were informed it was a study about their 'local environment'.

Topic area	Item	Topic	Required information
Social survey sample	6	Sample selection	The target population of the survey was residents of households who live in proximity to a UK airport which operates flights during the period of 21.00-08.00.³⁹ Proximity was defined on estimated annual night-time aviation noise exposure around each airport (L_{night}) using 2022 data, rather than by geographical distance to an airport. A two-stage sampling framework was employed: Stage 1: purposive sampling of airports with night-flights based on sampling airports with freight versus passenger flights; night-flight restrictions; quota scheme; voluntary restrictions; different ambient background noise/populations (urban/rural) and availability of exposure data to use for sampling. All eligible airports were classified according to each of these characteristics and airports were selected within specific categories so that airports with different patterns of night-time noise exposure were included. Stage 2: stratified random population survey of addresses around each selected airport. Addresses around the selected airports were classified by L_{night} (2016) (≥ 35dB) and overflight data. All sampled addresses ($n=15,774$) were sent an invitation letter that invited two adults aged 18 and older in the household to complete a 20-minute online questionnaire. Participants were able to self-select which two household members took part. A £10 shopping voucher was offered to all participants who completed the survey.
	7	Achieved sample	A total of 4,183 individual participants took part, from 2,899 eligible addresses. The adjusted address-level response rate, i.e., the proportion of eligible addresses where the questionnaire was fully completed by at least one adult aged 18 and older, was 20%. A total of 4,183 individual responses were received. As individuals were not invited to participate, an individual-level response rate cannot be calculated.
Social survey data collection	8	Survey methods	This was a push-to-web survey which could be completed as an online survey or as a paper questionnaire. Three follow-up/reminder letters were sent. 26% of responses were from the paper questionnaire (1,085) and 74% (3,098) from the online survey.

³⁹ The standard definition of the night period is 23.00-07.00 and is used in both UK planning and aviation policy. The Department for Transport currently uses the period 23.30-06.00 as the period when movement and noise quotas apply at noise-designated airports. This period is commonly referred to as the 'night quota period'. 'The ANNE study is also incorporating two hours before (21.00-23.00 – referred to in the report as 'evening') and the hour after (07.00-08.00 – referred to in the report as 'morning').

Topic area	Item	Topic	Required information
	9	Questionnaire wording	The question asked “<i>Thinking about this summer, when you were here at home, how much does noise from aircraft, airports or airfields bother, disturb or annoy you during the night (11pm to 7am)?</i>”. The 5-point verbal response scale was used: ‘not at all’, ‘a little’, ‘moderately’, ‘very’, ‘extremely’. The ‘summer’ period was defined as 16th June to 15th September before the question, reflecting the 92-day summer period used in UK policy. The same format question was used to assess ‘sleep disturbance’.
	10	Precision of sample estimate	N=4,183; mean time to complete the survey was 15 minutes (range 5 to 38). Assessment of completion rates excluded 18 subjects.
Acoustical conditions (if applicable)	11	Noise source	Primary noise source - night-time aircraft. Defined as $\geq 35\text{dB } L_{\text{night}}$.
	12	Noise metrics	The following aircraft noise exposure metrics were examined: • $L_{\text{Aeq},8\text{h}}$ (92-day) – average summer night noise exposure measured between 23.00 and 07.00 for the 92-day summer period (16th June to 15th September 2022); • L_{night} (annual) – annual average night-time noise exposure between 23.00 and 07.00 for 365-day period for 2022 estimated using all tracks for each airport as occurred in 2022 therefore reflecting actual conditions; • $L_{\text{Aeq},1\text{h}}$ (92-day) – average summer noise exposure for 1-hourly periods between 21.00 and 08.00 for the 92-day summer period (16th June to 15th September 2022); • N60 (92-day) – average summer night-time number of aircraft noise events equal to or above 60dB between 23.00 and 07.00 for the 92-day summer period (16th June to 15th September 2022); and • Overflights (92-day) – average summer night-time number of overflights passing over the participant’s home based on CAP1498 Definition of an overflight published by the UK Civil Aviation Authority. Definitions included a 48.5 degree at the ground receiver at 7,000ft and 4,000ft (92-day); and degree at the ground receiver at 7,000ft and 4,000ft between 23.00 and 07.00 for the 92-day summer period (16th June to 15th September 2022).

Topic area	Item	Topic	Required information
	13	Time period	8-hour night-time period 23.00-07.00. The study also asked questions about 1-hour periods between 21.00-08.00. $L_{Aeq,8h}$, $L_{Aeq,1h}$, N60 and overflights were for the 92-day summer period (16th June to 15th September). This aligned with the reference period for the annoyance questions. L_{night} was annual for 2022. Participants who reported living at their address for less than 6 months were excluded.
	14	Estimation/ measurement procedure	All noise exposure metrics (i.e., $L_{Aeq,8h}$, L_{night}, $L_{Aeq,1h}$, and N60) were prepared using 2022 datasets obtained directly from the airports. These datasets included radar flight tracks and aircraft noise event measurement data from each of the airport's fixed noise monitoring terminals. Using this data, a noise model for each airport has been developed in AEDT 3.0e (Aviation Environmental Design Tool – a software system that models aircraft performance in space and time to estimate fuel consumption, emissions, noise, and air quality consequences used internationally). Each model has been prepared adopting the best standard of modelling described by the CAA in publication CAP2091.
	15	Reference position	Noise calculations made at nominal location assuming free-field conditions i.e. without reflection.
	16	Precision of noise estimate	Estimated uncertainty of +/- 1 dB.

Topic area	Item	Topic	Required information																																																																																																																			
Basic dose/ response analysis	17	Dose/response relationships	Highly annoyed (HA_v) by L_{Aeq,8h} $HA_v = \frac{100}{1 + e^{12.065 - 0.2312 \cdot Z - 0.0446 \cdot Y}} \text{ where } Z$ $= \min(L_{Aeq,8h}, 47), Y = \max(0, L_{Aeq,8h} - 47)$ Highly annoyed (HA_v) by L_{night} $HA_v = \frac{100}{1 + e^{10.210 - 0.1902 \cdot Z - 0.0405 \cdot Y}} \text{ where } Z$ $= \min(L_{night}, 48), Y = \max(0, L_{night} - 48)$ Highly sleep disturbed by L_{Aeq,8h} $HSD = \frac{100}{1 + e^{12.551 - 0.2365 \cdot Z - 0.0320 \cdot Y}} \text{ where } Z$ $= \min(L_{Aeq,8h}, 47), Y = \max(0, L_{Aeq,8h} - 47)$ Highly sleep disturbed by L_{night} $HSD = \frac{100}{1 + e^{10.174 - 0.1827 \cdot Z - 0.0162 \cdot Y}} \text{ where } Z$ $= \min(L_{night}, 49), Y = \max(0, L_{night} - 49)$ <table><tr><th>dB</th><th>L_{night} by HA_v</th><th>L_{Aeq,8h} by HA_v</th><th>L_{night} by HSD</th><th>L_{Aeq,8h} by HSD</th></tr><tr><td>40</td><td>6.8%</td><td>5.6%</td><td>5.4%</td><td>4.3%</td></tr><tr><td>41</td><td>8.2%</td><td>7.0%</td><td>6.5%</td><td>5.3%</td></tr><tr><td>42</td><td>9.7%</td><td>8.6%</td><td>7.7%</td><td>6.7%</td></tr><tr><td>43</td><td>11.5%</td><td>10.6%</td><td>9.1%</td><td>8.3%</td></tr><tr><td>44</td><td>13.6%</td><td>13.0%</td><td>10.7%</td><td>10.3%</td></tr><tr><td>45</td><td>16.0%</td><td>15.8%</td><td>12.6%</td><td>12.7%</td></tr><tr><td>46</td><td>18.7%</td><td>19.2%</td><td>14.7%</td><td>15.5%</td></tr><tr><td>47</td><td>21.8%</td><td>23.0%</td><td>17.2%</td><td>18.9%</td></tr><tr><td>48</td><td>25.2%</td><td>23.8%</td><td>19.9%</td><td>19.4%</td></tr><tr><td>49</td><td>25.9%</td><td>24.6%</td><td>23.0%</td><td>19.9%</td></tr><tr><td>50</td><td>26.7%</td><td>25.5%</td><td>23.3%</td><td>20.4%</td></tr><tr><td>51</td><td>27.5%</td><td>26.3%</td><td>23.6%</td><td>20.9%</td></tr><tr><td>52</td><td>28.3%</td><td>27.2%</td><td>23.9%</td><td>21.4%</td></tr><tr><td>53</td><td>29.1%</td><td>28.1%</td><td>24.2%</td><td>22.0%</td></tr><tr><td>54</td><td>29.9%</td><td>29.0%</td><td>24.5%</td><td>22.5%</td></tr><tr><td>55</td><td>30.8%</td><td>30.0%</td><td>24.8%</td><td>23.1%</td></tr><tr><td>56</td><td>31.6%</td><td>30.9%</td><td>25.1%</td><td>23.7%</td></tr><tr><td>57</td><td>32.5%</td><td>31.9%</td><td>25.4%</td><td>24.3%</td></tr><tr><td>58</td><td>33.4%</td><td>32.9%</td><td>25.7%</td><td>24.8%</td></tr><tr><td>59</td><td>34.3%</td><td>33.9%</td><td>26.0%</td><td>25.4%</td></tr><tr><td>60</td><td>35.2%</td><td>34.9%</td><td>26.3%</td><td>26.1%</td></tr><tr><td>61</td><td>36.1%</td><td>35.9%</td><td>26.6%</td><td>26.7%</td></tr></table>	dB	L _{night} by HA _v	L _{Aeq,8h} by HA _v	L _{night} by HSD	L _{Aeq,8h} by HSD	40	6.8%	5.6%	5.4%	4.3%	41	8.2%	7.0%	6.5%	5.3%	42	9.7%	8.6%	7.7%	6.7%	43	11.5%	10.6%	9.1%	8.3%	44	13.6%	13.0%	10.7%	10.3%	45	16.0%	15.8%	12.6%	12.7%	46	18.7%	19.2%	14.7%	15.5%	47	21.8%	23.0%	17.2%	18.9%	48	25.2%	23.8%	19.9%	19.4%	49	25.9%	24.6%	23.0%	19.9%	50	26.7%	25.5%	23.3%	20.4%	51	27.5%	26.3%	23.6%	20.9%	52	28.3%	27.2%	23.9%	21.4%	53	29.1%	28.1%	24.2%	22.0%	54	29.9%	29.0%	24.5%	22.5%	55	30.8%	30.0%	24.8%	23.1%	56	31.6%	30.9%	25.1%	23.7%	57	32.5%	31.9%	25.4%	24.3%	58	33.4%	32.9%	25.7%	24.8%	59	34.3%	33.9%	26.0%	25.4%	60	35.2%	34.9%	26.3%	26.1%	61	36.1%	35.9%	26.6%	26.7%
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	18	Participants counted as “not highly annoyed”	(see Section 6.7 for further details of this table) Participants who indicated “do not know” were treated as “not highly annoyed” in modelling where regression analysis is used.																																																																																																																			

