A questionnaire survey on health effects of aircraft noise for residents living in the vicinity of Narita International Airport:

Part-1 Background and summary

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ABSTRACT

A questionnaire survey on health effects of aircraft noise was performed by the Narita International Airport Corporation (NAA) for residents living in the vicinity of Narita International Airport. This survey was implemented based on the agreement for conditional relaxation of curfew (23:00-6:00) at the meeting of NAA and Narita Community Council. We reported the background, summary and brief result of the survey on health effects of aircraft noise in this paper (Part-1), and the methodology and the results of the survey in another paper (Part-2). In order to enhance the competitiveness of Narita International Airport and improve convenience of customers, the conditional relaxation of curfew proceeded according to the agreement in 2013. However the health effects caused by aircraft noise were considerable concern for residents living around Narita International Airport. So, survey committee composed of several experts on health effects of aircraft noise was set up, and the survey was implemented under committee leadership. And the results of the survey on the health effects of aircraft noise were released in June 2015. We also refer to the attention of the impact of aircraft noise exposure considering the further expansion of airport capacity.

Keywords: Health effect, Aircraft noise, Questionnaire survey
I-INCE Classification of Subjects Numbers: 62.5, 62.2, 63.4, 63.2

1. INTRODUCTION

Narita International Airport has played an important role over 38 years since 1978 as a hub airport in East Asia as well as a main entrance to Tokyo metropolitan area by air. The airport was equipped with a 4,000-m runway, that is a Runway-A, at the opening of the port, and a Runway-B of 2,180-m long was constructed to keep pace with the increased demand for air transport in 2002. Then the Runway-B was expanded to a length of 2,500 m in 2009. Through these expansions of the airport, the number of aircraft movement increased continuously and ran up to 235,190 annual flight movements in Fiscal 2015, as shown in Figure 1. In recent years, the Low Cost Carriers (LCC) have huge growth especially and the rate of LCC to total flights is around 25 %. Currently, NAA is planning to strengthen

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the function of airport and expanding the airport capacity to enhance international competitiveness of airport among neighboring countries in East Asia through active cooperation with Tokyo-Haneda Airport.

On the other hand, this large-scale inland airport has attempted to reduce noise environment surrounding areas. Against aircraft noise exposure, NAA has carried out various original countermeasures under the two laws of Aircraft Noise Prevention Law (ANPL) and Special Act for Aircraft Noise Prevention (SAANP) (1). The former is aimed to reduce noise impact by relocation or sound proofing of existing houses with the assistance of subsidization. The latter is aimed to prevent the surrounding area of airport from becoming urbanized by land-use regulation. In addition to these actions based on ANPL and SAANP, NAA put some restrictions on aircraft operation such as nighttime curfew and exact flight route in shortly after takeoff and before landing. However, in preparation for current Open Skies Agreements, the remarkable increase of LCC’s flight movements and the hosting of Tokyo Olympic and Paralympic Games in 2020 (2), it is necessary to enhance operational performance with ensuring safety by partially relaxing restrictions of aircraft operation.

In this paper, at first, we indicated background that led to the growing demand for a survey on health effect of aircraft noise under in the circumstances. Secondly we explained noise impact due to conditional relaxing restrictions of aircraft operation. Finally, we reported summary and brief result of the survey on health effects of aircraft noise.

2. BACKGROUND OF THE SURVEY ON HEALTH EFFECT

NAA has carried out various countermeasures and operating restrictions for surrounding community to reduce the impact of aircraft noise. Especially in nighttime, the government and NAA impose nighttime curfew to bans operations between 23:00 and 6:00 except for emergency and to limit the flight operations after 22:00 within a maximum of 10 movements for each runway. On the other hand, in 2010, Tokyo-Haneda Airport was re-internationalized to respond to the increase demand for transportation by air to Tokyo metropolitan area. And it is forecasted that the demand for air transport to East Asia would grow rapidly. On the basis of these situations, the government and NAA have implemented conditional relaxation of nighttime curfew since three years ago to both enhance competitiveness in air transport in East Asia and improve convenience for customers. At the conditional relaxation on nighttime curfew, we approve the applications for the delay in take-off and landing until 24:00, which is both caused by either bad weather or emergency conditions and not responsible for air transport companies. And the information of these delays was disclosed on the home page of NAA by the next day.

