THE FINNISH ENVIRONMENT 33en | 2007

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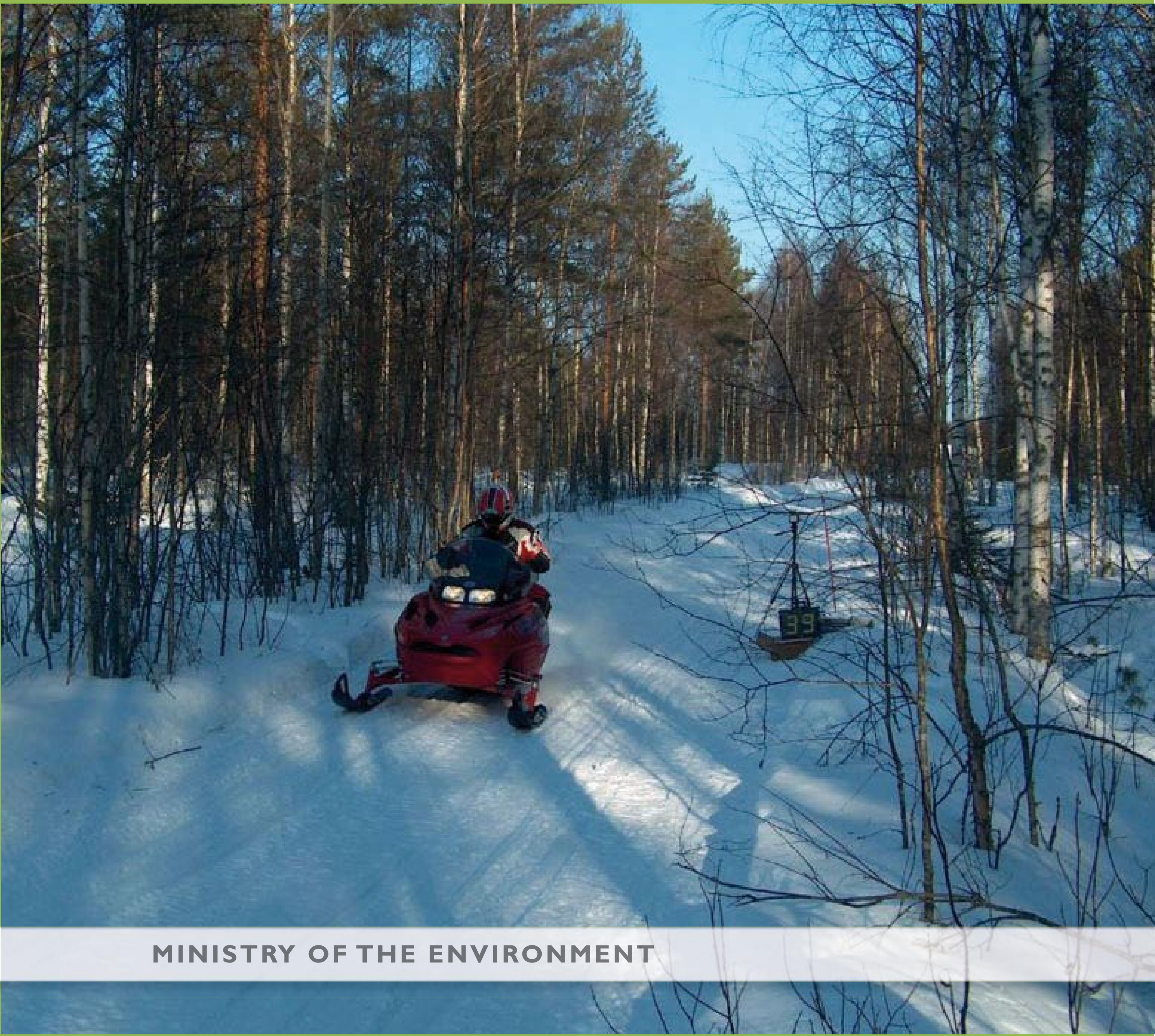
ENVIRONMENTAL PROTECTION



MINISTRY OF THE ENVIRONMENT

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Helsinki 2008

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FOREWORD

This report has been commissioned by the Ministry of the Environment and compiled by WSP Finland Oy, with participation from Larri Liikonen M.Sc., Technician Mikko Alanko, Sirpa Jokinen M.Sc., Ilkka Niskanen M.Sc. and Lauri Virrankoski M.Sc. (Agric.). Measurement expert was Erkki Björk Ph.D. from the Noise Laboratory of the University of Kuopio. The snowmobiles operated and owned by the Ylä-Satakunnan Moottori- ja kelkkakerho (Motor & Snowmobile Club of Ylä-Satakunta) club members. Measurement of snowmobile speeds, and riding of one snowmobile were the responsibility of representatives of the Traffic Police. The tasks were coordinated by Senior Inspector Pekka Tuunanen from the Ministry of the Environment. The Ministry of the Environment would like to thank everyone who participated in the study on snowmobile noise.

Ministry of the Environment

CONTENTS

1 Introduction

The number of snowmobiles and the use of the vehicle for recreational purposes have increased dramatically over the past few years. In 2005, there were nearly 102,000 registered snowmobiles in Finland. The increase in snowmobiling has also brought about discussions on the harm caused by snowmobiles.

One of the most significant detrimental impacts of snowmobiling is noise. The disturbance caused by snowmobiles, as far as regards other people enjoying the recreational use of nature, is especially related to the fact that snowmobile routes are often located close to other routes used for recreational purposes. In addition to others engaged in recreation in nature, snowmobiles also cause disturbances to permanent and holiday housing. With respect to housing, the most problematic places are routes that travel close to built-up areas where traffic numbers are often at their highest, which is primarily due to the availability of fuelling, resting and accommodation areas.

Noise disturbances caused by snowmobiles are made worse by the fact that when snow and ice conditions are at their best, snowmobiles can be used to traverse almost anywhere where terrain forms or vegetation allows. According to the Act on Off-Road Vehicles (1710/1995), a motorised vehicle may not be used to traverse, stopped or parked in the terrain without permission from the landowner or leaseholder. In some cases, however, this permit is not required (e.g. official tasks, patient transportation). Everyone has the right to traverse frozen waterways, as stipulated by Chapter 1, Section 24 of the Water Act (264/1961).

With the popularity of snowmobiling on the increase, the problems it causes have received more attention. More information is required in order for harm caused by such activities to be mitigated and thereby safeguard the possibilities of snowmobiling being a pastime of private individuals, a tourist activity and a business.

2 Purpose of the task

The planning of snowmobile routes, and the necessity for possible restrictions to off-road traffic requires knowledge of the noise impacts of snowmobile traffic. Snowmobile noise has been studied in 2004 with "Preliminary study on snowmobile traffic noise" (Finland's Environmental Administration 712) and the report "Snowmobiling for recreation, utility and disturbance" (Finland's Environmental Administration 53/2006). The aforementioned studies included a review of literature on snowmobile noise and a questionnaire study on the disturbance of snowmobile noise in respect to e.g. housing located close to snowmobile routes, and the attitudes of others outdoors on the disturbances caused by snowmobiling.

The purpose of this task was to examine the noise caused by snowmobiles and noise dispersion in the environment using terrain measurements. The dispersion of snowmobile noise was measured in the forest and on ice covered waterways using varying speeds, driving styles and traffic numbers. Using the findings obtained, the intention was to assess the protective distance of snowmobile routes required by housing and recreational areas on the basis of guideline values for noise levels issued by the Council of State.

On the basis of information obtained in this study, the task of planning routes may avoid the dispersion of noise levels/noise areas, that exceed guideline values, into areas intended for housing or recreational use, thereby mitigating the disturbance experienced from noise. From the perspective of the various needs related to the recreational use of nature, the implementation of snowmobile routes is problematic.

3 Sources of snowmobile noise

This study investigated snowmobile noise during acceleration and pass-bys at constant speeds. The study did not examine technical details and mechanisms affecting noise emissions by snowmobiles, or the role of such on total noise emissions.

The most significant sources of snowmobile noise are the engine, exhaust and track. Furthermore, noise emissions are essentially affected by driving style and chassis.

Earlier studies and their findings indicate that the engine noise of modern snowmobiles is most significant at low speeds when examining total noise emissions. At higher speeds, the noise caused by the track produces the most noise.

Recreational snowmobiling has a number of characteristics often associated with motor sports, such as fast acceleration and braking. Therefore riding a snowmobile is essentially different from driving a car or motor boat.

3.1

Engine

The engine used for snowmobiles is a two or four-stroke combustion engine. Fuel is fed by carburettors, or by injection in newer models. The engines are liquid or air cooled, and power is shifted to the track via a transmission.

In recent years it has been possible to reduce the noise caused by the engine. For example, the new four-stroke engines are a little quieter than the traditional two-stroke engines (Daily 2002). However, such findings were not obtained in this study.

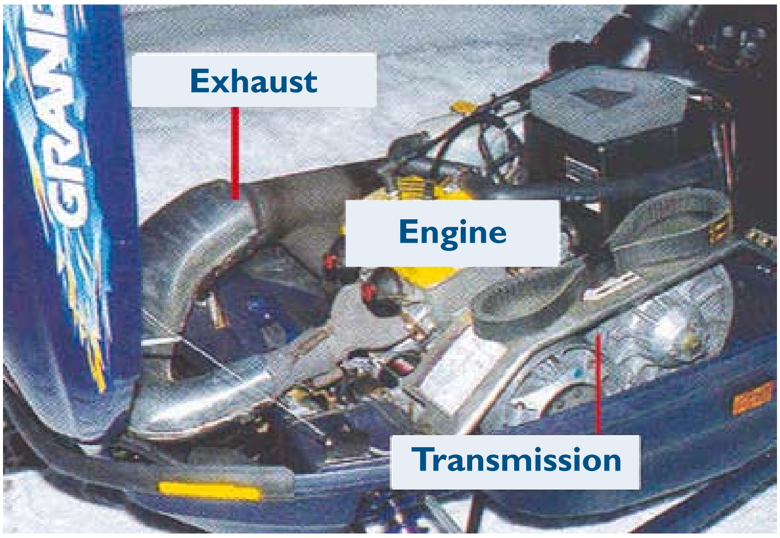


Figure 1. Engine space of a snowmobile. Source: MK magazine.

The sound quality caused by a four-stroke engine could be less annoying than a two-stroke engine. In the future, the further reduction of engine noise will require even more technical input. The noisiest part of the engine is the exhaust, so in the main, the noise caused by a snowmobile is slightly higher on the exhaust side. In measurements conducted by Miers et al. (2000), the noise emitted from the exhaust side of the snowmobile was approximately 1 dB higher than on the clutch side.

The location and height of the noise source denotes how the noise is dispersed into the surroundings and how the ground (snow) muffles noise. Depending on the model of snowmobile, the engine and exhaust are located at a height of 35–50 cm from the surface of the trail. The engine used for snowmobiles is a two or four-stroke combustion engine. Fuel is fed by carburettors, or by injection in newer models. The engines are liquid or air cooled, and power is shifted to the track via a transmission.

3.2 Track

The length and width of the snowmobile's track varies according to the purpose of use. Snowmobiles designed for touring and sports use usually have a track with a width of 38 cm and length starting from 307 cm. In utility snowmobiles the width of the track is usually 50 or 60 cm, with an approximate length of 397 cm.

The noise caused by the track depends on the width, length and tread of the track. The noise is made by the track hitting the snowmobile route at great speeds. In this case, the hardness of the route is also significant: the harder the surface, the noisier the track. In addition, noise is caused by the contact between the track and the rollers.

3.3 Driving style and route

Riding a snowmobile is very different from driving a car or motor boat. The biggest reason for these differences is the routes used. Snowmobile routes most often traverse forests, where sustaining a constant speed is difficult. One characteristic of snowmobiling is that driving is a combination of accelerating and braking, which is done using the engine, releasing the throttle or braking (locking track revolution). This being the case, the characteristics of the snowmobile route have huge impacts on noise emissions. The narrow and winding route often leads to plenty of acceleration and braking. On the other hand, a wide route in good condition may encourage snowmobile riders to significantly exceed legal speed limits (60 km/h in the forest and 80 km/h on ice). This increase in speed leads to an increase in noise emissions.