6.5 Exposure-response functions for L_{night}

Figure 32: Plot of mean annoyance score (5-point verbal scale) as a function of L_{night} noise exposure (dB)

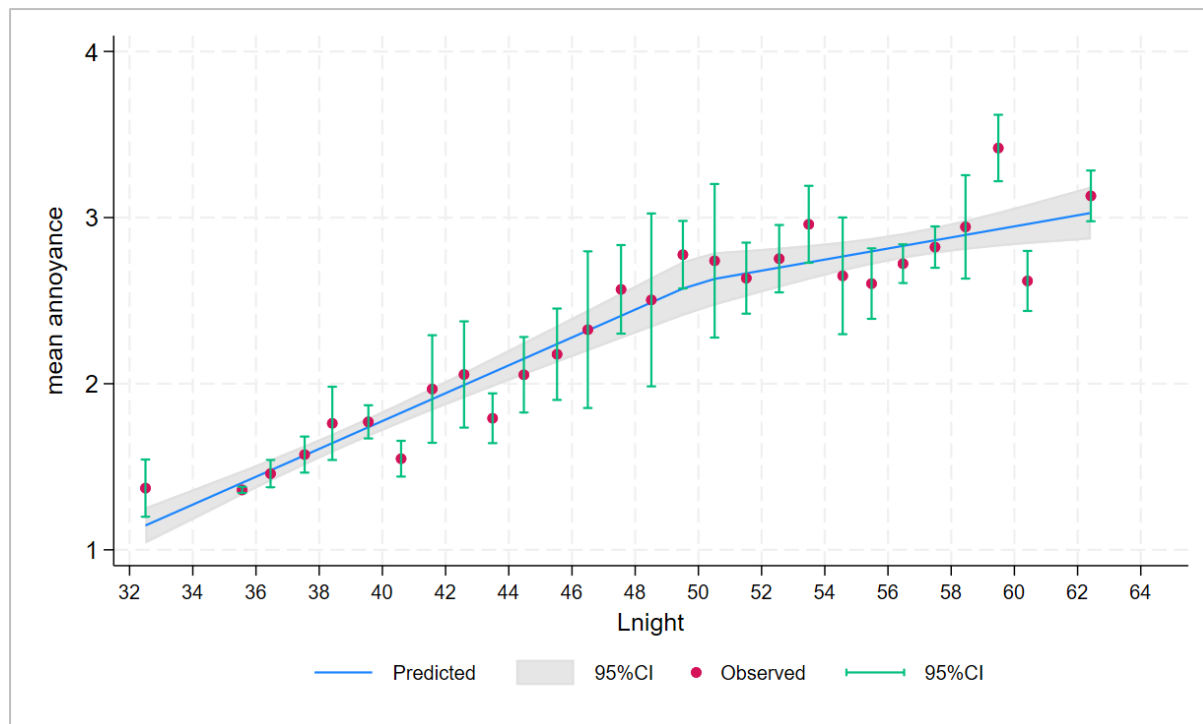


Figure 33: Plot of highly annoyed (5-point scale) (HA_v) as a function of L_{night} noise exposure (dB)

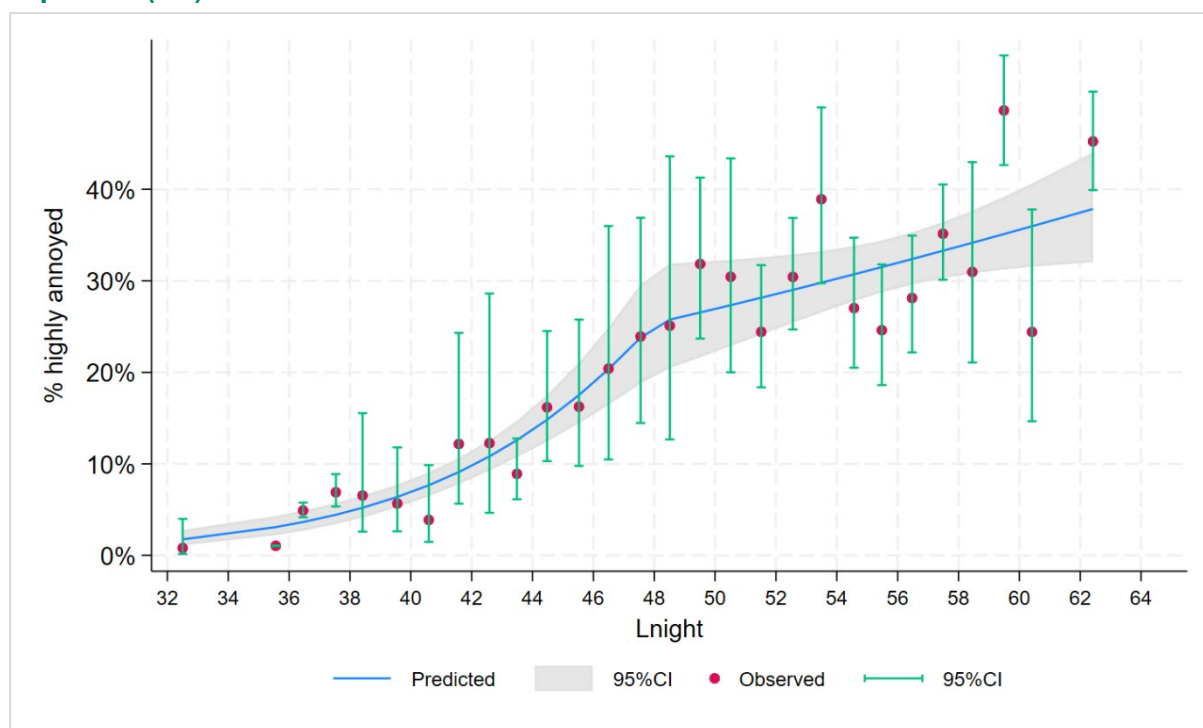


Figure 34: Plot of mean sleep disturbance score as a function of L_{night} noise exposure (dB).