As mentioned before, Narita International Airport has steadily increased flight movements in respond to social demand for air transport. Because, in these situations, noise impact to residents around the airport became a major concern, Narita Airport Regional Symbiosis Foundation conducted a questionnaire survey on health effect of aircraft noise for residents around the airport in 2003 just on time before the opening of Runway-B (3). Recently, studies on the impact assessment of night

![Figure 1 – Trend in aircraft movements at Narita International Airport](image-url)
noise were actively developed in European countries (4) and their results were reflected to countermeasures against noise impact and operating restrictions in each country. Moreover, we had a strong demand from surrounding community for assessing health effect due to nighttime aircraft noise corresponding to the conditional relaxation of curfew.

Under these backgrounds, we decided to conduct a survey on health effects of aircraft noise on the occasion of implementing conditional relaxation of nighttime curfew.

3. NOISE IMPACT DUE TO CONDITIONAL RELAXATION OF CURFEW

3.1 Trend of noise exposure in nighttime

Figure 2 shows the trend of daily flight movements in the nighttime and in the early morning for Runway-A and Runway-B over the 14 years since Fiscal 2002, when Runway-B opened. N1 means the total of daily flight movements in the early morning from 0:00 to 07:00, whereas N4 shows the total of daily flight movements in the nighttime from 22:00 to 24:00. Note that the nighttime is defined as a nine-hour period from 22:00 to 7:00 in the Japanese noise guideline “Environmental Quality Standard for Aircraft Noise,” in which noise index was replaced from WECPNL to $L_{den}$ in 2007. From the figure, we can see that the total flight movements, $N_1 + N_4$ remained almost the same level up to Fiscal 2011, because flight movements using Runway-B after 22:00 had been restricted for the expansion of the runway from Fiscal 2005 to Fiscal 2008. After Fiscal 2012, flight movements using Runway-B has gradually increased, as is shown in Figure 2. Thus, the increase in noise exposure due to flight movements in the nighttime would be a concern in the future.

Figure 3 shows the trend of nighttime noise exposure, evaluated using five noise metrics, i.e., “nighttime-average sound level ($L_{Aeq,night}$)” and “Nighttime Number Above ($N_{65,night}$, $N_{70,night}$, $N_{75,night}$ and $N_{80,night}$)” at four levels from 65 dB to 80 dB at an interval of 5 dB and at four unattended noise monitoring stations owned by NAA: NMS01 and NMS02 (Runway-A) and NMS03 and NMS04 (Runway-B). NMS02 and NMS04 are located under the flight path at around 8 km away from the end of each runway respectively, whereas NMS01 and NMS03 are located at around 1 km to the side from flight path. Note that the nighttime is defined as the nine hour time period from 22:00 to 07:00.

As is shown in Figure 3, noise exposure at the two sites NMS01 and NMS02 (Runway-A), tends to decline due to the replacement of older aircraft with newer low-noise aircraft year by year. However, $N_{65,night}$ is increasing at NMS02, located under the flight path of Runway-A, after FY2011. The cause is guessed to be the increase in take-off events of low-noise aircraft of up to 65-70dB in $L_{A,\text{Smax}}$. Operational procedures using the two runways have been changed in FY2011: Runway-A is now used for take-off and Runway-B for landing. On the other, at NMS03 and NMS04, $L_{Aeq,night}$ remains unchanged, whereas level of Number Above indices is gradually increasing. It means the total noise exposure in the nighttime is unchanged for Runway-B, because the increase in flight movements cancels the decrease in noise exposure due to the introduction of lower noise aircraft. As a result, we can conclude that there is no significant influence of the conditional curfew relaxation.
3.2 Summary of the conditional relaxation of nighttime curfew