3.4
Noise dispersion

The silencing of noise was affected by the distance of the inspection point from the source, air absorption, terrain forms and weather conditions. Distance and air absorption are factors that most influence silencing of noise, the affect of which is evident in all conditions. In respect to noise dispersion, the most influential factors are wind (direction and speed) and the quality of the ground surface. In winter conditions the thickness of snow cover has a significant impact on the absorption of noise. Soft snow effectively absorbs noise, whereas frozen snow reflects sound waves. Silencing is more effective at high frequencies. The terrain affects noise emissions. For instance, forest terrain acts as an effective silencer of noise, whereas hard snowdrifts or hard surfaced ice reflects noise that is carried far.

4 Implementation of the task

4.1

Methods

A standard does exist for snowmobile and maximum noise measurement. Of these American standards, the SAE J192 has been developed for the measurement of maximum noise, and is the basis for the threshold values set for Finnish snowmobile noise. The SAE J1161 standard has been developed to describe noise made by snowmobiles (driving noise) in regular use, i.e. riding at constant speeds.

In both standards, the measurement of snowmobile noise is performed at a distance of 15.2 metres from the sprint track (figure 2). During measurement riding direction is changed, so measurements are taken from both sides of the snowmobile.

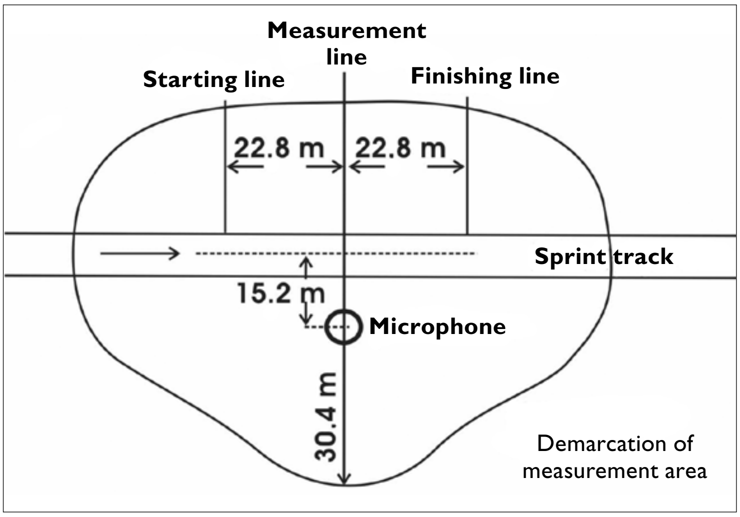


Figure 2. Set-up for measuring snowmobile noise in accordance with the SAE J192 standard. Source: SEA 2003, SAE 1983.

The microphone is placed at a height of 1.2 metres from the surface of the snow. No surfaces that may reflect noise (vehicles, signs, etc.) may be within 30 metres of the measurement area. The ground surface, including the sprint track, can have a maximum of 75 mm of loose snow. At least 50 mm of compacted snow should lie beneath the loose snow. Measurement may alternatively be conducted on a grass base (max. 75 mm). The location of the snowmobile (starting line, measurement line, finishing line) is specified by the front skis. Measurement is not recommended in conditions with a wind speed exceeding 5 m/s. Air pressure should be between 93 and 103 kPa. (SAE 2003, SAE 1983).

No other persons in addition to the snowmobile rider and person taking noise measurements may be within 15 metres of the noise meter or snowmobile during measurements. The microphone used for measurements shall be protected with a wind muffler. The measurement device should be a class 1 noise level meter (IEC 651 or IEC 804). The noise level from other sources should be at least 10 dB lower than the snowmobile subject to measurement. (Previously mentioned study).

When measuring the riding noise of a snowmobile *(Operational Sound Level)* in accordance with SAE J1161, pass-by occurs at a constant 24 ± 3 km/h speed in such a way that the snowmobile is accelerated to the desired speed before the finishing line (figure 2). Between the starting line and finishing line the snowmobile may not stray over one metre to the side of the central line of the sprint track. The pass-by L_{ASmax} value is used to illustrate noise level (highest A frequency weighted and slow time weighted sound level). Measurements are repeated until three readings are obtained within 2 dB. Measurements are taken separately from both sides of the snowmobile, and a mean value is calculated from three measurements to the precision of one decibel. The final reading is taken from the mean of three measurements from the "noisier side" of the snowmobile (SAE 1983).

In addition, a maximum noise level was specified for the snowmobiles involved *(Maximum Exterior Sound Level)*, the measurement of which (SAE J192) uses the same method as for specifying the operational sound level, with the exception of pass-by measurement. The approach occurs at a constant speed of 24 km/h, but when approaching the finishing line, the throttle is fully opened until reaching the finishing line. If the snowmobile fails to reach the desired speed of 24 km/h before the starting line, the starting line is crossed at full speed. Measurements should also verify the engine's highest revolution during measuring (SAE 2003). The margin of error for measurements for both standards was specified as ± 2 dB (SAE 2003, SAE 1983).

4.2 Measurements

Snowmobile noise measurements were conducted on 15–17 March 2005. Measurements applied the methods illustrated in section 4.1. Diverging from the standard, the L_{AFmax} level was measured for pass-by, riding noise and maximum noise level of this study. The L_{AFmax} level was measured, as it is often used as a figure for illustrating people's feelings and experiences of momentary noise. The L_{AFmax} level is employed in for instance, Sweden as a figure for noise guideline values for motor sport race tracks. This 60 dB L_{AFmax} level is also applied in Finland in legal cases related to the Environmental Permit for motor sports tracks.

Measurement equipment included the 1st class sound pressure level meter: Norsonic 121 (a single 2-channel meter), Norsonic 118 (one unit) and RIon NL-32 (two units). The placement of measuring devices for various measurements is shown in figures 3 and 5. Measurements were conducted using the recommended operating temperatures.

Calibration employed the calibrators of the manufacturers of the instruments. The measurement equipment was calibrated at the beginning and end of the measurement sessions, and after any other possible breaks.

Noise caused by snowmobiling was measured in three different situations:

1. Single snowmobile, acceleration
2. Single snowmobile, constant pass-by speed
3. Snowmobile safari, constant speed

Measurements were made in two different terrains:

1. Forest
2. Frozen lake

Snowmobile safari noise was only measured in forest terrain, because very strong winds prevailed on the day planned for conducting measurements.

Measurements were conducted in two series of 4–5 measurement points. The closest measurement point, the reference point situated at a distance of 15.2 metres from the route, remained the same throughout.

Measurement series 1: Acceleration and pass-by of individual snowmobiles

1. 15 metres (reference point), measurement heights 1.2 and 3.6 metres from surface of snow (NOR-121)
2. 30 metres (RION NL-32)
3. 100 metres (RION NL-32)
4. 200 metres (NOR-118)

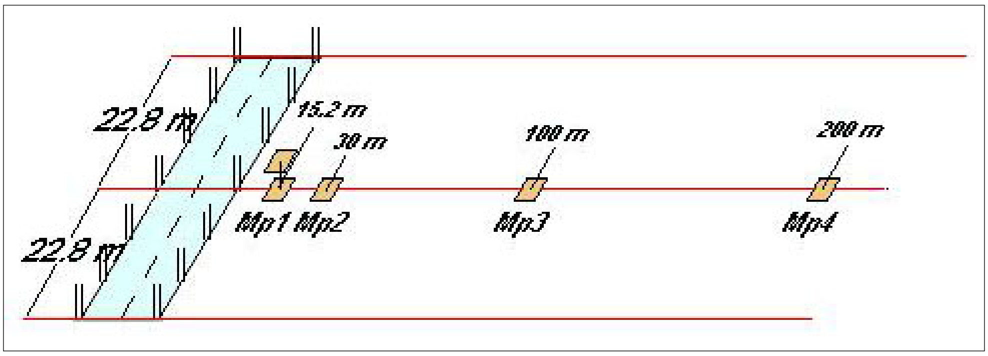


Figure 3. The locations of measurement points for acceleration and pass-by measurements of individual snowmobiles.


Figure 4. The speeds of individual snowmobiles were measured using radar.

Measurement series 2: Pass-by of safari groups

1. 15 metres (reference point), measurement height 1.2 metres from surface of snow (NOR-121, ch. 2)
2. 30 metres (NOR-121, ch. 1)
3. 100 metres (RION NL-32
4. 250 metres (NOR-118)
5. 500 metres (RION NL-32)

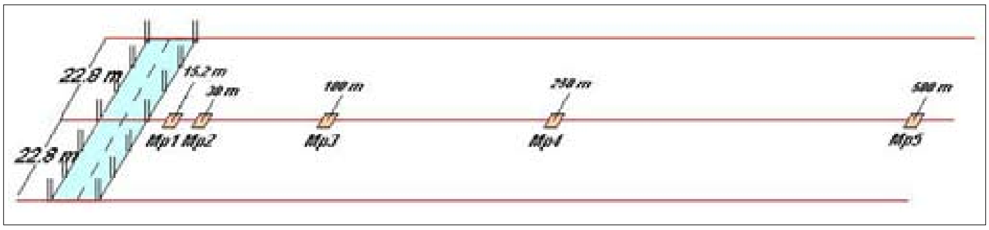


Figure 5. Locations of measurement points during safari.

Figure 6. In safari trips snowmobiles travel in convoy employing a safe distance that is normally adhered to in snowmobile safaris.

The pass-bys of individual snowmobiles were measured 5–10 times/speed. Pass-bys were conducted in such a way that both sides of the snowmobile were measured. For the purpose of the analysis of findings, the measurement minutes recorded for each measurement which side of the exhaust the instrument was placed. The measurements for individual snowmobiles were conducted according to SAE standards. Various snowmobile makes were obtained for the purpose of the measurements, some of which were two-stroke, and some four-stroke combustion engines. In connection with this study, the noise emissions of eight different types of snowmobiles (table 1).

Table 1. The snowmobile makes used for this study and principle technical data.

Snowmobile	Engine size cm^3	2/4-stroke	Track length and width	Year
Yamaha RS Vector	1000	4	307/38	2005
Lynx Enduro 600	600	2	307/38	2002
Lynx Forest Fox 440	440	2	396/38	2001
Ski-Doo GTX	380	2	345/38	2005
Ski-Doo 500	500	2	307/38	1997
Ski-Doo 380	380	2	307/38	1997
Polaris 800	800	2	365/38	2004
Lynx 600	600	2	307/38	2002
Lynx 800	800	2	307/38	2005
Yamaha 700 triple	700	2	307/38	2000
Polaris 600	600	2	307/38	2003

Measurements for safari rides were conducted in such a way, that the group comprised 4 or eight snowmobiles. The safari group travelled a route of approximately 3 kilometres at an agreed speed. The distance between snowmobiles was specified as the normally used safety distance.

Speeds used in measurements

As snowmobile speed has a large impact on the noise emissions produced, noise levels were measured at the speeds listed below. Snowmobile speeds were measured using the vehicle's own speedometer in addition to using precision radar instruments of the traffic police.