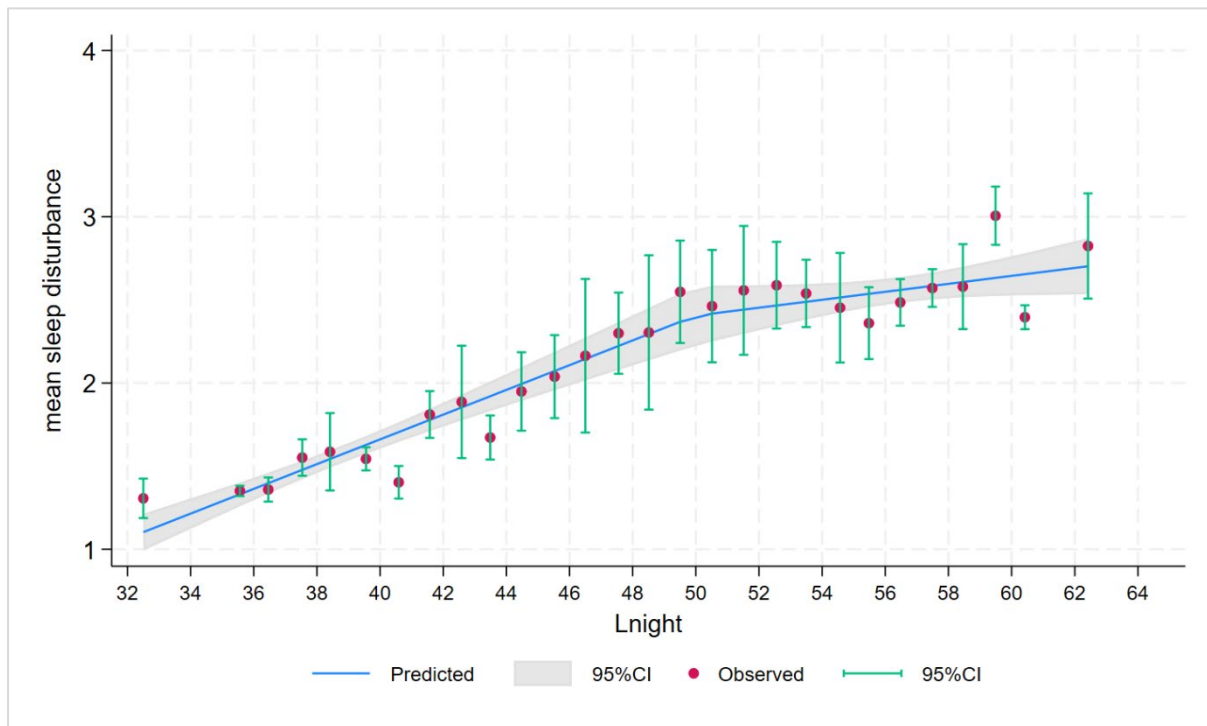


Figure 35: Plot of highly sleep disturbed as a function of L_{night} noise exposure (dB).

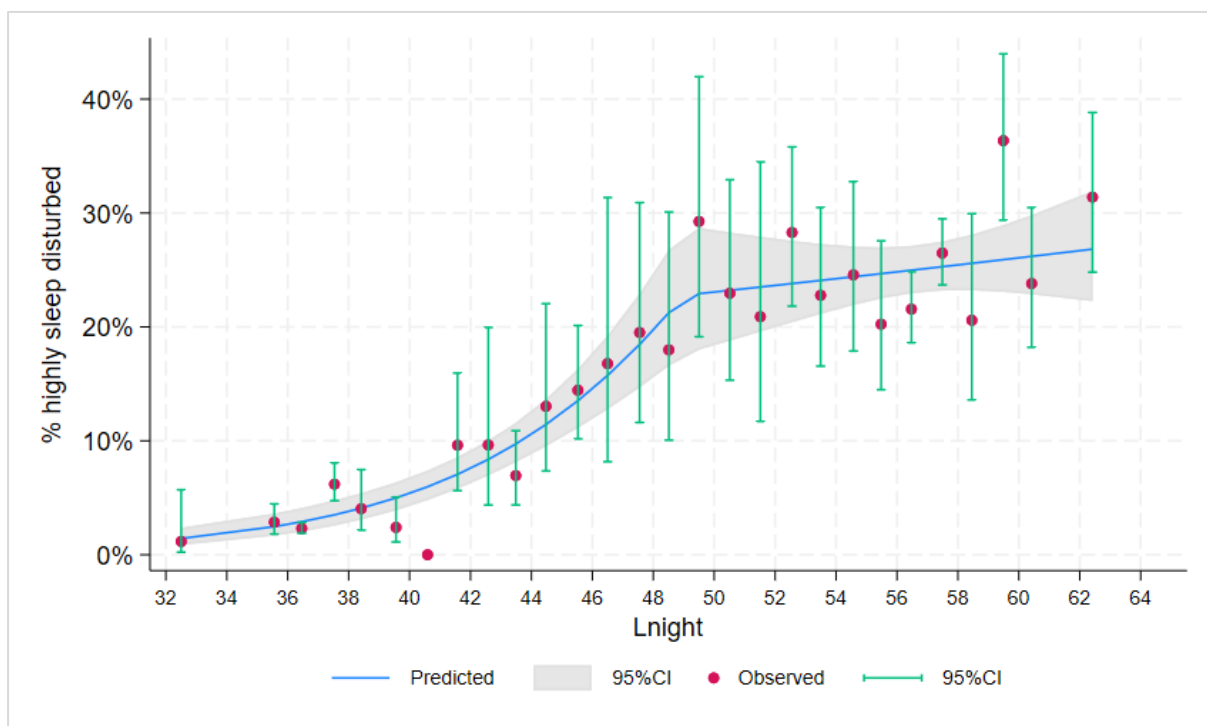
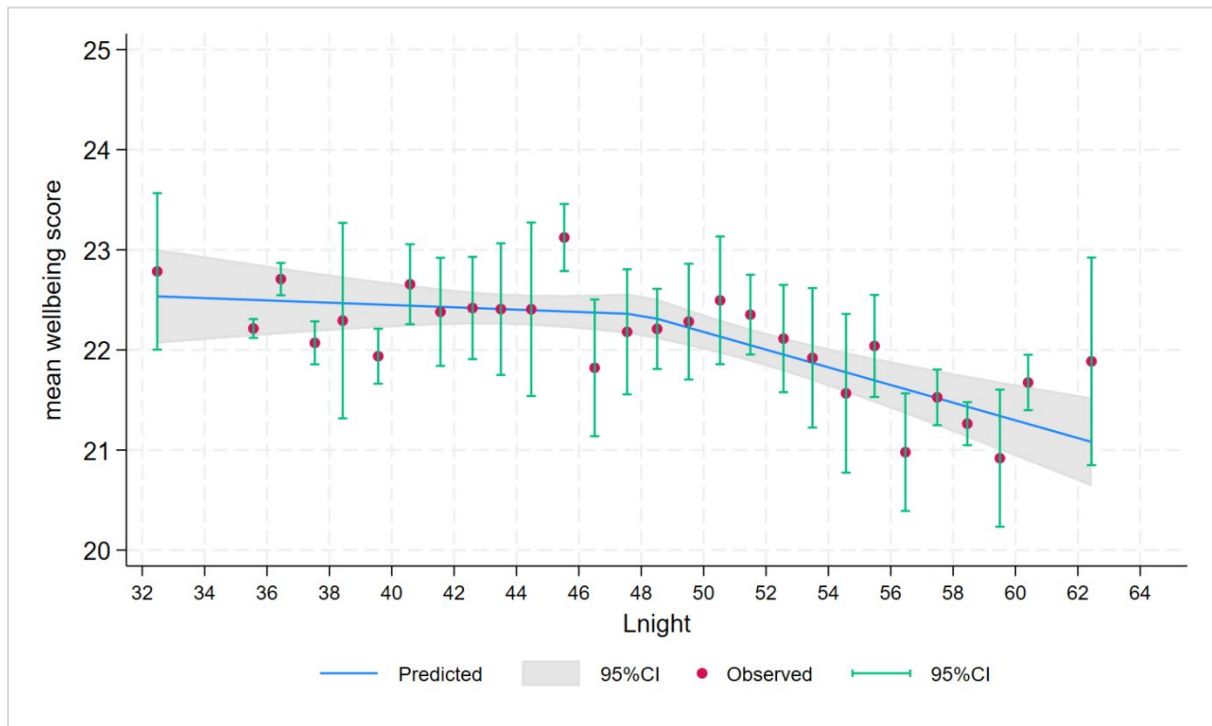
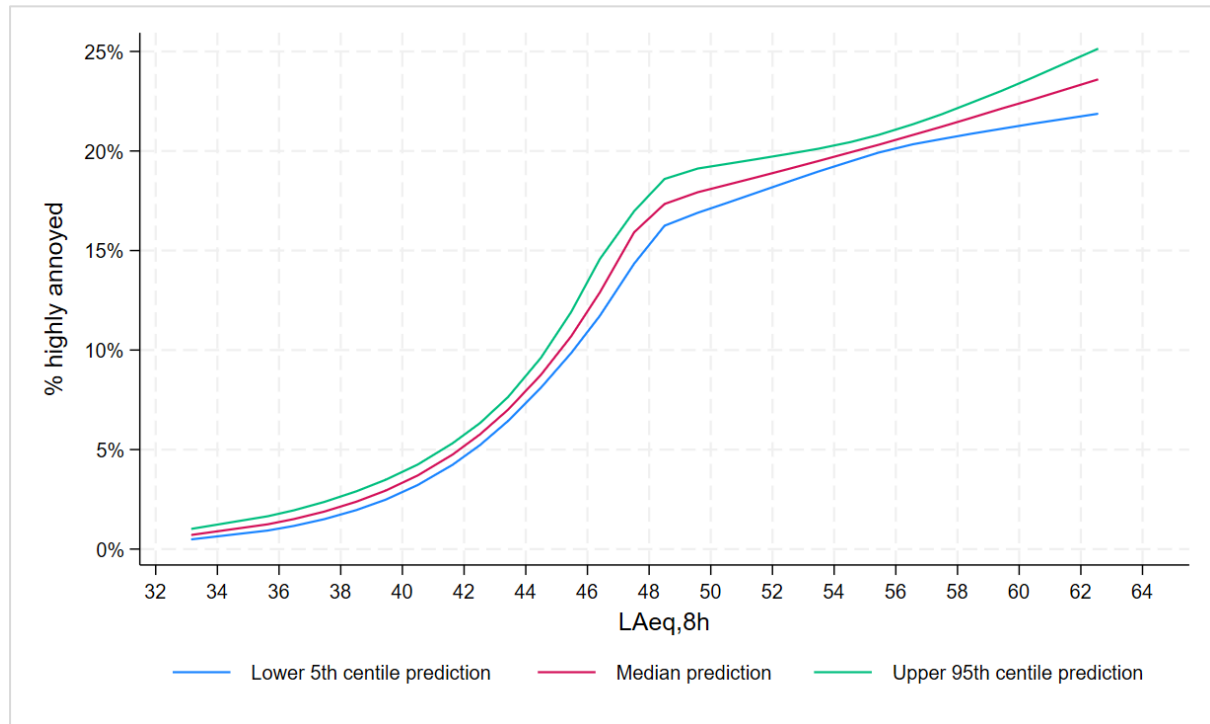