Since 31 March in 2013, at the conditional relaxation of nighttime curfew, we have approved the applications for the delay in take-off and landing until 24:00 in the limited terms as follows:

a. Delayed landing of aircraft at Narita due to unavoidable reasons such as unusual bad weathers, sudden/serious medical cases and/or system failures at the airport of departure
b. Delayed landing of aircraft at Narita through another airport due to unavoidable reasons happened during the flight
c. Delayed landing of aircraft at Narita as a result of chain-reaction delays due to unavoidable reasons happened for ensuring safety in flight operation
d. Landing of aircraft at Narita by turning back due to unavoidable reasons happened at the destination airport
e. Delayed take-off or landing of aircraft due to unavoidable reasons mentioned above

Target aircrafts complied with the relaxation of the flight ban are limited to those of Categories A through C, specified in Narita Aircraft Noise Rating Index. On the basis of noise-related landing charge system, the airline companies, whose aircrafts were operated by applying to the conditional relaxation on nighttime curfew, have to pay an additional charge equal to the normal landing charge. The accumulated fund for additional charges is distributed equally between six local governments around the airport as appropriations for countermeasures and regional development aid. NAA promised to officially announce the information on the applications, i.e., airline name, flight number, reasons for the delay and so on.

3.3 Nighttime aircraft noise exposure caused by the conditional relaxation of curfew

Table 1 shows the number of flight movements associated with the conditional relaxation of nighttime curfew during the 3 years from Fiscal 2013 to Fiscal 2015. It indicates that, in only 33% at the maximum of all applications to the conditional relaxation of curfew, aircraft actually flew after the time limit for the nighttime ban. In other word, the increase in daily average number of flight movements per day was not greater than 0.2.
Figure 4 shows level difference in noise indices of $L_{Aeq,\text{night}}$ and $L_{den}$ between usual operation days without relaxation and special days when conditional curfew relaxation was applied in Fiscal 2014. In this figure, colored circles indicate 34 unattended noise monitoring stations owned by NAA, while the area surrounded by a blue border means a “noise zone” determined by ANPL (Aircraft Noise Prevention Law). Two-line figures are shown at each monitoring station: upper figures mean level difference in $L_{Aeq,\text{night}}$, and lower figures mean level difference in $L_{den}$. The maximum difference is 0.075 dB in $L_{Aeq,\text{night}}$ and 0.026 dB in $L_{den}$, which suggests that effects of conditional curfew relaxation on daily average noise exposure is negligible up to now.

Table 1 – Flight movements associated with conditional relaxation of nighttime curfew

<table>
<thead>
<tr>
<th>Year</th>
<th>The number of applications</th>
<th>The number of fight movement from 23:00 to 24:00</th>
</tr>
</thead>
<tbody>
<tr>
<td>FY2013</td>
<td>198</td>
<td>58</td>
</tr>
<tr>
<td>FY2014</td>
<td>231</td>
<td>56</td>
</tr>
<tr>
<td>FY2015</td>
<td>195</td>
<td>65</td>
</tr>
</tbody>
</table>

Figure 4 – Differences of noise indices in $L_{Aeq,\text{night}}(22-07)$ and $L_{den}$

(upper portion: $L_{Aeq,\text{night}}(22-07)$, lower portion: $L_{den}$)

4. SUMMARY OF SURVEY ON HEALTH EFFECT

In order to implement the survey on health effect of aircraft noise in a fair and equitable manner, NAA established the committee, consisted of academic experts and a chief of local government, to both remain in control of the survey and evaluate the results. The investigative bureau, designated by the committee, implemented the survey on health effect under strict supervision by the committee.

The detail procedure of a questionnaire survey on health effect of aircraft noise around Narita International Airport is shown in Figure 5.

The survey areas consisted of “exposure areas” surrounding the airport and “control area” where are adjacent to the airport but have not affected by aircraft noise exposure. Eight thousands of participants aged from 20 to 79 years old were sampled from residents’ ledger by means of the stratified random sampling method with respect to aircraft noise in exposure areas. However all residents of target age group were selected in exposure areas of high level, because of small population of appropriate residents in the area. Two thousands of participants of target age group were sampled by the same method in control areas. In exposure areas 3,035 residents (39.2 %) agreed, and 624 (31.7 %) did in control area. 1,496 adults (49.3 %) in exposure area and 293 (50.0 %) in control area were males out of 3,659 respondents. In both areas, around 60 % of them were aged in their fifties or above and average ages of male and female were 50’s. About 70 % and over in exposure area and around 80 % in control area had been living for more than 10 years at the same place. About 30 % and over of them was employee in both areas.