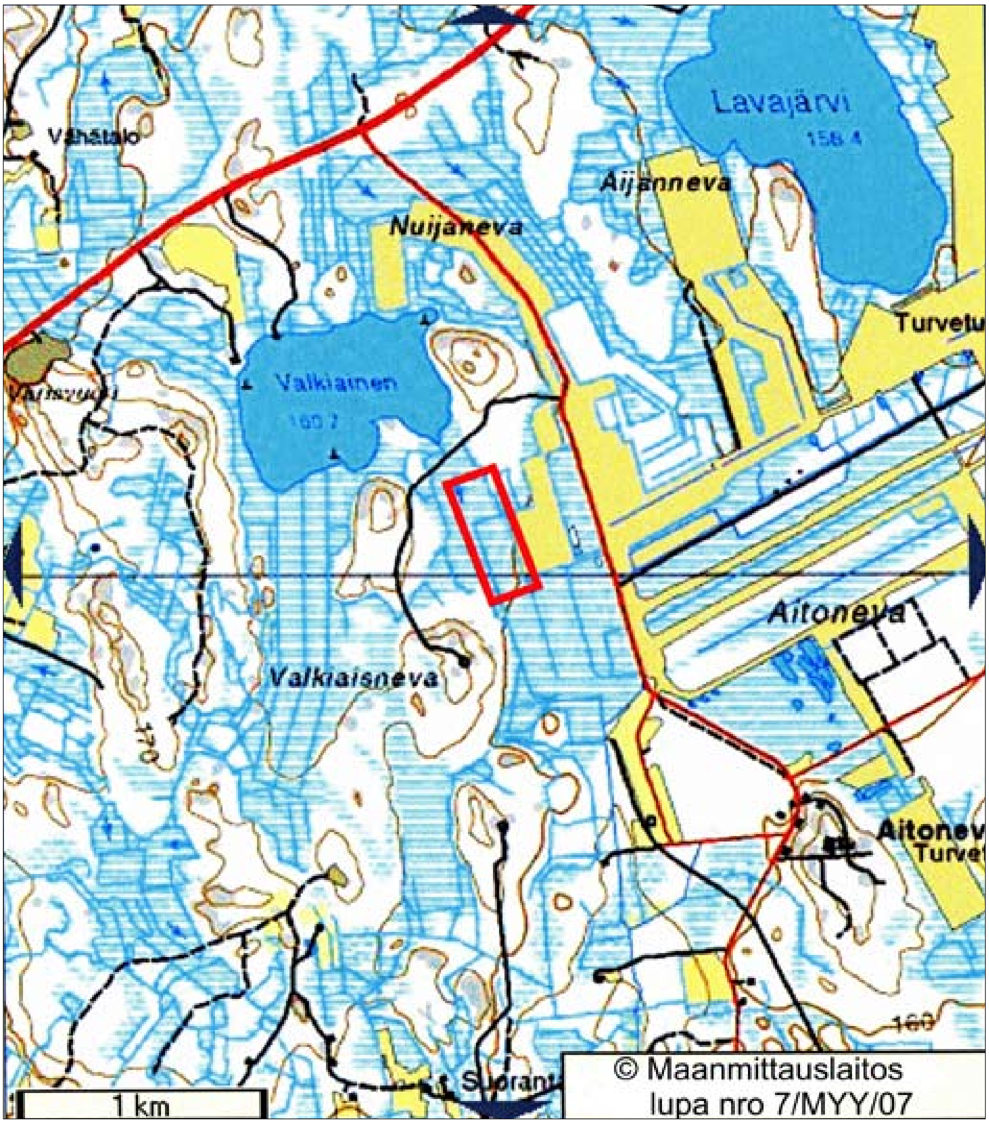
Measurement speeds:

Single snowmobile	*Safari*
20 km/h	20 km/h
30 km/h	
40 km/h	40 km/h
50 km/h	
60 km/h	60 km/h
70 km/h	
80 km/h	

4.3
Terrain

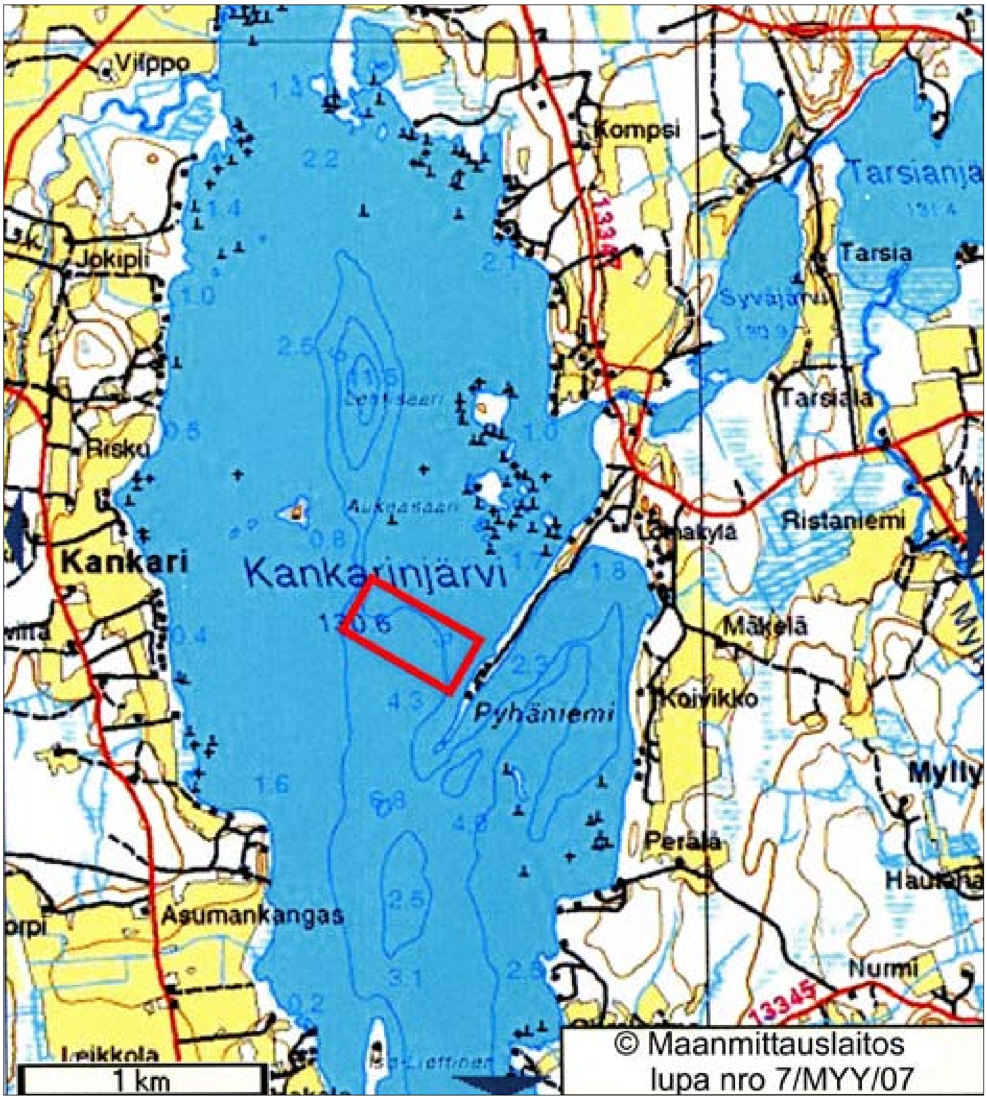
The locations of measurement areas are shown in map 1 (forest) and 2 (lake). The selection of areas gave consideration to the aforementioned parts of the SAE standard concerning minimum requirements and other possible noise sources. However, naturally it was not possible to satisfy the requirements for an open area in the forest areas. As the measurement distances were large, in particular in measurement series 2, and the expected snowmobile sound levels rather low, the areas were chosen in such a way that no other significant sources of noise (e.g. road, track, forest work, quarrying, industrial plant) were located within a distance of 1.5 – 2 km.

The terrain of the forest area was relatively even on both sides of the measurement track for a distance of around 500 metres. The thickness of snow cover was 38–43 cm.



Map 1. Measurement site 1 (forest).

Figure 7. Measurement series performed in the forest terrain.



Map 2. Measurement site 2 (frozen lake).

Figure 8. Measurement set-up on frozen Lake Kankarinjärvi.

4.4
Weather conditions

The weather conditions during measurement were obtained from the Lamminkoski road weather observation point of the Finnish Road Administration on Highway VT3, which is located approximately 20 km from measurement point no. 1 and approximately 10 km from measurement point no. 2. The weather conditions during measurements taken in the forest (measurement area 1, see map 1) were very good and constant throughout the entire measurement stage. However, during measurements performed on the frozen lake, the wind speed and direction affected the measured findings in such a way, that the comparison of such to corresponding forest measurement findings is problematic.

Table 2. Weather conditions during measurement 15–17 March 2005.

date/time	wind (m/s)	wind direction (°)	tempera-ture °C
15 March 2005			
13:00	3.0	335	- 8.1
14:00	3.0	336	- 7.5
15:00	3.0	336	- 7.3
16:00	2.8	327	- 7.0
17:00	2.2	318	- 7.2
16 March 2005			
14:00	1.0	190	- 3.5
15:00	1.7	175	- 3.6
16:00	1.3	163	- 3.9
17:00	1.4	184	- 4.2
18:00	0.7	179	- 5.7
17 March 2005			
13:00	1.0	100	- 4.2
14:00	0.7	77	- 3.9
15:00	0.8	85	- 3.7
16:00	0.6	58	- 3.8

4.5
Analyses

The purpose of analyses was to investigate the most typical noise emissions caused by snowmobiles and the dispersion of noise in the snowmobile route environment in varying terrain, in the forest and on the frozen lake. On the basis of the findings, the intention is to assess the average sound level caused by snowmobiles in the surroundings of the route. In this way, the data obtained may be utilised in the planning of routes, and when estimating the disturbance caused by snowmobiles.

The maximum levels caused by acceleration L_{AFmax} were analysed from the measurement findings. In addition, the affect of the number of snowmobiles on noise levels and noise silencing between measurement points was also analysed. Measurements taken by third octave frequency bands calculated the sound power levels by octave bands.

Pass-bys and safari rides done at constant speeds were subject to analyses by sound sensitivity levels L_{AE} and maximum levels L_{AFmax}, as well as average sound levels (L_{Aeq}). In addition, the impact of using a number of snowmobiles on the noise levels and noise silencing between measurement points were analysed. n vaikutusta melutasoihin sekä melun vaimentumista mittauspisteiden välillä.

4.6
Uncertainty of measurement

The uncertainty of measurements increases with the increase in measurement distance. The impact of conditions on the findings is even smaller, the closer the measurements are taken to the source. In this study, the closest measurement points were located at a distance of 15.2 metres from the passing snowmobile. According to the measurement standard, the uncertainty of measurement for the measurement distance in question is ± 2 dB.

According to general measurement guidelines provided by the Ministry of the Environment (Measurement of Environmental Noise, Guideline 1/1995), the uncertainty of the results of a single measurement is 2 dB at a measurement distance of 30 metres, 4 dB at a distance of 100 metres, and 7 dB at a distance of 500 metres. These uncertainties concern situations where the wind direction from the noise source is located within a 45-degree sector, and wind speed is less than 5 m/s. If conditions in accordance with measurement guidelines were not achieved, or measurement distances are greater than those mentioned in the guidelines, the measurement uncertainty is regarded as being 10 dB (Ministry of the Environment 1995). In this study, in particular the measurement uncertainties for the sound pressure levels measured at distances of 250 and 500 metres is high, especially when taking into consideration that the sound pressure levels measured at the distances in question were very low.

5 Measurement findings

5.1

Key figures for measured noise

This study primarily uses two figures for noise, momentary maximum level (L_{AFmax}) and the sound sensitivity level (L_{AE}). The momentary fast time weighted and A frequency weighted maximum level (L_{AFmax}) illustrates the short-term maximum noise level, which was a stage lasting 125 milliseconds. The L_{AFmax} level is often used as a figure for illustrating people's feelings and experiences of momentary noise. The L_{AFmax} level is employed in for instance, Sweden as a figure for noise guideline values for motor sport race tracks. This 60 dB L_{AFmax} level is also applied in Finland in legal cases related to the Environmental Permit for motor sports tracks.