Figure 36: Plot of SWEMWBS as a function of L_{night} noise exposure (dB)



6.6 Exposure-response function for percent highly annoyed (HA_{vw}) (5-point weighted verbal scale)

Figure 37: Plot of highly annoyed (weighted 5-point scale) (HA_{vw}) as a function of $L_{Aeq,8h}$ (92-day average summer night, dB) noise exposure: Monte Carlo estimate of 28% cut-off



6.7 Regression proportions

Table 65: Regression proportions for highly annoyed (HA_v) and highly sleep disturbed (HSD)

dB	L_{night} by HA_v	L_{Aeq,8h} by HA_v	L_{night} by HSD	L_{Aeq,8h} by HSD
40	6.8%	5.6%	5.4%	4.3%
41	8.2%	7.0%	6.5%	5.3%
42	9.7%	8.6%	7.7%	6.7%
43	11.5%	10.6%	9.1%	8.3%
44	13.6%	13.0%	10.7%	10.3%
45	16.0%	15.8%	12.6%	12.7%
46	18.7%	19.2%	14.7%	15.5%
47	21.8%	23.0%	17.2%	18.9%
48	25.2%	23.8%	19.9%	19.4%
49	25.9%	24.6%	23.0%	19.9%
50	26.7%	25.5%	23.3%	20.4%
51	27.5%	26.3%	23.6%	20.9%
52	28.3%	27.2%	23.9%	21.4%
53	29.1%	28.1%	24.2%	22.0%
54	29.9%	29.0%	24.5%	22.5%
55	30.8%	30.0%	24.8%	23.1%
56	31.6%	30.9%	25.1%	23.7%
57	32.5%	31.9%	25.4%	24.3%
58	33.4%	32.9%	25.7%	24.8%
59	34.3%	33.9%	26.0%	25.4%
60	35.2%	34.9%	26.3%	26.1%
61	36.1%	35.9%	26.6%	26.7%

6.8 Online questionnaire script

Version: 1

Introduction

{ASK ALL}

INTRO

Dear Participant, welcome to this national survey that will ask for your views on your local environment, any issues you have and how these might impact your life.

The survey is funded by the Department for Transport who will use the study findings to help inform key policy decisions.

The survey should take you around 20 minutes to complete. You don't have to complete the whole survey in one go – any progress you make will be saved and you can start where you left off when you next log in.

Please confirm that you have received and read the invitation letter and are happy to take part.

1. I have read the invitation letter and I'm happy to take part
2. I have not read the invitation letter and/or I do not want to take part

{IF INTRO = 2}

CONSENTCHK

Please ensure that you have read the invitation letter and are happy to take part. If you have lost the invitation letter, you can read about the study on this website:
natcen.ac.uk/ANNESurvey

1. Go back to change your answer [GoTo INTRO]
2. Exit the questionnaire

NO DK/NO REF

{IF CONSENTSHK = 2}

Thanks for thinking about taking part. If you change your mind, you can log back in and take part another time.

Aircraft noise annoyance during the night-time period and shoulder hours

{ASK ALL}

ANNOYINTRO

Now some questions about your local environment.

{ASK ALL}

NEIGHBOURHOOD {Q1}

On the whole, how much do you like living in this neighbourhood? Please provide your answer on a scale of 1 to 7, where 1 equals 'definitely like' and 7 equals 'definitely don't like'.

- 1 Definitely like
- 2
- 3
- 4
- 5
- 6
- 7 Definitely don't like

{ASK ALL}

SOURCES {Q2}

Which of the noise sources listed below particularly **bother, disturb or annoy** you during the night (**11pm to 7am**).

- 1 Road traffic noise
- 2 Aircraft, airports, and airfields
- 3 Trains or railway stations
- 4 Building, construction, demolition, renovation or roadworks
- 5 Neighbours (inside their homes)
- 6 Neighbours (outside their homes)
- 7 Entertainment, leisure or sports facilities
- 8 Industrial sites
- 9 Other – please describe
- 10 None of the above [EXCLUSIVE]

{ASK ALL}

INTRO1

The following questions are specifically about your experiences during **this summer**. By this we mean the period from mid-June to mid-September 2022.

{ASK ALL}

ANNOYNIGHTRD {Q3}

Thinking about **this summer**, when you were here at home, how much does noise from road traffic **bother, disturb or annoy** you during the night (**11pm to 7am**)?

- 1 Not at all
- 2 Slightly
- 3 Moderately
- 4 Very

5 Extremely

HELP: What do we mean by “this summer?”: “We mean the period from mid-June to mid-September 2022.”

{ASK ALL}

INTRO2

The next few questions ask about aircraft, airports or airfields.

Please only think about commercial airlines and light aircraft. Do **not** include helicopters, military aircraft, hot air balloons, people or vehicles coming or going from airports or airfields.