Annual averaged outdoor noise exposures of residents’ houses in exposure area, $L_{den}$ and $L_{Aeq,\text{night}}(22-07)$, were determined at an interval of 5 dB from the measured results of aircraft noise at 89
The survey on health effects of aircraft noise for residents living around the airport was carried out by a postal questionnaire during about two-and-a-half months. The questionnaire consisted of both Total Health Index (THI) questionnaire (7) and a general questionnaire asking about living environment (8) and sleep impact (9). Especially, both THI and sleep impact were asked without specified noise sources in the questionnaire.

Using THI questionnaire, physical and mental health was assessed in terms of 130 subjective symptoms concerning the following 12 scales: many Subjective symptoms (SUSY), Respiratory (RESP), Eye and skin (EYSK), Mouth and anal (MOUT), Digestive (DIGE), Irritability (IMPU), Lie scale (LISC), Mental instability (MENT), Depression (DEPR), Aggression (AGGR), Nervousness (NERV) and Irregularity of life (LIFE). A response to each symptom was scored into from 1 to 3 points, and summed up by the above item groups for calculating scores of the above 12 scales. Moreover, the following 5 secondary scales were derived from these primary ones: psychosomatics (PSD), neurotics (NEURO), schizophrenic (SCHZO), and two additional scales, named T1 and T2. Where, the higher T1 score means there are the more symptoms and psychological distress, the higher T2 score indicates many physical problems without mental distress. And then we converted from a score to a percentile of each scale on basis of the distribution of scores for middle-aged and senior

Table 2 – The number of respondents in both exposure groups and control one

<table>
<thead>
<tr>
<th>L_{den}</th>
<th>Ctrl.</th>
<th>52-57 dB</th>
<th>57-62 dB</th>
<th>62-67 dB</th>
<th>67- dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ctrl.</td>
<td>624</td>
<td>1,260</td>
<td>1,404</td>
<td>352</td>
<td>19</td>
</tr>
<tr>
<td>40-45 dB</td>
<td>755</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45-50 dB</td>
<td>1,909</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50-55 dB</td>
<td></td>
<td></td>
<td></td>
<td>352</td>
<td></td>
</tr>
<tr>
<td>55- dB</td>
<td></td>
<td></td>
<td></td>
<td>19</td>
<td></td>
</tr>
</tbody>
</table>

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adults supported by the authors of THI plus.

In the questionnaire on living environment developed by INCE/Japan, the important questions about community response to noise are following two questions and a sub-question: [Q-1] Thinking about the last one year or so, when you are here at home, how much do the following noises (#1.Road, #2.Aircraft, #3.Railway, #4.Factory, #5.Construction, #6.Others) bothers, disturb, or annoy you; 1.Extremely, 2.Very, 3.Moderately, 4.Not so much or 5.Not at all? [Q-2] What is the most bothering, disturbing, or annoying noise from #1 to #5 listed in the above Q-1? [SQ-1] What kind of annoyance do you receive by the noise you mentioned in Q-2? (Circle the appropriate number as many as you like): |1|.disturbs listening to TV etc., |2|.disturbs conversation, |3|.disturbs sleep, and so on. Annoyance of aircraft noise was measured by Q-1, and responding “Extremely” as the answer was classified as “highly annoyed”. The disturbances of daily life caused by aircraft noise were measured by both question Q-2 (noise source) and sub-question SQ-1 (daily activity).

Insomnia was defined by responses of following questions: Q-4) Do you have any troubles with sleep, Q-5) Do you have the following four symptoms – SQ5-1) difficulty in initial sleep (DIS), SQ5-2) difficulty in sleep maintenance (DSM), SQ5-3) premature morning waking (PMW) and SQ5-4) a feeling of light overnight sleep (LOS), and Q-6) Do you have the following troubles in daily life caused by the above four symptoms – /1./have a bad morning, /2./almost late for work or school, /3./cannot hustle on business with sleep, /4./take a nap in the daytime, /5./make so many mistakes on the job, /6./get really sleepy. Therefore, in this study, insomnia was defined regardless of the reason for sleeplessness.