The sound sensitivity level is used to illustrate the noise source when the signal is time restricted. The sound sensitivity level illustrates the maximum level and duration of the noise peak. The sound sensitivity level may be used to show noise disturbance when the disturbances caused by noise events of different durations are being assessed. The sound sensitivity level is especially applicable when calculating the average sound level caused by a number of individual events. In addition, information is also required on distance and speed. The sound sensitivity level is therefore a particularly technical variable, which may not, however, be used alone to make conclusions on the air pressure levels and experiences related to a certain event. Figure 9 shows an example of one figure used for pass-by noise. The horizontal axis shows time (one gap = one second), and the vertical axis the sound level (dB). The green "steps" shows the momentary maximum level (L_{AFmax}) and the broken line above shows the sound sensitivity calculated for the entire ten seconds (L_{AE}). The dotted line shows the average sound level for the stage (L_{Aeq}).

The sound power level (L_{WA}) shows the sound emissions of the sound source. It is a basic variable that may be used to calculate the dispersion of noise to any point, also to other points than the measurement distances. The line source should be used per unit of length for sound power, i.e. length sound power level ($L_{WA.1}$).

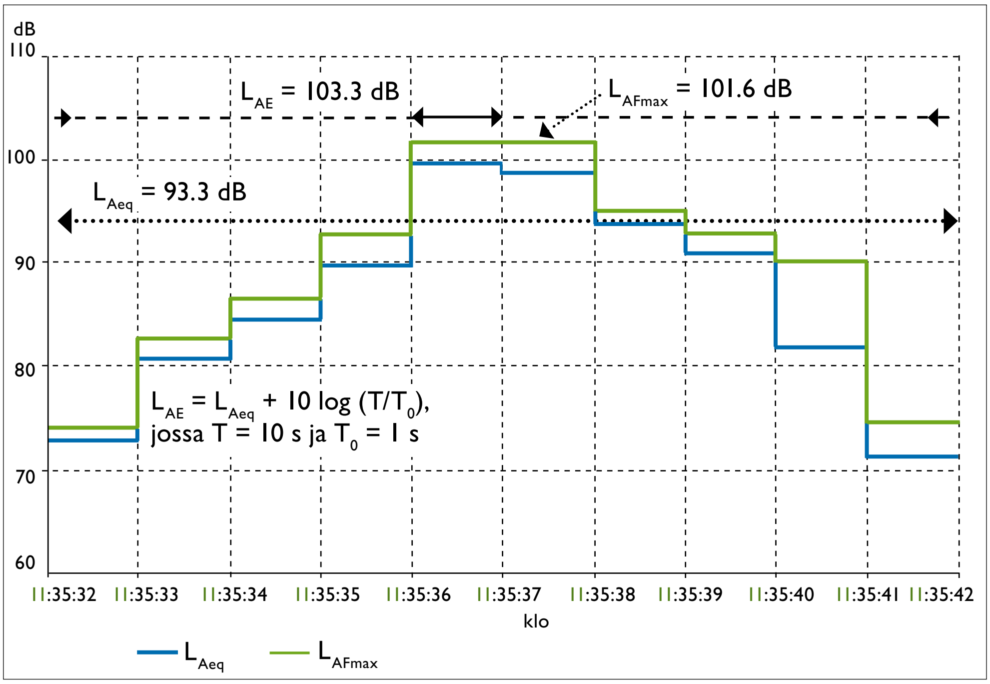


Figure 9. Figures for single time noise events: L_{Aeq} = average sound level for a 10-second stage, L_{AE} = pass-by sound sensitivity level, and L_{AFmax} = momentary maximum level caused by pass-by.

5.2

Maximum sound levels during acceleration

The sound levels of the snowmobiles involved in accordance with the standard were examined using maximum level measurements, which were conducted in accordance with the SAE J192 standard. The measurement findings were also compared to the decree for the maximum sound level for snowmobiles.

The decree of the Ministry of Transport and Communications on the design and equipment of tractors, motor-driven machinery and off-road vehicles, their trailers and towable devices (1251/2002) stipulates the restrictions for snowmobile noise (Section 49):

> *"A snowmobile should have an efficient silencer. The loudness of a snowmobile, measured in accordance with the SAE J192A standard, shall not exceed 78 dBA."*

Table 3 shows the maximum sound levels measured for snowmobiles involved in this study. The maximum levels shown in the table are energy averages for 9–10 acceleration (pass-by). Some of the snowmobiles were subject to analyses for maximum levels separately for both sides of the snowmobile. The purpose of the analysis was to examine whether the location of the exhaust pipe (located on the right side of analysed snowmobiles) has a significant impact on noise levels. At the measurement height of 3.6 metres, the results were higher than those for the 1.2 metre height, because the absorption of the snow surface is not as effective at the higher height.

Table 3. The maximum noise levels made by snowmobiles (L_{AFmax}) during acceleration (distance 15.2 m).

Measure-ment date	Distance/height from surface of snow (snow 38–43 cm)	15.2/1.2 dB	dB	15.2/3.6 dB	dB
	Snowmobile	Left	Right	Left	Right
15 March	Yamaha RS Vector	80.4		83.8	
15 March	Lynx Enduro 600	82.8	83.4	84.3	84.7
15 March	Lynx Forest Fox 440	78.4	79.9	80.0	81.5
15 March	Ski-Doo GTX	80.3	82.2	81.9	82.7
16 March	Ski-Doo 500	78.0		82.0	
16 March	Ski-Doo 380	76.6		80.3	
16 March	Polaris 800	79.9		84.8	
16 March	Lynx 600	82.7		86.1	
17 March	Lynx 800	82.0		84.2	
17 March	Yamaha 700 Triple	81.8		83.8	
17 March	Polaris 600	80.8		82.2	

Measurement findings may not be directly compared with the maximum level as stipulated in the decree of the Ministry of Transport and Communications (1251/2002), because the measurements were not subject to slow time weighting as stipulated with the SAE J192A standard. Based on noise measurements conducted at motor sports tracks, the slow time weighted maximum levels (L_{ASmax}) caused by pass-bys of motocross motorbikes and open class car races are approximately three decibels lower than fast time weighted maximum levels (L_{AFmax}). This difference is probably similar for snowmobiles. When this difference is taken into consideration for inspecting the findings of Table 3, we may verify that the momentary noise levels caused by some snowmobiles probably exceeded the 78 dB (L_{ASmax}) level.

One possible explanation for this may be that all the snowmobiles used for the measurements had been in use for at least a year. Therefore, the silencing properties of exhaust pipes no longer necessarily achieved the same level as new snowmobiles, and the track and rollers are more worn than with new snowmobiles. The findings of earlier studies (e.g. Miers, et al. 2000) are also similar.

All measurement findings from the right side of the snowmobiles were higher than the sound pressure levels measured for the left side, and in some measurements these differences were significant.

5.3
Maximum sound levels during steady riding

Table 4 and Figure 10 show the maximum noise levels caused by different snowmobiles at a distance of 15.2 metres and height of 1.2 metres, with the snowmobiles passing the measurement point at a constant speed 30–80 km/h.

Table 4. Maximum levels (L_{AFmax}) caused by snowmobiles at constant speeds. Measurement distance 15.2 metres and height 1.2 metres from the ground level.

	Lynx 800	Yamaha 700	Yamaha RS Vector *	Yamaha RS Vector *	Polaris 600	Lynx 600
30 km/h	67.9	67.0	64.5	63.3	65.2	68.8
40 km/h	69.2	68.9	66.9	65.7	68.5	70.1
50 km/h	71.4	72.1	68.1	67.9	70.7	71.7
60 km/h	71.9	71.8	71.4	70.2	72.5	73.0
70 km/h	72.6	73.2	73.5	73.0	73.4	73.8
80 km/h	74.3	75.5	76.5	76.3	74.7	75.1

*Two different makes of Yamaha RS Vector snowmobiles were used in measurements.

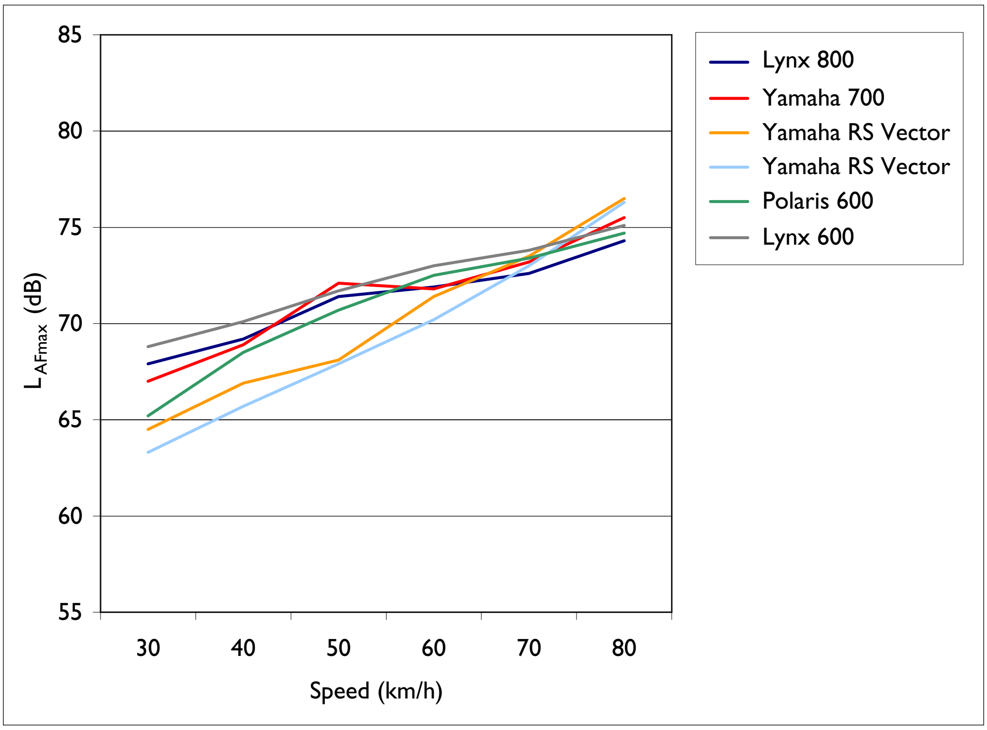


Figure 10. Maximum levels L_{AFmax} caused by snowmobile pass-bys at constant speeds, distance 15.2 m, height 1.2 m.

In the main, the maximum levels caused by snowmobiles increase as the speed increase. For some snowmobiles, however, the increase in maximum levels stopped when speed increased from 50 km/h to 60 km/h.

At slower speeds, according to measurements the four-stroke snowmobiles were quieter than the two-stroke models, but at the higher speed of 80 km/h they were in fact nosier.

Figure 11 shows the average maximum sound levels of the snowmobiles measured at different speeds and while accelerating. The figure shows that when speeds increase from 30 km/h to 80 km/h, the maximum levels caused by pass-by increase by around 10 dB. The maximum sound levels caused by acceleration were 81 dB on average.

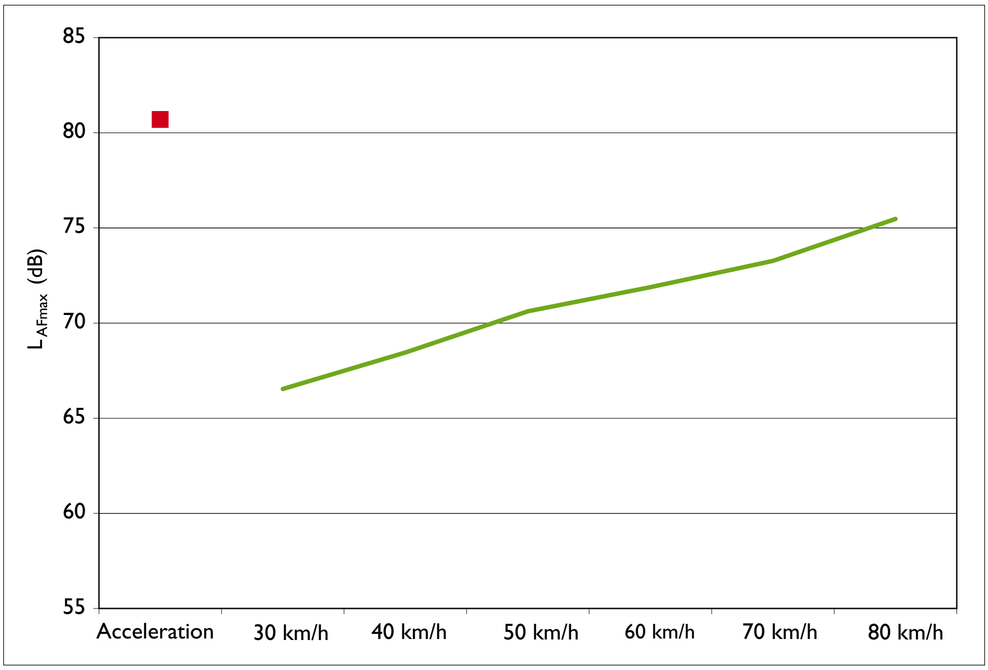


Figure 11. Average maximum sound level caused by measured snowmobiles passing by at L_{Fmax} constant speeds, distance 15.2 m, height 1.2 m, individual snowmobiles. The red square indicates the noise level for the measurement sites caused by acceleration.