{ASK ALL}

ANNOYNIGHTSUMMER {Q4}

Thinking about **this summer**, when you were here at home, how much does noise from aircraft, airports or airfields **bother, disturb or annoy** you during the night (**11pm to 7am**)?

- 1 Not at all
- 2 Slightly
- 3 Moderately
- 4 Very
- 5 Extremely

HELP: What do we mean by “this summer?”: “We mean the period from mid-June to mid-September 2022.”

{ASK ALL}

ANNOYNIGHTSUMMERSCALE {Q5}

This next question uses a 0 to 10 opinion scale for how much aircraft, airport or airfield noise **bothers, disturbs or annoys** you when you are here at home. If you are not annoyed choose 0; if you are extremely annoyed choose 10; if you are somewhere in between choose a number between 0 and 10.

Thinking about **this summer**, when you were here at home, what number from 0 to 10 best shows how much you were **bothered, annoyed or disturbed** by noise from aircraft, airports or airfields during the night (**11pm to 7am**)?

0 – Not at all 10 – Extremely

HELP: What do we mean by “this summer?”: “We mean the period from mid-June to mid-September 2022.”

{ASK ALL}

ANNOYTIMESUMMERA {Q6}

Thinking about **this summer**, when you were here at home, how much does noise from aircraft, airports or airfields **bother, disturb or annoy** you during these times?

GRID ROWS:

Not at all
Slightly
Moderately
Very
Extremely

GRID COLS:

1. 9pm-10pm
2. 10pm-11pm
3. 11pm-12am
4. 12am-1am
5. 1am-2am
6. 2am-3am
7. 3am-4am
8. 4am-5am
9. 5am-6am
10. 6am-7am
11. 7am-8am

HELP: What do we mean by "this summer?": "We mean the period from mid-June to mid-September 2022."

Subjective sleep disturbance

{ASK ALL}

HEALTHINTRO

Now some questions about your health.

{ASK ALL}

HEALTH {Q7}

How is your health in general?

Would you say it is ...

1. Very good
2. Good
3. Fair
4. Bad
5. Very bad

{ASK ALL}

PSQI1 {Q8}

During the **past month** or so, how would you rate your sleep quality overall?

- 1 Very good
- 2 Fairly good
- 3 Neither good nor bad
- 4 Fairly bad
- 5 Very bad

{ASK ALL}

MEDICINE {Q9}

During the **past month**, how often have you taken medicine (prescribed or “over the counter”) to help you sleep?

- 1 Not during the past month
- 2 Less than once a week
- 3 Once or twice a week
- 4 Three or more times a week

{ASK ALL}

SLPDISORDER {Q10}

Have you ever been diagnosed by a health professional with any of the following sleep disorders?

- 1 Sleep apnoea
- 2 Narcolepsy
- 3 Restless leg syndrome
- 4 Periodic limb movement syndrome
- 5 Insomnia
- 6 Other (please specify)
- 7 None of the above [EXCLUSIVE]

{ASK ALL}

CONDITIONS {Q11}

Have you ever been diagnosed by a health professional with any of the following conditions?

- 1 Hypertension / high blood pressure
- 2 Arrhythmia / irregular heartbeat

- 3 Heart disease
- 4 Diabetes
- 5 Cancer
- 6 None of the above [EXCLUSIVE]

{ASK ALL}

CARING {Q12}

Is there someone living in your home that frequently requires your care during the night?

- 1 Yes
- 2 No

{ASK ALL}

FALLASLEEP {Q13}

During the **past month**, how long (in minutes) has it usually taken you to fall asleep each night?

0...999 Minutes

{ASK ALL}

SLEEPDURATION {Q14}

During the **past month**, how many hours of actual sleep did you get at night (this may be different than the number of hours you spent in bed)?

Please answer in hours and minutes, for example, if you got 90 minutes of actual sleep at night that would be 1 hour 30 minutes.

0...24 Hours

0...59 Minutes of sleep per night

{ASK ALL}

WAKE {Q15}

During the **past month**, how often did you wake up during the night?

Please enter the number of times per night.

OPEN

Range: 0...99 times per night

{ASK ALL}

WINDOWSWARM {Q16}

In warmer seasons, do you usually sleep with the windows....

- 1 Closed
- 2 Partially open
- 3 Completely open
- 4 Sleep in room with no windows

{ASK ALL}

WINDOWSCOLD {Q17}

In colder seasons, do you usually sleep with the windows....

- 1 Closed
- 2 Partially open
- 3 Completely open
- 4 Sleep in room with no windows

{ASK ALL}

WINDOW {Q18}

What kind of windows do you have in the room where you sleep?

- 1 Openable – single glazed
- 2 Openable – secondary glazed
- 3 Openable – double glazed
- 4 Openable – triple glazed
- 5 Openable – acoustic glazed
- 6 Openable – don't know glazing [Cannot be answered with 1, 2 3,4]
- 7 Non-openable – single glazed
- 8 Non-openable – secondary glazed
- 9 Non-openable – double glazed
- 10 Non-openable – triple glazed
- 11 Non-openable – acoustic glazed
- 12 Non-openable – don't know glazing [Cannot be answered with 7, 8, 9, 10, 11]
- 13 Sleep in room with no windows [EXCLUSIVE]

{ASK ALL}

SLEEPDISTURB {Q19}

Thinking about **this summer**, when you were here at home, how much does noise from aircraft, airports or airfields **disturb your sleep** during the night (**11pm to 7am**)?

- 1 Not at all
- 2 Slightly
- 3 Moderately
- 4 Very
- 5 Extremely

HELP: What do we mean by “this summer?”: “We mean the period from mid-June to mid-September 2022.”

{ASK ALL}

SLEEPTIMEA {Q20}

Thinking about **this summer**, when you were here at home, how much does noise from aircraft, airports or airfields **disturb your sleep** during these times?

GRID ROWS:

- Not at all
- Slightly
- Moderately
- Very
- Extremely

Do not usually sleep during this time

GRID COLS:

1. 9pm-10pm
2. 10pm-11pm
3. 11pm-12am
4. 12am-1am
5. 1am-2am
6. 2am-3am
7. 3am-4am
8. 4am-5am
9. 5am-6am
10. 6am-7am
11. 7am-8am

HELP: What do we mean by "this summer?": "We mean the period from mid-June to mid-September 2022."

{ASK ALL}

SLEEPPATTERNTIME {Q21}

Does noise from aircraft, airfields or airports interfere with your sleeping patterns such as the time you go to bed or get up?

- 1 Yes
- 2 No

{ASK ALL}

SLEEPPATTERNWIN {Q22}

Does noise from aircraft, airfields or airports interfere with sleeping with your windows open?

- 1 Yes
- 2 No
- 3 Sleep in room with no windows

Health status

{ASK ALL}

WELLINTRO

You will now read some statements about feelings and thoughts.

Please choose the option that best describes your experience of each over the **last 2 weeks**.

{ASK ALL}

WELLBEING1 {Q23}

(Over the **last 2 weeks**) I've been feeling optimistic about the future.

- 1 None of the time
- 2 Rarely
- 3 Some of the time
- 4 Often

5 All of the time

{ASK ALL}

WELLBEING2 {Q24}

(Over the **last 2 weeks**) I've been feeling useful.

- 1 None of the time
- 2 Rarely
- 3 Some of the time
- 4 Often
- 5 All of the time

{ASK ALL}

WELLBEING3 {Q25}

(Over the **last 2 weeks**) I've been feeling relaxed.

- 1 None of the time
- 2 Rarely
- 3 Some of the time
- 4 Often
- 5 All of the time

{ASK ALL}

WELLBEING4 {Q26}

(Over the **last 2 weeks**) I've been dealing with problems well.

- 1 None of the time
- 2 Rarely
- 3 Some of the time
- 4 Often
- 5 All of the time

{ASK ALL}

WELLBEING5 {Q27}

(Over the **last 2 weeks**) I've been thinking clearly.

- 1 None of the time
- 2 Rarely
- 3 Some of the time
- 4 Often
- 5 All of the time

{ASK ALL}

WELLBEING6 {Q28}

(Over the **last 2 weeks**) I've been feeling close to other people.

- 1 None of the time
- 2 Rarely
- 3 Some of the time
- 4 Often
- 5 All of the time

{ASK ALL}
WELLBEING7 {Q29}

(Over the **last 2 weeks**) I've been able to make up my own mind about things.