And then we asked for some important questions as follows: i) noise sensitivity estimated by response to a contracted form of Weinstein’s Noise Sensitivity Scale (WNS-6B) (10), ii) sex, age, height and weight (BMI), and systolic and diastolic blood pressure, occupations, iii) past treatment, disease under treatment, iv) residence year and effective year of house.

5. CONCLUDING RESULTS AND FUTURE APPROACHES

5.1 Brief results

In this paper, we reported brief results of the questionnaire survey on health effects as will another paper (11) be described in detail. The following results were derived from analyze response of questionnaire with the exception of the group in the highest exposure level, because of a small sample in the group.

Firstly, the percentages of highly annoyed, listening and conversation disturbances by categories of noise exposure are shown in Table 3 along with noise sensitivity. As shown in Table 3, in this survey, the ratio of noise-sensitive respondents in each group almost equaled each other. From the results, it was clear that noise exposure was correlated closely with highly annoyed, listening and conversation disturbances. The difference of percentages for between sensitive and non-sensitive respondents in every groups indicated that the significant factor was noise sensitivity.

Secondly, the percentages of insomnia, sleep disturbances by categories of noise exposure are shown in Table 4 along with noise sensitivity. From the results, it seemed to be correlated noise exposure with insomnia and sleep disturbances. While annoyance had a tight connection with noise exposure, insomnia did a loose connection with noise exposure.

Finally, let show examples of analysis results on physical impact. Table 5 shows the odds ratios of physical health which were assessed by response to THI questionnaire with 95 % confidence intervals. From the results of logistic regression analysis, noise exposure level did not associate with physical health, that is SUSY, RESP, EYSK, MOUT and DIGE, while annoyances, disturbances of daily life, insomnia seemed to be correlated with noise exposure. Figure 6 shows the relationship, which is derived by using logistic regression analysis adjusted on the basis of sex, age-group and noise sensitivity, between aircraft noise exposure and average blood pressure calculated from (self-reported) systolic and diastolic blood pressures. This result show that blood pressure, which is one of risk factor for cardiovascular, is not associated with aircraft noise exposure. The result analyzed on self-reported blood pressure was given the same one as the above subjective symptoms evaluated by using response to THI questionnaire.
Table 3 – The percentages of highly annoyed, two disturbances and noise sensitivity by noise exposure categories in $L_{den}$

<table>
<thead>
<tr>
<th>$L_{den}$</th>
<th>highly annoyed</th>
<th>listening disturbance</th>
<th>conversation disturbance</th>
<th>Noise-sensitive respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ctrl.</td>
<td>3.0 (5.6)</td>
<td>23.9 (29.8)</td>
<td>6.9 (8.5)</td>
<td>29.6</td>
</tr>
<tr>
<td>52-57 dB</td>
<td>22.8 (35.7)</td>
<td>72.1 (76.2)</td>
<td>31.5 (37.2)</td>
<td>29.3</td>
</tr>
<tr>
<td>57-62 dB</td>
<td>34.5 (44.9)</td>
<td>82.2 (85.7)</td>
<td>44.9 (51.8)</td>
<td>34.1</td>
</tr>
<tr>
<td>62-67 dB</td>
<td>43.9 (56.2)</td>
<td>86.9 (91.5)</td>
<td>56.5 (71.8)</td>
<td>34.9</td>
</tr>
</tbody>
</table>

Note: the value in a bracket means a percentage for noise-sensitive respondents.

Table 4 – The percentages of insomnia, sleep disturbance and noise sensitivity by nighttime noise exposure categories in $L_{Aeq,night(22-07)}$

<table>
<thead>
<tr>
<th>$L_{Aeq,night(22-07)}$</th>
<th>Insomnia</th>
<th>Sleep disturbance</th>
<th>Noise-sensitive respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ctrl.</td>
<td>12.8 (17.3)</td>
<td>8.5 (11.7)</td>
<td>29.6</td>
</tr>
<tr>
<td>40-45 dB</td>
<td>14.3 (25.2)</td>
<td>15.7 (26.1)</td>
<td>26.8</td>
</tr>
<tr>
<td>45-50 dB</td>
<td>17.1 (25.7)</td>
<td>24.2 (33.4)</td>
<td>33.9</td>
</tr>
<tr>
<td>50-55 dB</td>
<td>20.2 (35.8)</td>
<td>26.7 (40.2)</td>
<td>34.9</td>
</tr>
</tbody>
</table>

Note: the value in a bracket means a percentage for noise-sensitive respondents.