5.4

Sound exposure levels for steady riding

Table 5 and Figure 12 show the sound sensitivity levels caused by different snowmobiles at a distance of 15.2 metres, height of 1.2 metres, with the snowmobiles passing the measurement points at constant speeds of 30–80 km/h.

Table 5. Sound sensitivity levels (L_{AE}) of pass-bys at constant speeds, individual snowmobiles. Measurement distance 15.2 metres, at a height of 1.2 metres from the ground surface.

	Lynx 800	Yamaha 700	Yamaha RS Vector *	Yamaha RS Vector *	Polaris 600	Lynx 600
	dB	dB	dB	dB	dB	dB
30 km/h	73.3	72.4	69.6	68.7	72.5	73.9
40 km/h	73.5	73.0	70.1	69.3	72.4	74.0
50 km/h	74.5	75.3	70.7	71.0	73.6	74.8
60 km/h	74.0	73.6	72.7	72.3	74.8	75.2
70 km/h	74.0	75.0	74.6	74.4	75.1	75.3
80 km/h	75.1	76.7	76.6	76.7	75.9	76.2

* Two different makes of Yamaha RS Vector snowmobiles were used in measurements.

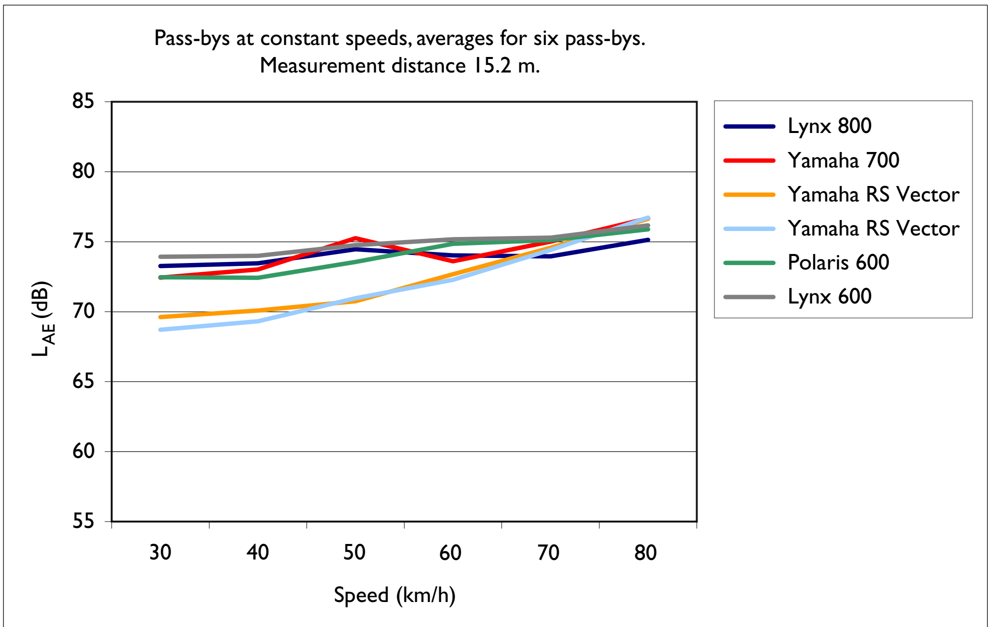


Figure 12. Sound sensitivity levels (L_{AE}) of pass-bys at constant speeds, individual snowmobiles.

When comparing the findings of different snowmobiles, it is evident that four-stroke snowmobiles (Yamaha Vector) were distinctly quieter than other snowmobiles at speeds below 60 km/h. At speeds over 60 km/h, the differences between different snowmobiles were minimal. The levelling out of differences between sound sensitivity levels at higher speeds appears to indicate, that with noise dispersion calculations, it should be possible to use the values of an average snowmobile, without too much concern over uncertainty.

Another rather interesting point is that the increase in speed for two-stroke snowmobiles does not appear to correlate that much with noise emissions. In some cases, pass-bys done at higher speeds provided an even lower sound sensitivity level than at lower speeds.

In addition, with some two-stroke snowmobiles, it is evident that the sound sensitivity level does not increase significantly with speed increasing from 50 km/h to 60 km/h. The exhaust noise from the engine appears to be the dominant noise for two-stroke engines, at almost any speed. With four-stroke snowmobiles, the change in speed and sound sensitivity level distinctly correlate with one another.

Figure 13 and Table 6 show the average sound sensitivity level caused by snowmobiles at different speeds and while accelerating. The figure shows that when speed increases from 30 km/h to 80 km/h, the sound sensitivity level caused by pass-by rises by about 4 dB. The sound sensitivity levels caused by acceleration are at an average of 82 dB.

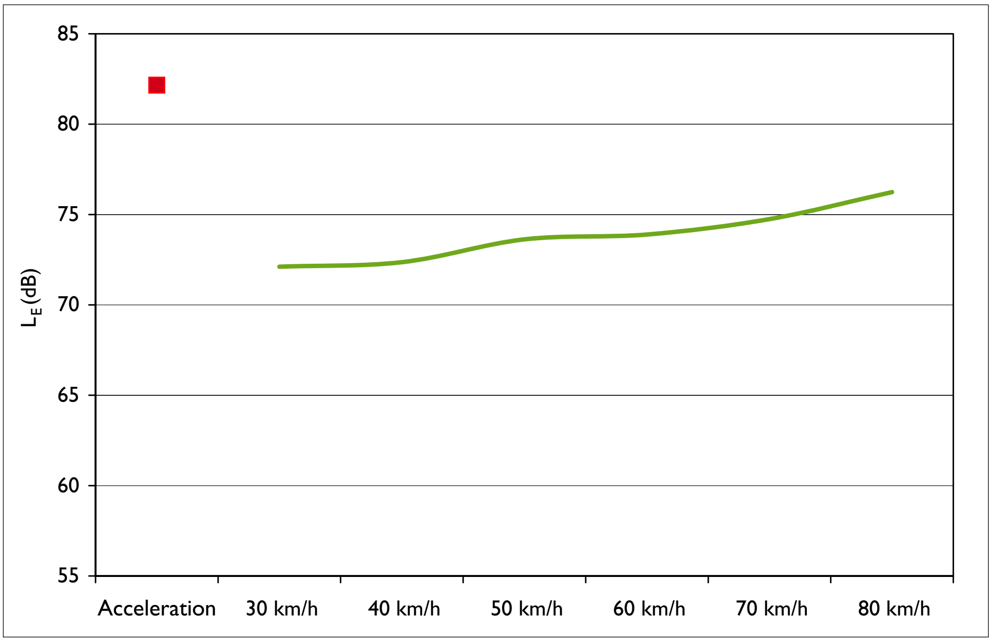


Figure 13. Average sound sensitivity levels for measured snowmobiles (L_{AE}) of pass-bys at constant speeds, measurement distance 15.2 metres, at a height of 1.2 metres, individual snowmobiles. The red square shows the noise level caused by acceleration by the measurement points.

Table 6. Average sound sensitivity levels of pass-bys at constant speeds.

Speed	Acceleration	30 km/h	40 km/h	50 km/h	60 km/h	70 km/h	80 km/h
Average L_{AE} level	82.2 dB	72.1 dB	72.4 dB	73.6 dB	73.9 dB	74.7 dB	76.2 dB

5.5

Sound power levels of snowmobiles

Sound power levels for snowmobiles were calculated from the sound sensitivity levels at a distance of 15.2 metres. In order to specify the average mid-range zone, the distanced sound power level $L_{WA,I}$ was calculated (Table 8), and for specifying the maximum level, the maximum sound power level L_{WAmax} (Table 7). As there were no large differences between the noise emissions of two and four-stroke snowmobiles, only the noise emissions of four-stroke snowmobiles are presented in these findings.

Table 7. Maximum sound power levels (L_{WAmax}) of snowmobiles at different speeds.

L_{WAmax} octave band	Acceleration dB	30 km/h dB	40 km/h dB	60 km/h dB	80 km/h dB
31.5	55	54	56	61	66
63	69	62	64	69	74
125	90	77	79	84	89
250	104	86	88	93	98
500	109	90	92	97	102
1000	110	90	92	97	102
2000	109	91	94	98	103
4000	107	86	88	93	98
8000	100	79	81	86	91
L_{WAmax}	115	96	99	103	108

Table 8. Distanced sound power levels ($L_{WA,I}$) at different speeds.

L_{WAmax} octave band	30 km/h dB	40 km/h dB	60 km/h dB	80 km/h dB
31.5	< 1	< 1	< 1	4
63	5	5	8	12
125	20	20	23	27
250	29	29	32	36
500	33	33	36	40
1000	33	33	36	40
2000	34	35	37	41
4000	29	29	32	36
8000	22	22	25	29
$L_{WA,I}$	39	40	42	46

5.6
Impact of several snowmobiles on noise levels

One way of using a snowmobile is the so-called snowmobile safari trip, where snowmobiles are ridden in convoy groups. Using measurements, the affect of several snowmobiles on the measured noise levels was examined by traversing a familiar safari route at constant speeds, and in groups of four and eight snowmobiles.

Figure 14 illustrates the sound sensitivity levels for different distances and speeds.

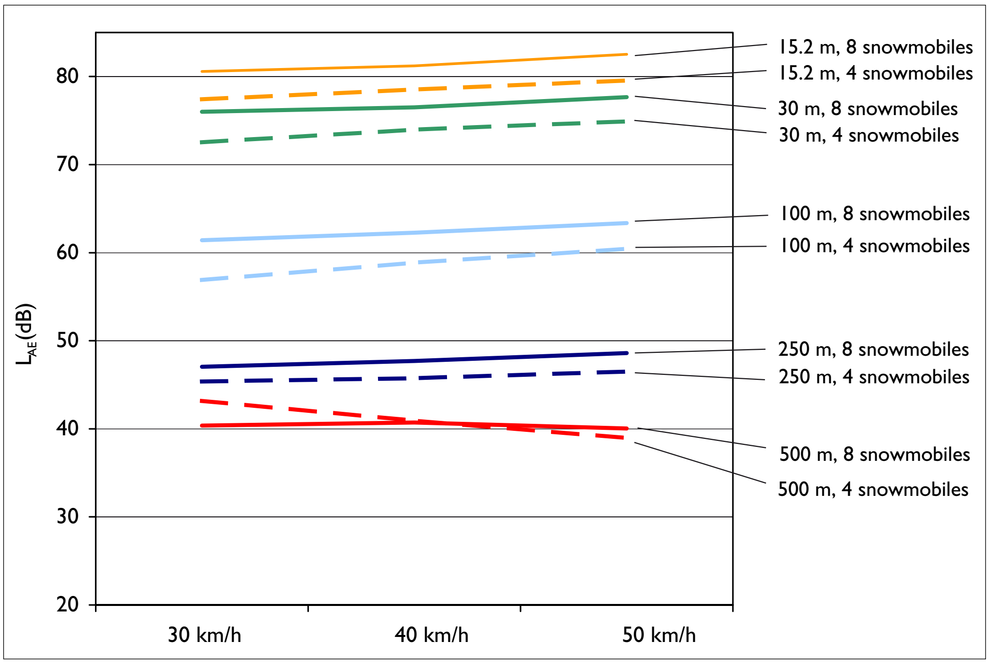


Figure 14. Sound sensitivity levels caused by snowmobiles on safari using different speeds and measurement distances 15.2–500 m.