- 1 None of the time
- 2 Rarely
- 3 Some of the time
- 4 Often
- 5 All of the time

Non-acoustic factors

{ASK ALL}
ATTITUDE {Q30}

To what extent do you agree or disagree with the following statements?

GRID ROWS:

- 1 Noise from aeroplanes is bad for the health of myself or my household
- 2 Noise from aeroplanes is bad for children's education at the local schools
- 3 Noise from aeroplanes makes my home less valuable
- 4 Having an airport in the area is good for the local economy
- 5 I worry about plane crashes around here
- 6 Having an airport in the area makes my home more valuable
- 7 It is convenient to have an airport in the area
- 8 Air travel harms the environment
- 9 I like flying
- 10 Having an airport in the area makes my home less valuable
- 11 I worry about more land being taken over by the airport
- 12 I like watching the aeroplanes.

GRID COLS:

- 1. Strongly disagree
- 2. Disagree
- 3. Not sure
- 4. Agree
- 5. Strongly agree

{ASK ALL}
FLYING {Q31}

When was the last time you flew from a UK airport?

- 1 Within the last 12 months
- 2 Longer than 1 year ago, up to 2 years ago
- 3 Longer than 2 years ago, up to 4 years ago
- 4 Longer than 4 years ago, up to 10 years ago
- 5 More than 10 years ago
- 6 Never

{IF FLYING=1 Within the last 12 months}

FLYING12MTHS {Q32}

How many trips by air have you made in the **last 12 months**?

Please count outward and return flights and any transfers as one trip. If you are not sure then your best estimate is fine.

- 1 1
- 2 2
- 3 3
- 4 4
- 5 5
- 6 Over 5

{ASK ALL}

COPING {Q33}

Which of these things, if any, have you or anyone else in your household done about the noise from aircraft, airfields and airports during the night-time (**11pm to 7am**) within the **last 12 months**?

- 1 Made our own noise (e.g. playing music/white noise) so that we could not hear the noise
- 2 Used earplugs or headphones to avoid hearing the noise
- 3 Keep windows closed
- 4 Started, signed or participated in a campaign, protest or petition
- 5 Took advice, e.g., from Citizen's Advice Bureau, another advice or Legal organisation
- 6 Slept in a different room in the home
- 7 Installed secondary, double, triple or acoustic glazing
- 8 None of the above [EXCLUSIVE]

{ASK ALL}

COMPLAINED {Q34}

Did you complain, write or speak to any of the following about the noise from aircraft, airfields and airports during the night-time (**11pm to 7am**) within the **last 12 months**?

- 1 An airport, airport owner, airport operator or airport consultative committee
- 2 One or more airlines
- 3 The Civil Aviation Authority
- 4 A newspaper or TV/Radio Station
- 5 A resident's association
- 6 The Environmental Health Department in the Local Authority (Council)
- 7 Another Local Authority (Council) Department
- 8 A government department
- 9 The police

- 10 A councillor
- 11 A Member of Parliament
- 12 Other (please write in)
- 13 None of the above [EXCLUSIVE]

{ASK ALL}

INSULATION {Q35}

Has your home had any of the following changes made to it as part of a **noise insulation scheme** run by an airport?

- 1. Double, or triple glazing
- 2. Secondary glazing
- 3. Acoustic glazing
- 4. Insulation for roofs, lofts, doors or windows
- 5. Changes to the walls (e.g. soundproofing)
- 6. Changes to the ceiling (e.g. overboarding/soundproofing)
- 7. Replacement external doors
- 8. Ventilation units (to allow fresh air into your home without opening windows and doors)
- 9. Other
- 10. No changes have been made to my home as part of a noise insulation scheme run by an airport [EXCLUSIVE]
- 11. Don't know

Sociodemographic and household factors

{ASK ALL}

HHINTRO

The next questions are about you and your household.

{ASK ALL}

AGE {Q36}

Which of these age groups are you in?

- 1 18-19 years
- 2 20-24 years
- 3 25-34 years
- 4 35-44 years
- 5 45-54 years
- 6 55-64 years
- 7 65-74 years
- 8 75 years or older

{ASK ALL}

SEX {Q37}

At birth, were you described as...

- 1 Male
- 2 Female

{ASK ALL}

GENDER {Q38}

Which of the following options describes how you think of yourself? As a...

- 1 Man/boy
- 2 Woman/girl
- 3 In another way (please describe)

{ASK ALL}

ETHNICITY {Q39}

What is your ethnic group?

Choose one option that best describes your ethnic group or background.

- 1 White – English/Welsh/Scottish/Northern Irish/British
- 2 White – Irish
- 3 White – Gypsy or Irish Traveller
- 4 White - Roma
- 5 Any other white background (please describe)

Mixed/multiple ethnic groups:

- 6 White and Black Caribbean
- 7 White and Black African
- 8 White and Asian
- 9 Any other Mixed/Multiple ethnic background (please describe)

Asian or Asian British:

- 10 Indian
- 11 Pakistani
- 12 Bangladeshi
- 13 Chinese
- 14 Any other Asian background (please describe)

Black/African/Caribbean/Black British

- 15 African
- 16 Caribbean
- 17 Any other Black/Black British/African or Caribbean background (please describe)

Other ethnic group

- 18 Arab
- 19 Latin American
- 20 Any other ethnic group (please describe)

{ASK ALL}

HOUSING {Q40}

Which of these applies to your home?

- 1 Being bought on a mortgage
- 2 Owned outright by household
- 3 Rented from local authority
- 4 Rented from housing association
- 5 Rented from a private landlord
- 6 Shared ownership
- 7 Tied to employment
- 8 Other

{ASK ALL}
HHADULTS {Q41}

How many adults, apart from yourself, aged 18 and over are there in your household?

0...99 Adults aged 18+

{ASK ALL}
HHCHILD {Q42}

How many children aged under 18 are there in your household?

0...99 Children aged 0 to 17

{ASK ALL}
HEIGHT {Q43}

What is your height?

Would you like to write this in metres or in feet and inches?

- 1 Metres
- 2 Feet and inches
- 3 Don't know
- 4 Prefer not to say

{IF HEIGHT = 1 Metres}

HEIGHTM {Q44}

Please record your height in metres and centimetres e.g. if you are 1 meter 50 centimetres tall, please record 1.50.

0.01..2.44

{IF HEIGHT = 2 Feet and inches}

HEIGHTFT {Q45}

Please record your height in feet and inches.

First enter the number of feet.

0..7

{IF HEIGHT = 2 Feet and inches}

HEIGHTINCH {Q45}

Now enter the number of inches.

0..11

{ASK ALL}
WEIGHT {Q46}

What is your weight?

Would you like to write this in kilograms or in stones and pounds?

- 1 Kilograms
- 2 Stones and pounds
- 3 Don't know
- 4 Prefer not to say

{IF WEIGHT = 1 Kilograms}

WEIGHTKG {Q47}

Please record your weight in kilograms.

1.0..201.0

{IF WEIGHT = 2 Stones and pounds}

WEIGHTST {Q48}

Please record your weight in stones and pounds.

First enter the number of stones.

1..32

{IF WEIGHT = 2 Stones and pounds}

WEIGHTSP {Q48}

Please record your weight in stones and pounds.

Now enter the number of pounds.

0..13

{ASK ALL}

HEARING {Q49}

Do you have any problems or difficulties with your sense of hearing?

This could include conditions that may affect your ability to hear e.g. tinnitus, an ear infection.

1 Yes

2 No

{ASK ALL}

NOISESENSITIVITY {Q50}

How sensitive would you say you are to noise? Please provide your answer on a scale of 1 to 7, where 1 equals 'not at all sensitive' and 7 equals 'very sensitive'.

1 Not at all sensitive

2

3

4

5

6

7 Very sensitive

{ASK ALL}

WORK {Q51}

Which of these best describes your current situation?

1 Working full time (30 hours a week or more)

2 Working part time

3 Unemployed and looking for work

4 Retired from paid work altogether

5 In full-time education

6 Looking after the home or family

7 Something else

{IF WORK = 1 Working full time OR 2 Working part time}
WORKHOME {Q52}

Do you ever work from home?

- 1 Yes
- 2 No

{IF WORK = 1 Working full time OR 2 Working part time}
NIGHTSHIFT {Q53}

Does your job require overnight shift work?

Overnight shift work refers to work for at least 4 hours between 00:00 midnight to 06:00 am in the morning.