Table 5 – Results of logistic analysis of physical health assessed by responses of THI questionnaire

<table>
<thead>
<tr>
<th>$L_{den}$</th>
<th>SUSY (p)</th>
<th>RESP (p)</th>
<th>EYSK (p)</th>
<th>MOUT (p)</th>
<th>DIGE (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ctrl.</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>52-57 dB</td>
<td>1.24 (0.97-1.59)</td>
<td>1.30 (0.98-1.71)</td>
<td>1.25 * (1.00-1.55)</td>
<td>0.91 (0.70-1.20)</td>
<td>1.17 (0.91-1.50)</td>
</tr>
<tr>
<td>57-62 dB</td>
<td>1.15 (0.90-1.47)</td>
<td>1.24 (0.94-1.63)</td>
<td>1.16 (0.93-1.44)</td>
<td>0.86 (0.66-1.12)</td>
<td>1.09 (0.85-1.40)</td>
</tr>
<tr>
<td>62-67 dB</td>
<td>1.17 (0.84-1.63)</td>
<td>1.22 (0.84-1.76)</td>
<td>0.90 (0.66-1.22)</td>
<td>0.76 (0.51-1.11)</td>
<td>0.97 (0.69-1.37)</td>
</tr>
</tbody>
</table>

Note: * $p < 0.05$, where $p$-value indicates the significance probability of logistic analysis.

Figure 6 – Odds ratios and 95% confidence intervals of relative high blood pressure vs. aircraft noise exposure by $L_{den}$

5.2 Future approaches

It is one year since the completion of the survey on health effects of aircraft noise at Narita and publication of the result. There have been four applications to the conditional curfew relaxation program in Fiscal 2016 as of the end of April, but the rate of increase is not different from the last
three years. No noise complaints from the residents were brought in association with the conditional curfew relaxation except for those due to seasonal changes in runway use. The result of the health effect survey suggests that the nighttime noise impact is not significant up to now under the current situation of aircraft noise exposure around the airport. However, the government and NAA are under planning of further enhancement in functional means for expanding airport capacity at Narita: [1] re-extension of Runway-B to 3,500m, [2] construction of an additional third runway, and [3] further relaxation of operational restrictions in the nighttime. Implementation of such further curfew relaxation will no doubt increase the nighttime noise exposure. Under the condition that there is no legislation or guideline for controlling night-time noise exposure and its health effect in Japan, NAA is requested to plan and explain how to prevent or minimize such noise impact in a polite manner as the airport operator to residents living around the airport. NAA must continue to watch the situation of nighttime aircraft operations and it has also to carry out similar surveys on health effects of aircraft noise if necessary.

6. CONCLUSIONS

NAA carried out various noise measures and set operating restrictions on noise under the constraints of located inland. And the conditional relaxation of nighttime curfew was approved at the meeting of Narita Airport and Community Council in order to enhance the competitiveness of Narita International Airport and improve convenience of customers. And a large scale of questionnaire survey on health effects of aircraft noise for resident living around the airport was conducted based on agreement exchanged in the decision of conditional relaxation of nighttime curfew at the meeting. The aim of the survey on health effects was to clarify current relationship between various health effects of residents living around the airport and aircraft noise exposure.

However, flight movements caused by conditional relaxation after 23:00 was not so many and corresponding increase of noise exposure was small in these three years. And we could not find out the presence of correlations between noise exposures caused by the conditional relaxation of nighttime curfew around the airport and various health effects.

In conclusion, it is important to be conducted epidemiological survey continuously to confirm how to vary the correlation and so on between noise annoyances, sleep effects, psychological and physical effects and noise exposures along with future variation in noise exposures.

REFERENCES