The sound sensitivity levels caused by a pass-by of eight snowmobiles at distances of 15.2–250 metres were approximately 3 dB higher than the pass-by of a four snowmobile group. The observations of the measurement point located furthest from the snowmobile route (500 m) differed from the general outcome. At this point, the sound sensitivity level caused by four snowmobiles was even higher than a pass-by of an eight snowmobile group. This result was probably due to changes in weather conditions. The reliability and readability of the findings of the furthest located measurement point were made difficult by the fact that the measured sound pressure levels were very low.

5.7
Noise dispersion

Weather conditions, especially with long distances, have a significant impact on how expansive an area, and in which direction noise may be heard. In addition to weather, the form of the terrain, placement of routes in the terrain, snow conditions (snow depth and quality: soft/hard) tree stands (height, species) and the snow on branches also affect the dispersion of noise. This report studied the dispersion of noise in two different types of terrain; the forest and frozen lake.

Table 9. Maximum sound levels L_{AFmax} dB caused by snowmobile acceleration at different distances (15.2 m–200 m). Measurements in the forest were conducted during 15–16 March 2004, and on the frozen lake on 17 March.

Measu-rement date	Distance/height from surface of snow (snow 38–43 cm)	15.2/1.2	15.2/3.6	30/1.2	100/1.2	200/1.2
FOREST	Snowmobile					
15 March	Yamaha RS Vector	80.4	83.8	71.3	56.2	46.2
15 March	Lynx Enduro 600	82.8	84.3	73.2	57.4	47.5
15 March	Lynx Forest Fox 440	78.4	80.0	70.6	53.8	43.8
15 March	Ski-Doo GTX	80.3	81.9	72.0	55.7	45.5
FOREST	Snowmobile					
16 March	Ski-Doo 500	78.0	82.0	70.8	58.4	49.4
16 March	Ski-Doo 380	76.6	80.3	69.8	56.8	47.5
16 March	Polaris 800	79.9	84.8	72.7	59.8	52.0
16 March	Lynx 600	82.7	86.1	75.5	63.6	53.7
LAKE	Snowmobile					
17 March	Lynx 800	82.0	84.2	74.9	63.2	56.8
17 March	Yamaha 700 Triple	81.8	83.8	74.1	61.0	55.0
17 March	Polaris 600	80.8	82.2	73.6	61.4	56.4

Figure 15 and Table 10 show the differences between maximum noise levels of measurement points located at different distances. The findings from measurements indicate that noise silencing is theoretically greater in forested (rather young, 15–20 year old pine seeding stand, no snow on trees), snowy terrain than in open terrain and hard ground surfaces. According to the findings, when the measurement distance increases from 15 metres to 30 metres, the maximum sound levels of the snowmobiles fell by an average of 7–9 dB (arithmetic mean). When the distance increases from 30 metres to 100 metres, the maximum levels fell by an average of 12–16 dB, and when the distance increases from 100 metres to 200 metres, by 6–10 dB.

The differences in noise silencing between the measurement days 15–16 March indicate that weather conditions and probably also the microclimate formed within the forest has on the dispersion of noise. The impact of the microclimate is supported by the following factors. The conducting of noise measurements and the equipment used (by measurement point) were similar on both days, and based on calibration findings, the instruments operated flawlessly on both days. Furthermore, according to weather information and sensory observations made on-site, weather conditions were very similar on both days. As the weather conditions were not measured on-site, and not at various elevations, the affect of the microclimate on the dispersion of noise remained, however, hypothetical.

Table 10. Maximum sound level differences at measurement points located at different distances.

Date	Fall in maximum sound level (dB) between			Fall in maximum sound level (dB) between
	15.2–30 m	30–100 m	100–200 m	15.2–200 m
15 March	8.7 dB	16 dB	10 dB	34.7 dB
16 March	7.1 dB	12,6 dB	9 dB	28.7 dB
17 March	7.3 dB	12,4 dB	5,8 dB	25.5 dB
Range of fluctuation for silencing	7–9 dB	12–16 dB	6–10 dB	26–35 dB

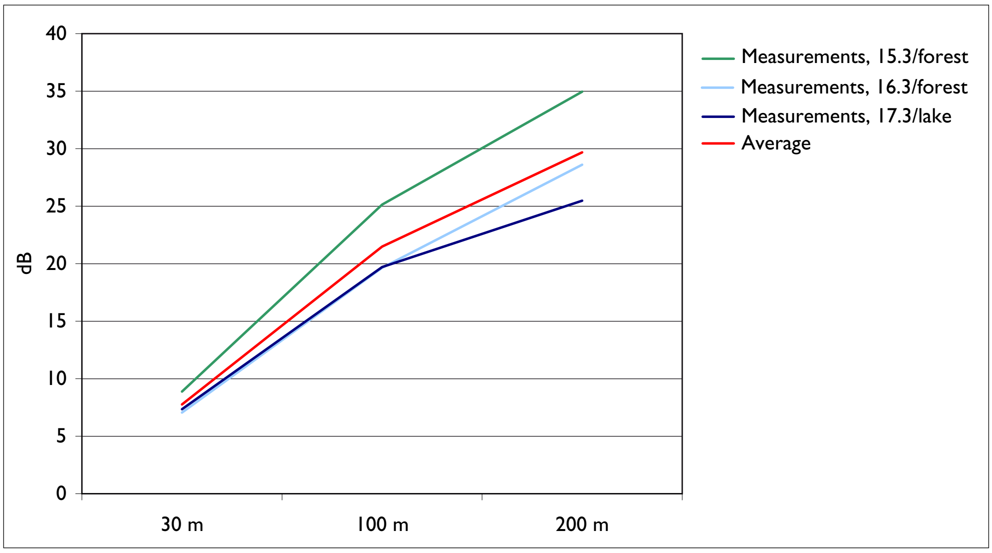


Figure 15. Silencing of maximum levels on different measurement days and the average silencing.

Noise silencing was also examined during a safari trip. Figure 16 shows the sound sensitivity levels at different distances. Safaris were conducted at three different speeds and two different sized groups, four and eight snowmobiles.

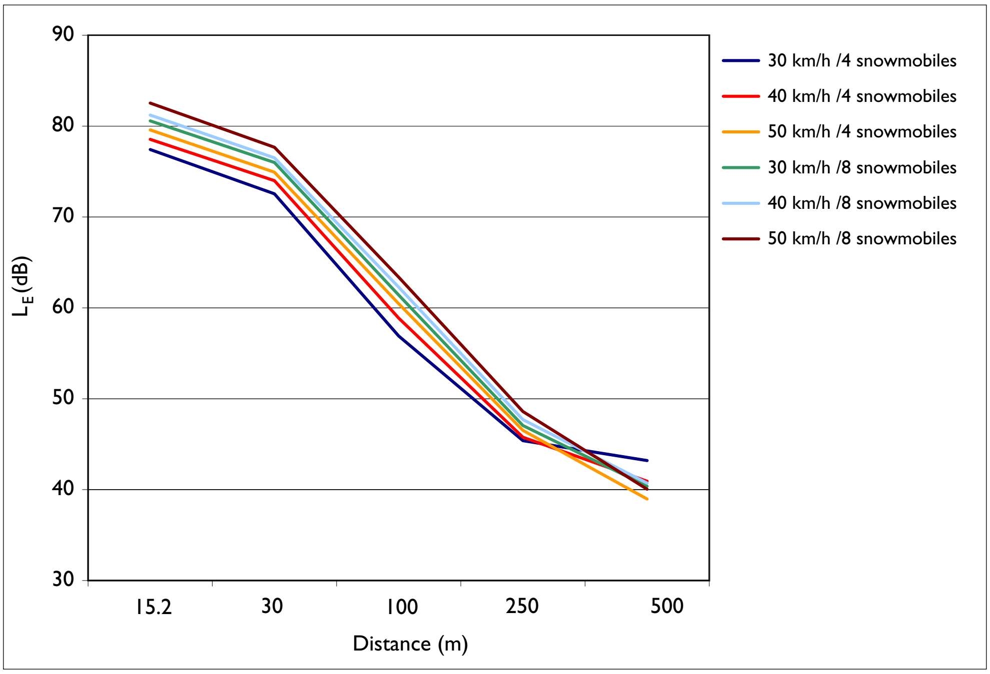


Figure 16. Silencing of sound sensitivity levels of pass-by at constant speeds with different distances and number of snowmobiles.

Further away from the measurement point (shortest distance to snowmobile route 500 metres) the sound levels caused by a snowmobile safari were so low, that the background noise level and occasional brief noises, as well as the properties of the measurement instruments affected the measurement findings. Figure 17 shows the average silencing of noise at different distances.

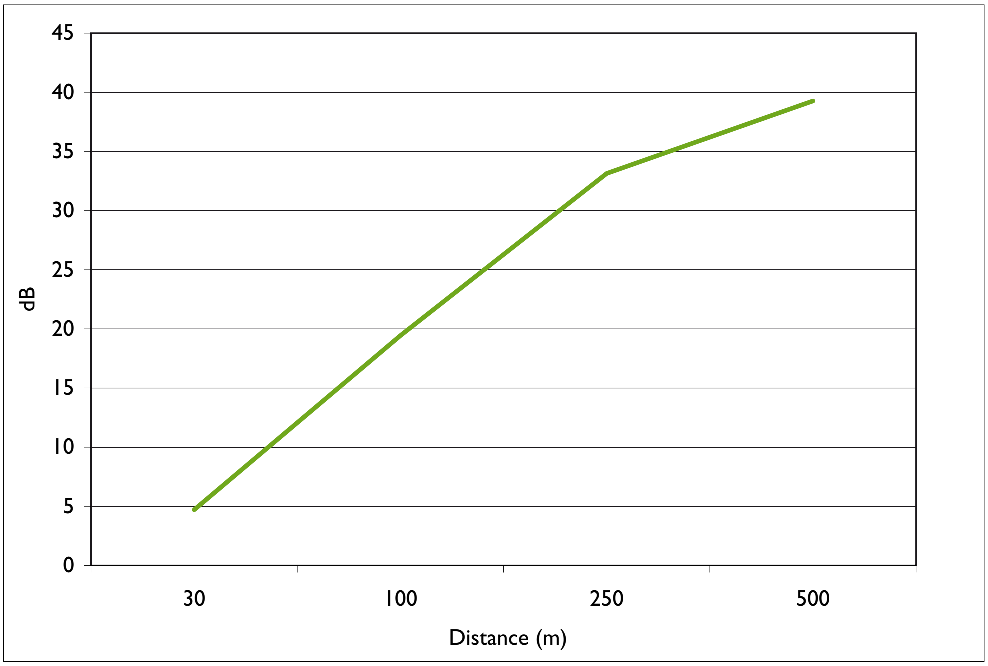


Figure 17. Average silencing of snowmobile noise (sound sensitivity levels) on safari.

5.8
Noise areas caused by snowmobile traffic

Regarding noise levels, the basis for planning are the guideline values issued by the Council of State (VNp 993/1992). The guideline value is applied in the planning for land use and construction, the planning of traffic planning for various forms of traffic, as well as the permit procedure for construction. These guideline values have been issued for the prevention of detrimental noise, and for the safeguarding of the pleasantness of the environment. In housing areas, the daytime guideline value applied is 55 dB and at night 45 or 50 dB. In recreational and nature conservation areas, the guideline values applied are 45 dB in the daytime and 40 dB at night.

Table 11. Guideline values for noise levels in outdoor and indoor spaces (VNp 993/1992).