- 1 Yes
- 2 No

{ASK ALL}
INTROJOB

The following questions refer to your current main job, or if you are not working now to your last main job.

{ASK ALL}
EMPSTAT {Q54}

Do (did) you work as an employee or are (were) you self-employed?

- 1 Employee
- 2 Self-employed with employees
- 3 Self-employed or freelance without employees
- 4 I have never had a job

{IF EMPSTAT = 1 OR 2}
EMPLOY {Q55}

IF EMPSTAT = 1 Employee: How many people work (worked) for your employer at the place where you work (worked)?

IF EMPSTAT = 2 Self-employed with employees: How many people do (did) you employ?

- 1 1 to 24
- 2 25 or more

{IF EMPSTAT = 1 Employee OR 2 Self-employed with employees}
SUPERVISE {Q56}

Do (did) you supervise any other employees? (A supervisor or foreman is responsible for overseeing the work of other employees on a day-to-day basis).

- 1 Yes
- 2 No

{IF EMPSTAT = 1 Employee OR 2 Self-employed with employees OR 3 Self-employed or freelance without employees}

OCCUPATION {Q57}

Which of the following best describes the sort of work you do in your current job? If you are not working now, please select which best described what you did in your last job.

- 1 **Modern professional occupations** such as: teacher, nurse, physiotherapist, social worker, welfare officer, artist, musician, police officer (sergeant or above) or software designer
- 2 **Clerical and intermediate occupations** such as: secretary, personal assistant, clerical worker, office clerk, call centre agent, nursing auxiliary or nursery nurse
- 3 **Senior managers or administrators** (usually responsible for planning, organising and co-ordinating work, and for finance) such as: finance manager or chief executive
- 4 **Technical and craft occupations** such as: motor mechanic, fitter, inspector, plumber, printer, tool maker, electrician, gardener or train driver
- 5 **Semi-routine manual and service occupations** such as: postal worker, machine operative, security guard, caretaker, farm worker, catering assistant, receptionist or sales assistant
- 6 **Routine manual and service occupations** such as: HGV driver, van driver, cleaner, porter, packer, sewing machinist, messenger, labourer, waiter/waitress or bar staff
- 7 **Middle or junior managers** such as: office manager, retail manager, bank manager, restaurant manager, warehouse manager or publican
- 8 **Traditional professional occupations** such as: accountant, solicitor, medical practitioner, scientist or civil/mechanical engineer

{IF EMPSTAT <> 4 I have never had a job}

WORKAIR {Q58}

Do you currently have work, or have you ever worked, in any of these kinds of employment?

- 1 Working for an airport
- 2 Working for an airline
- 3 Working for another company that does business at an airport
- 4 Work that is not at an airport but gets some benefit from the airport being there
- 5 Other work related to the aircraft or air travel industry
- 6 None of these [EXCLUSIVE]

{IF HHADULTS > 0}

WORKAIRHH {Q59}

Does anyone in the household have work that includes any of these kinds of employment?

- 1 Working for an airport
- 2 Working for an airline
- 3 Working for another company that does business at an airport
- 4 Work that is not at an airport but gets some benefit from the airport being there
- 5 Other work related to the aircraft or air travel industry
- 6 None of these [EXCLUSIVE]

{ASK ALL}

CAMPAIGNGRP {Q60}

Are you a member of any group campaigning against a local airport or the aviation industry?

- 1 Yes
- 2 No

{ASK ALL}
INTROHOME

The following questions are about your home.

{ASK ALL}
HOMEBUILT {Q61}

In what year was your home originally built?

- 1 Before 1919
- 2 1919 – 1940
- 3 1941 – 1960
- 4 1961 – 1990
- 5 1991 – 2000
- 6 2001 – 2010
- 7 2011 – 2020
- 8 After 2020
- 9 Don't know

{ASK ALL}
HOMELONG {Q62}

How long have you lived in this home?

- 1 Less than 6 months
- 2 Between 6 months and 1 year
- 3 Longer than 1 year, up to 2 years
- 4 Longer than 2 years, up to 5 years
- 5 Longer than 5 years, up to 10 years
- 6 More than 10 years

{IF HOMELONG = 1 LESS THAN 6 MONTHS}
HOMEMONTH {Q63}

How many months is that?
 If less than one month, enter 0.

0...5

{ASK ALL}
DWELLING {Q64}

Which of the following types of building is your home?

- 1 Flat, maisonette or apartment
- 2 Bungalow
- 3 House: mid terraced
- 4 House: semi detached
- 5 House: detached
- 6 Other

{ASK ALL}
BEDFLOOR {Q65}

On which floor of the building do you sleep? Enter -1 for basement and 0 for ground floor.

Range: -1, 0...999

{ASK ALL}

OUTSIDESPC {Q66}

Do you have use of an outdoor space such as a garden, terrace or balcony here?

- 1 Yes – garden
- 2 Yes – terrace
- 3 Yes – balcony
- 4 No – none [EXCLUSIVE]

Consent to recontact

{ASK ALL}

OBSTUDYCONSENT {Q67}

St George's, University of London, are planning to undertake a related sleep study that will take place over 7 nights in your home. The study does not involve any travel and does not involve anyone coming to your home. Not everyone is chosen to take part in this study.

If you are chosen, equipment will be shipped to your home. You will be compensated with up to £200 in the form of shopping vouchers for participating in the sleep study. St George's would contact you about the study between November 2022 and December 2023.

If you are chosen, would you be willing for us to provide St George's, University of London, with your name and contact details (address, email and telephone number) so they can get in touch with you and provide more information?

This does not mean you have to take part in this further research. The researchers will explain what taking part would involve and you will be free to refuse if you do not want to take part.

You can cancel this permission at any time by contacting NatCen Social Research either by emailing ANNEsurvey@natcen.ac.uk or by telephoning **0800 652 4570**.

- 1 Yes
 - 2 No
- NODK/REF

{ASK ALL}

GENSTUDYCONSENT {Q68}

In the future, the Department for Transport may want to contact you about further research on aviation noise. Would you be willing to be contacted again in the future?

This does not mean you have to take part in any future studies. The researchers will explain what taking part would involve and you will be free to refuse if you do not want to take part.

You can cancel this permission at any time by contacting NatCen Social Research either by emailing ANNEsurvey@natcen.ac.uk or by telephoning **0800 652 4570**.

- 1 Yes
- 2 No

NODK/REF

{IF OBSTUDYCONSENT = 1 Yes OR GENSTUDYCONSENT 1 Yes}

RECONNAME {Q69}

What is your full name?

Title [Title] First name [STRING: 20] NODK/NOREF Surname [STRING: 20] NODK/NOREF

IF OBSTUDYCONSENT = 1 Yes OR GENSTUDYCONSENT 1 Yes

RECONEMAIL {Q70 / Q71}

What is your email address?

: STRING[60]

Please confirm your email address by typing it in the box below again.

: STRING[60]

{HARD CHECK: If answer provided does not include @ or full-stop: "E-mail addresses should contain an @ character and a full stop. Please check and amend."}

{HARD CHECK: If the two email addresses do not match: "The two email addresses entered do not match. Please check and amend."}

- 1 I do not have an email address
- 2 I do not wish to provide my email address

{IF OBSTUDYCONSENT = 1 Yes OR GENSTUDYCONSENT 1 Yes}

RECONTEL {Q72} {Q73}

And what is your phone number?

OPEN

{HARD CHECK: If contains characters other than numbers "Please only use numbers without any additional characters or spaces."}

{HARD CHECK: If does not contain 10 or 11 digits or does not start with a 0. "Your answer is not a valid telephone number. UK phone numbers start with 0 and are 10 or 11 digits. Please check and amend."}

- 1 I do not have a telephone number
- 2 I do not wish to provide my telephone number

{ASK ALL}

VOUCHER

Finally, as a thank you for your time, we would like to offer you a £10 Love2Shop voucher. This will be an electronic voucher sent to your email account.

Please press 'Next' to continue.

{ASK ALL}

EMAILVOUCHER {Q74 /Q75}

Please provide an email address where you would like the voucher sent to:

OPEN

1. I would prefer to receive a physical voucher in the post, sent to my home address
2. I do not require a voucher

Please confirm your email address by typing it in the box below again.

: STRING[60]

HARD CHECK: If answer provided does not include @ or full-stop: "Please check and amend. E-mail addresses should contain an @ character and a full stop."

{HARD CHECK: If the two email addresses do not match: "The two email addresses entered do not match. Please check and amend."}

{IF EmailVoucher = <> 2 I do not require a voucher AND ReConName not answered}

VOUCHERNAME {Q76}

To receive the voucher, you will need to give us your full name:

Title [Title]

First name [STRING: 20] NODK/NOREF

Surname [STRING: 20] NODK/NOREF

1 I don't want to provide my name

{IF VoucherName = 1 I don't want to provide my name}

NOCONTACT

If you do not provide your full name you will not be able to receive the £10 voucher. Are you sure you do not want to provide this? Note, you will not be able to return to the questionnaire at a later date if you change your mind.

1 Yes, I don't want to provide my name

2 No, I would like to provide my name

NODK/NOREF

{IF EmailVoucher = 1 AND VoucherName = RESPONSE}

ADDVCH

To make sure your shopping voucher goes to the correct address, please could you confirm that your current address is...

{sample address}

Is this correct?

1 Yes – this address is correct

2 No – this address needs updating

{IF EmailVoucher = 1 AND VoucherName = RESPONSE AND AddVch = 2}

VOUCHADD

Please provide the address you would like us to send the voucher to.

If you do not provide your postal address we will not be able to send out a voucher.

{IF EmailVoucher = 1 AND VoucherName = RESPONSE AND AddVch = 2}
VOUCHADD_ADDRESSLINE

"First line:"

OPEN

DK/REF NOT ALLOWED

{IF EmailVoucher = 1 AND VoucherName = RESPONSE AND AddVch = 2}
VOUCHADD_ADDRESSLINE

"Second line:"

OPEN

ALLOW NA

{IF EmailVoucher = 1 AND VoucherName = RESPONSE AND AddVch = 2}
VOUCHADD_ADDRESSLINE

"Third line:"

OPEN

ALLOW NA

{IF EmailVoucher = 1 AND VoucherName = RESPONSE AND AddVch = 2}
VOUCHADD_ADDRESSLINE

"Town:"

OPEN

DK/REF NOT ALLOWED

{IF EmailVoucher = 1 AND VoucherName = RESPONSE AND AddVch = 2}
VOUCHADD_ADDRESSLINE

"County:"

OPEN

ALLOW NA

{IF EmailVoucher = 1 AND VoucherName = RESPONSE AND AddVch = 2}
POSTCODE

"Post Code:"

OPEN

NODK/NOREF

{IF (EmailVoucher = 1 AND VoucherName = RESPONSE AND (AddVch = 1 OR VouchAdd = RESPONSE)) OR EmailVoucher = RESPONSE}
VOUCHSENT

Please note that it may take up to 21 days for the voucher to arrive.

{IF EmailVoucher=RESPONSE: "Please check your SPAM folder to ensure the electronic voucher did not end up there by mistake."}

Thank you once again for participating in this survey. This is the end of the questions and your answers have been submitted. You can close your browser now.

{IF EmailVoucher = 2 I do not require a voucher OR NoContact = 1 Yes, I don't want to provide my name}

NOVOUCHER

{If NoContact = 1: "We do not have your name or postal address so we cannot send you a voucher.

If you want to update your records later, please contact our freephone or send us an email:
Freephone: 08006524570

Email: ANNESurvey@natcen.ac.uk”}

{If EmailVoucher = 2: “You have said you do not require a voucher. If you want to update your records later, please contact our freephone or send us an email:

Freephone: 08006524570

Email: ANNESurvey@natcen.ac.uk”}

Thank you once again for participating in this survey. This is the end of the questions and your answers have been submitted. You can close your browser now.

6.9 Origin of key annoyance and sleep disturbance questions

a) Annoyance

Question name	Origin	Comment
ANNOYNIGHTRD ANNOYNIGHTSUMMER	ISO/TS 15666	Standard 5-point question from ISO/TS 15666. This question is used to derive % HA (Highly Annoyed)– highly annoyed for the 24-hour period. ISO/TS 15666 states this question should be asked prior to any further questions about annoyance during particular times of the 24h period. SoNA 2014/NNAS 2012 asked participants if they ‘do not hear’ the noise source. ISO/TS 15666 now clarifies that if a question on audibility of the source is required it should follow and not be incorporated into the main annoyance question. It was decided for the ANNE study to align with the ISO/TS 15666 approach which does not assess audibility.
ANNOYNIGHTSUMMER	ISO/TS 15666	Standard 5-point question from ISO/TS 15666 asked for the hours matching $L_{Aeq,8h}$ in the UK – 11pm to 7am. This question is used to derive % HA – highly annoyed for the night-time period.

ANNOYNIGHTSUMMERSCALE	ISO/TS 15666	Standard 11-point question from ISO/TS asked for the hours matching $L_{Aeq,8h}$ in the UK – 11pm to 7am. This question is used to derive % HA – highly annoyed for the night-time period. ISO/TS 15666 states that where only one annoyance question is asked, so either the 5-point or 11-point scale that the 11-point scale is used. However, there were concerns about this advice as UK has typically used the 5-point scale in recent questionnaires, and additional concerns about difficulties of how the 11-point scale presents on mobile devices.
ANNOYTIMESUMMERA	ISO/TS 15666	Standard 5-point question from ISO/TS 15666 asked for the hourly periods in the shoulder hours and standard night-time period in the UK of 9pm to 8am. This question is used to derive % HA – highly annoyed for individual hourly periods of the night-time/shoulder hours.

b) Sleep disturbance

Question name	Origin	Comment
SLEEPDISTURB	FAA (Federal Aviation Authority)USA study	Standard question, borrows format from ISO/TS 15666 annoyance question. Similar question asked in SoNA 2014 but SoNA 2014 used the 11-point scale. This question is used to derive % HSD – highly sleep disturbed

SLEEPTIMEA	New question	Follows the format of SLEEP question above, addressing key issues of sleep disturbance during different individual hours of the nighttime.
FALLASLEEP	Item from Pittsburgh Sleep Quality Index, Also used in FAA USA Study	
SLEEPDURATION	Item from Pittsburgh Sleep Quality Index, Also used in FAA USA Study	
WAKE	FAA USA Study	
WINDOW	SoNA 2014	
WINDOWSWARM/ WINDOSWCOLD	SoNA 2014	
SLEPPATTERNTIME	SoNA 2014	
SLEPPATTERNWIN	SoNA 2014	
PSQI1	Item from Pittsburgh Sleep Quality Index, Also used in FAA USA Study. This item provides a sleep quality outcome for the study.	Item from Pittsburgh Sleep Quality Index This item provides a sleep quality outcome for the study.
MEDICINE	FAA USA Study	Exclusion criteria for objective sleep study
SLPDISORDER	FAA USA Study	Exclusion criteria for objective sleep study
CONDITIONS	FAA USA Study	Exclusion criteria for objective sleep study
CARING	FAA USA Study	Exclusion criteria for objective sleep study

c) Health Status

Question name	Origin	Comment
HEALTH	SoNA 2014	This is the standard 5-point general health questionnaire used in many national surveys.

WELLBEING 1 TO 7	This is the Short Warwick Edinburgh Mental Wellbeing Scale. All items are needed to be able to make the summary score. This measure was also used in SoNA 2014.	
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d) **Sociodemographic and household factors**

Question name	Origin	Comment
ETHNICITY	Census 2021	Asked in previous noise surveys.
HOUSING	NNAS 2012; SoNA 2014	
WORK	SoNA 2014	
NIGHTSHIFT	FAA USA study	Asked in previous noise surveys: we have simplified the question and added a time-frame. Exclusion criteria for the objective sleep study.
WORKAIR WORKAIRHH	SoNA 2014	
HEARING	FAA USA study	In SoNA 2014/NNAS 2012, the Interviewer noted whether participant had hearing issues. The ANNE survey used the question in the FAA USA study which is self-report.
NOISESENSITIVITY	NNAS 2012/SoNA 2014	
HOMEBUILT	NNAS 2012/SoNA 2014	
HOMELONG/HOMEMONTH	NNAS 2012/SoNA 2014	
DWELLING BEDFLOOR	SoNA 2014	
OUTSIDESPC	NNAS 2012/SoNA 2014	
HEIGHT		Exclusion criteria for the objective sleep study.
WEIGHT		Exclusion criteria for the objective sleep study.

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