Site	Average daytime sound level $L_{Aeq\ 7–22}$, dB	Average night-time sound level $L_{Aeq\ 7–22}$, dB
Areas used for housing, recreational areas located in built-up regions and their immediate vicinity, as well as areas for treatment or educational facilities	55 dB	45–50 dB [1) 2)]
Areas used for holiday housing, camping grounds, recreational areas located outside built-up areas and nature conservation areas.	45 dB	40 dB [3)]

[1)] In new areas the night-time guideline value for noise level is 45 dB.
[2)] No night-time guideline value is applied for areas used for educational facilities.
[3)] No night-time guideline value is applied for nature conservation areas that are not usually used for outdoor pursuits or night-time nature watching.

The text of the resolution of the Council of State gives separate mention to the guideline values not concerning shooting or motor sports track noise. The snowmobile noise as a deficient instrument for measuring disturbance: even by a busy route the noise is rarely continuous, rather occasionally repeated. The experienced disturbance does, however, significantly affect the momentary noise level.

In Sweden, motor sports tracks have been issued guideline values based on the momentary maximum level (L_{AFmax}). These guideline values have been separately stipulated for daytime and evenings (Table 12). These guideline values provide separate mention for areas intended for outdoor use where the low noise level is an important factor of quality.

The Swedish guideline values have also been applied in Finland for considering the environmental permit and Administrative Court resolutions for motor sports tracks. The noise caused by snowmobiles may be seen as corresponding to the noise produced by motor sports tracks. Consequently, this report also examines noise zones using the figure for momentary maximum level (L_{AFmax}).

Table 12. Sweden's noise guideline values for motor sports tracks (http://www.naturvardsverket.se).

Area	Maximum sound level, dBA shown as fast weighted		
	Daytime 7 a.m.–7 p.m.	Evening 7–10 p.m.	Night 10 p.m.–7 a.m.
Area intended for permanent and holiday housing (in front of façade)	60	55	Motor sports tracks may not cause noise at night
Areas of treatment facilities (in front of façade)	55	50	
Areas of educational facilities (in front of façade)	55	50	
Outdoor areas [1)]	55	50	

[1)] Areas intended in the master planning for recreational activity or other public outdoor use, where nature experiences are important and the noise level has a big impact on overall quality. The background noise level is low and the area does not have any other disturbing activities, such as noise caused by shooting alleys, recreational boating or snowmobiles.

Based on measurements, the noise caused by snowmobiles was at its greatest during acceleration, when the momentary noise levels at an approximate distance of 15 metres, depending on make of snowmobile, were 80–86 dB. With snowmobiles travelling at a constant speed, the sound sensitivity levels (LAE) at a distance of 15.2 metres and a speed of 80 km/h varied between 74–76 dB. When travelling at slower speeds, the noise level was naturally lower, and at a speed of 30 km/h the sound sensitivity levels were 6–12 dB smaller than when travelling at a speed of 80 km/h.

5.8.1

Noise dispersion estimated from measurement findings

The average noise level caused by snowmobiles at the measured distances on the route may be estimated using the average sound sensitivity levels and number of noise events shown on page 22.

Tables 13 and 14 show calculations of how many pass-bys at constant speeds are required in order for the average sound level to exceed 55 and 45 dB at various distances from the snowmobile route.

Table 13. Number of pass-by snowmobiles that exceed 55 dB during the daytime (7 a.m.–10 p.m.).

55 dB	30 km/h	50 km/h	80 km/h	Acceleration
15.2 m	1 053	745	410	103
30 m	2 900	2 200	1 420	400
100 m	33 500 *	24 000 *	12 950	8 200
200 m	85 000 *	58 000 *	31 800	53 000

* The number of snowmobiles calculated at a speed of 80 km/h based on noise level silencing.

Table 14. Number of pass-by snowmobiles that exceed 45 dB during the daytime (7 a.m.–10 p.m.).

45 dB	30 km/h	50 km/h	80 km/h	Acceleration
15.2 m	105	75	41	10
30 m	290	220	142	40
100 m	3 350 *	2 400 *	1 295	820
200 m	8 500 *	5 800 *	3 180	5 300
* The number of snowmobiles calculated at a speed of 80 km/h based on noise level silencing.				

According to the calculation, exceeding the guideline value of 55 dB average noise level intended for housing areas at a distance of 15 metres from the route requires a very busy route, at least by Finnish standards. With normal speeds used in the forest (50 km/h), around 750 snowmobiles would be needed passing by between 7 a.m. – 10 p.m., and with speeds used on ice (80 km/h) 400 snowmobiles would be needed. Nevertheless, at certain places where the majority of snowmobiles usually accelerate fast, the guideline values are exceeded at a distance of 15 metres with a relatively small number of snowmobiles (100). In order for the 55 dB guideline value to be exceeded at distances greater than 15 metres, many more snowmobiles are required.

The 45 dB level is clearly exceeded with fewer snowmobiles at shorter distances (15–30 metres). At a distance of 30 metres, depending on speed, 45 dB is exceeded with a pass-by of 40–300 snowmobiles. For accelerating snowmobiles, even with snowmobile numbers in Finland, the average sound level of 45 dB may even be exceeded at a distance of 100 metres.

The measurements conducted in this study for the noise emissions caused by acceleration could not be directly used for analysing the noise emissions caused by acceleration in regular use. In regular use, acceleration seldom occurs as quickly as it did during measurement sessions. In addition, the departure speed and duration of acceleration may differ greatly from the measurement conditions. Acquiring sufficient information on the affects of various accelerations on the noise emissions of pass-bys would require an enormous number of measurements where snowmobiles are accelerated in different ways with different starting speeds.

The findings of the measurements conducted do, however, provide relatively reliable picture of what kinds of traffic numbers will become significant along the route in respect to the use of these areas.

The extent of noise areas around the snowmobile routes may be estimated on the basis of information regarding information acquired on noise silencing, as well as by placing noise emission data specified by measurement findings into the calculation model.

Based on measurements conducted during safari, it may be estimated that with a gentle downwind, the noise emissions caused by snowmobiles fall as shown in Figure 15 compared to noise levels at a distance of 15.2 metres from the snowmobile route.

Table 15. Average silencing of average sound levels at different distances (safaris).

Distance from snowmobile route	30 m	100 m	250 m
Silencing	5 dB	20 dB	35 dB

5.8.2

Noise dispersion estimated from sound power levels

The width of noise zones caused by snowmobiles was also estimated using the calculation model for soft and hard surfaces. The sound power level calculated from measurement findings was placed in the calculation model. The widths of momentary maximum level and average sound level zones did not show any essential differences, which is why tables 16 and 17 only show the widths of noise zones caused by four-stroke snowmobiles. These zones are measured in open area conditions. In forested terrain, the noise zones are narrower.

Based on the calculated estimate, exceeding the guideline value for daytime average sound levels set for housing areas, 55 dB, is possible near a busy (over 200 snowmobiles/day) snowmobile route. As a result of a hard surface, the average sound level zones are over three times wider than the zones estimated for soft snow areas (Table 16).

Table 16. The average sound zone noise ($L_{Aeq\ 7\text{-}22}$) widths (metres) caused by snowmobile pass-bys with different traffic numbers for soft and hard snow surfaces. The distanced sound power levels have been estimated at a constant speed of 80 km/h based on measurement findings for pass-bys. The calculation assumes the terrain to be open.

Soft snow	Traffic numbers/snowmobiles per day							
$L_{Aeq\ 7–22}$	50	100	200	300	500	1000	1500	2000
dB	m	m	m	m	m	m	m	m
55	< 10	< 10	10	10	10	20	30	30
50	10	10	10	20	30	50	60	70
45	10	20	30	40	60	100	130	160
40	30	50	70	100	140	200	250	280
Hard snow	**Traffic numbers/snowmobiles per day**							
$L_{Aeq\ 7–22}$	50	100	200	300	500	1000	1500	2000
dB	m	m	m	m	m	m	m	m
55	< 10	10	10	20	30	60	80	110
50	10	20	40	50	90	160	210	250
45	30	60	110	150	220	320	390	460
40	90	160	250	310	410	570	670	770

The momentary maximum level zone scopes caused by snowmobile noise were estimated at momentary maximum levels between 35–70 dB. Based on calculated estimates, the momentary noise caused by snowmobile acceleration may be heard at a distance of up to two kilometres from the snowmobile (Table 17).

Table 17. Zone widths (m) for momentary noise levels (L_{AFmax}) caused by snowmobile pass-bys in open terrain.

L_{AFmax}	Soft snow	Hard surface	Soft snow	Hard surface	Soft snow	Hard surface	Soft snow	Hard surface
	Acceleration	Acceleration	80 km/h	80 km/h	60 km/h	60 km/h	40 km/h	40 km/h
dB	m	m	m	m	m	m	m	m
70	40	70	20	30	10	20	< 10	10
65	70	140	30	60	20	30	10	20
60	110	250	50	100	30	60	20	30
55	180	430	90	200	50	110	30	60
50	280	700	150	350	90	200	60	110
45	440	1110	240	580	150	350	90	210
40	670	1680	380	930	240	580	150	360
35	990	> 2000	580	1440	380	930	250	600

Unfortunately, there is no real information available on the traffic numbers on snowmobile routes. Consequently, it is difficult to provide any accurate estimate as to how many routes may exceed the guideline values. Based on the findings, however, it may be assumed that the placement of snowmobile routes in or near built-up areas will not cause any problems for more expansive regions. Possible disturbances will probably be focused on individual sites (houses), which are located close to snowmobile routes or in particular, close to a section of snowmobile route where snowmobiles often accelerate fast.

Although routes located in built-up areas are not necessarily problematic, one point that becomes clear from the findings is the sensitivity of areas intended for recreational use to noise that exceeds guideline values. The findings show that in respect to areas intended for recreational use (guideline value 45 dB), even relatively few snowmobiles are significant. In addition, when taking into consideration the fact that holiday housing is often located on lake shores, and snowmobiles often travel on frozen lakes at speeds that exceed the permitted 80 km/h, routes that travel close to the shore may exceed guideline values.

It is easy to impact possible excesses in guideline values caused by snowmobile routes by increasing the distance of the route from sites sensitive to noise. Even a distance of 100 metres from the noise sensitive site can reduce the noise levels of pass-bys to such a degree, that with traffic numbers in Finland, only a few sites (even those intended for recreational use) would experience excesses in guideline values. In many places, another effective way of avoiding excess noise levels is by reducing the speed limits.

5.8.3

Noise areas of snowmobile routes

On the basis of the measurement findings, attempts were made to specify the distances required by snowmobile routes, using which the noise disturbances caused by snowmobiles may be avoided. There is little information available on disturbances cased by snowmobile noise. The point of departure for considering these planning principles are the guideline values for noise levels currently in force in Finland, as well as the guideline values stipulated in Sweden for motor sports tracks. The distances shown in Table 18 have been calculated for a hard surface, by taking into account the bearing capacity of the snow or ice conditions. In addition, it is assumed that speeds are not constant, as travel includes some acceleration and braking.

Table 18. Noise areas for snowmobile routes.

Application site	Protective distance (metres)		Justifications
	Forest terrain*	Open terrain	
Areas used for housing, recreational areas located within built-up areas and their vicinities, as well as areas serving treatment and educational facilities.	50	50	With a speed restriction of 40 km/h, the momentary noise level (L_{AFmax}) <60 dB and average sound level ($L_{Aeq\ 7\text{-}22}$) <55 dB.
Areas used for holiday housing, camping grounds, recreational areas located outside built-up areas, and nature conservation areas.	150	300	At a speed of 60 km/h, the momentary noise level (L_{AFmax}) <50 dB and average sound level ($L_{Aeq\ 7\text{-}22}$) even on busy snowmobile routes (200–1000 snowmobiles/day) <45 dB.
Areas with the intention of emphasising the tranquil landscapes**	1000	2000	Momentary noise level (L_{AFmax}) during acceleration is a maximum of approximately 35 dB and average sound level ($_{LAeq\ 7\text{-}22}$) even on busy snowmobile routes clearly below 30 dB.

* At least half of the trip between the snowmobile route and site is forested or otherwise significantly covered terrain.
** Areas such as these include, for instance, especially quiet and naturally tranquil areas, national parks and nature reserves, or parts of such, as well as other excursion and recreational areas that are otherwise quiet.

5.8.4

Example calculation of noise dispersion

On the basis of noise power levels specified for snowmobiles, noise dispersion was modelled on the CADNA/A 3.6 noise calculation application. Noise calculations were conducted on the selected region of Simola in Nilsiä. Calculations were, however, affected by the availability of data on traffic numbers. In particular, the estimation of speeds was difficult. The number of snowmobiles was measured in Nilsiä for a period of one week at a number of places along the snowmobile routes. On the basis of these measurements, the traffic numbers were estimated for the Simola snowmobile route (Table 19).

Table 19. Daytime (7 a.m.–10 p.m.) traffic numbers used in noise calculations.

	Average number of snowmobiles per day	Traffic numbers for the busiest day
West from Simola	60	170
East from Simola	60	170
From Simola to Nilsiä centre	30	90

Calculations were performed at riding speeds of 30 km/h and 80 km/h, thereby enabling differences between speeds to become evident. In addition, calculations were performed on the average traffic numbers of snowmobiles and maximum traffic numbers for a singe day. The largest traffic numbers at all traffic number measurement points was on Saturday. The frozen lake region of Simolanlahti was specified as hard in the calculation, and land areas were assumed to have a soft surface. Calculated at these rather small traffic numbers, the 55 dB average noise zone was not even measured at speeds of 80 km/h. Traffic numbers of this size, do not therefore cause excesses in guideline values in housing areas. Even the 45 dB average sound zone applied for holiday housing remained narrow. The average sound zone was at its widest (40 metres), on the frozen lake regions with a speed of 80 km/h. With average weekly traffic, this zone was 15 metres wide (speed 80 km/h).

The maximum levels for 60 dB snowmobile noise occurring in Simola are shown in Figure 18. The findings correspond with the findings of Table 17 (momentary noise levels caused by pass-by). The momentary noise levels for an accelerating snowmobile exceed 60 dB in housing areas. In Petäjäniemi and Uitinkylä snowmobiles travelling at speeds of 80 km/h caused excesses of 60 dB in housing areas. If snowmobiles adhere to the speed limits set for Simola, the guideline levels are not exceeded using the traffic numbers used for the calculations. Exceptions to this rule are a few buildings in Uitinkylä, the areas of which experience excesses of 60 dB when snowmobiles travel across the frozen Simolanlahti at speeds of 80 km/h. Acceleration also caused excesses of the 60 dB maximum level.

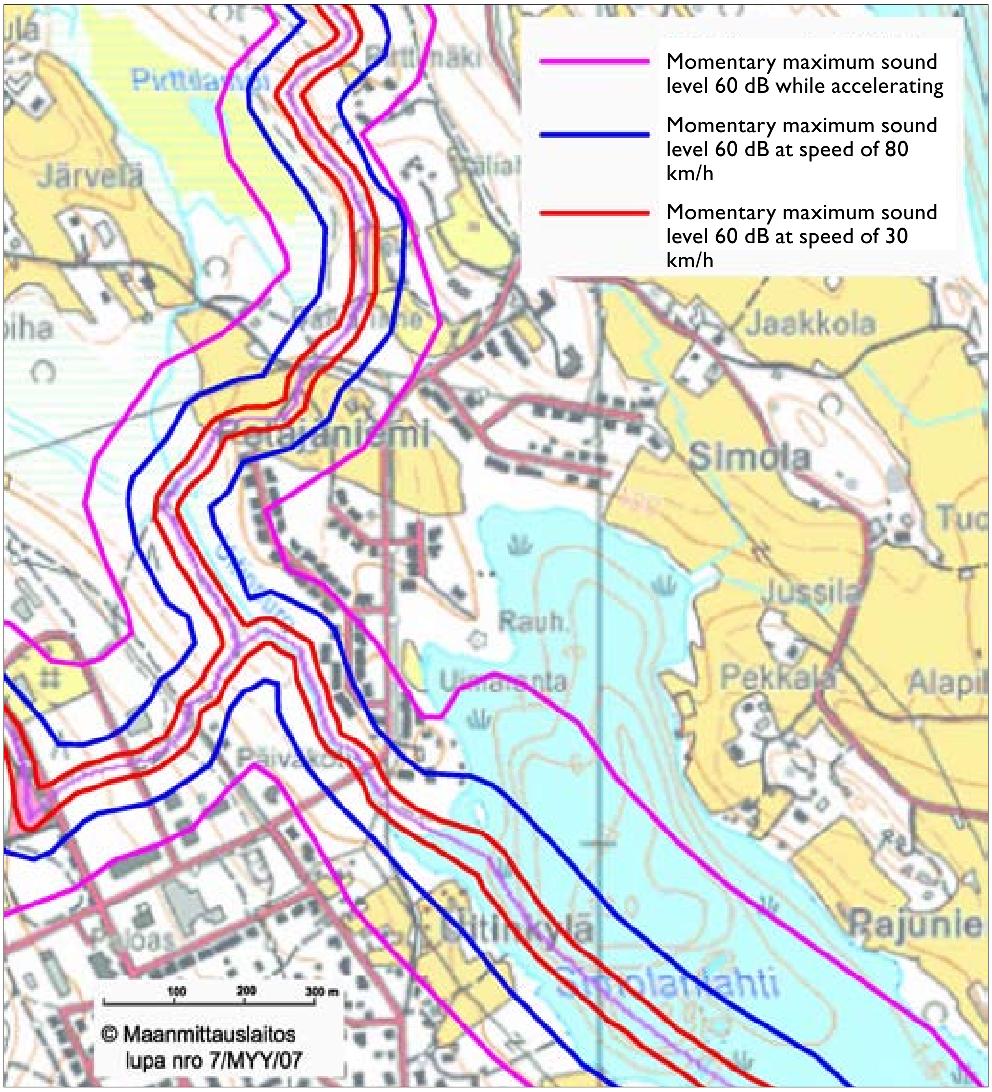


Figure 18. Dispersion of maximum levels of snowmobile noise at various speeds.

6 Conclusions

On the basis of the findings of the study, it may be concluded that the noise areas caused by snowmobile traffic remain very narrow, especially in relation to traffic numbers on Finland's busy snowmobile routes with less than 1000 snowmobiles per day. This being the case, good route planning may easily prevent exceeding guideline values stipulated for noise. In the planning of routes, the most important factor is sufficient distance from the noise sensitive points. If this is not possible, the route planning should give consideration to keeping unnecessary acceleration to a minimum. In addition, speed restriction may also reduce the noise caused by pass-by.

On the basis of the findings of the study, it has been possible to present rough interpretations as to how routes should be placed near built-up areas and holiday homes, if the intention is to fulfil the guideline values provided by the Council of State (993/1992). The findings shown in this report represent the conditions prevailing during measurement sessions, and these may not be applied to all winter conditions.

One of the biggest problems with performing the calculation models caused by snowmobiles is the diverse nature of snowmobiling. The differences between sound levels produced by different makes of snowmobiles may be several decibels, even up to ten decibels. There are also large differences between snowmobile routes, and even the characteristics for the same route can vary greatly, depending on utilisation rate, snow condition and condition of the route itself. In addition, driving styles of snowmobile riders also vary enormously. Some riders may traverse a route calmly, at a relatively constant speed, while others may traverse the same route ”aggressively” using plenty of acceleration and engine braking. The noise impacts of these two extremes on the surroundings significantly differ from one another.

In addition to sound levels, an aggressive or inappropriate driving style may cause other negative feelings with the person experiencing the noise. The subjective part of the noise experience may be examined by combining measurements with a panel of listeners who provide their own assessments based on experience.

The fluctuations in noise dispersion conditions in winter conditions cause significant differences in sound silencing. The assessment of noise and noise areas caused by snowmobiles not only requires representative information on noise emissions, but also information on the affects of different conditions on noise silencing.

The average sound level as a measurement of the disturbance caused by snowmobile noise is deficient. Even on a busy route, noise is seldom continuous, but moreover occasionally repetitive in nature. However, the experienced disturbance is significantly affected by momentary noise levels. Consequently, the protection zones of snowmobile routes presented in this report have been specified on the basis of Finland's noise level guideline values on the one hand, and on the other hand using the Swedish guideline values used for motor sports tracks. The latter are based on momentary maximum levels (L_{AFmax}).

The presented protection zones for snowmobile routes are specified on the basis of measurement findings obtained, assuming the terrain is hard and by giving consideration to riding noise caused by acceleration. The protective distance is largest in areas used for holiday accommodation, being 300 metres in open terrain. In built-up areas the protective distance is 50 metres. In areas intended for holiday accommodation, the protective distance ensures levels remain below the guideline value of 45 dB stipulated for holiday and recreational areas. In built-up areas the 55 dB average sound zone is not exceeded at a distance of 50 metres. Furthermore, the falling short of the 60 dB maximum sound level has been taken into account in the mitigation of disturbances caused by snowmobile noise. It has been thought that less than 1000 snowmobiles will travel the route.

For the examination of the dispersion of snowmobile noise and disturbances caused by such, well planned and controlled noise measurements should be conducted near the snowmobile routes, which would then be combined with registering the speeds and riding styles employed. These may either be performed by visual estimation, or by using radar and camera devices.

Naturally, noises may also be regarded as disturbing even if they do not exceed guideline values. The experience of noise is greatly affected by the expectations of the individual or group subjected to the disturbance. For instance, the noise of a single snowmobile reaching a holiday home or cross-country skiing trail may cause more disturbance than a busy snowmobile route producing continuous noise mixed with other noise in built-up areas.

This problem is related to recent discussions on quiet areas or pleasant sound environments. Quiet areas are often closely related to snowmobiling, and indeed both support the recreational use of nature and the development of nature tourism. Indeed the need for tranquil areas is mentioned in the decision in principle of the Council of State issued on 13 February 2003. Snowmobile routes and tranquil areas represent interrelated, yet at the same time awkwardly compatible values, the equal consideration of which requires long-term land use planning. The regional report on tranquil areas has proposed the alternative area boundary grounds as e.g. average sound levels 45 dB, 35 dB and 30 dB (Karvinen & Savola 2004, Kainuu Regional Plan 2020. Tranquil areas of the regional plan. Draft 2004, Liikonen, et al. 2006). This concerns lower guideline values of sound levels. Attaining sound levels such as these naturally requires a much broader protective area than the aforementioned between the snowmobile routes and tranquil areas.

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Abstract	Planning snowmobiling routes and considering the possible need for off-road traffic restrictions requires that the noise impact of snowmobile traffic is known. The objective of this report was to take off-road readings in order to determine snowmobile noise emissions and the spread of noise from snowmobile routes into the environment. Based on the readings taken, it can be said that the noise zones created by snowmobile traffic are quite narrow at current traffic levels. Noise pollution can be prevented with good planning. The biggest problem in assessing noise impact is the diversity of snowmobiling and incursion of noise into otherwise quiet areas.			
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Sammandrag	Planeringen av farleder för snöskotrar och prövningen av behovet av eventuella terrängtrafikbegränsningar förutsätter att man känner till bullerkonsekvenserna av snöskotertrafiken. Målet med denna utredning var att med hjälp av terrängmätningar undersöka hurdana bullerutsläpp snöskotrarna orsakar och hur bullret sprider sig i omgivningarna kring snöskoterfarlederna. Utifrån detta arbete kan man säga att de bullerområden som uppkommer av snöskotertrafiken är rätt snäva med de trafikvolymer vi har idag. Bullerolägenheter kan förebyggas genom bra planering. Det största problemet vid bedömningen av bullerkonsekvenserna är att snöskotrarna används på många olika sätt och att bullret uppkommer i områden som annars upplevs som stillsamma.			
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