ACOUSTICS AND NOISE CONTROL IN CANADA

THE CANADIAN ACOUSTICAL ASSOCIATION

L'ACOUSTIQUE ET LA LUTTE ANTIBRUIT AU CANADA

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CONTRIBUTIONS

Articles in English or French are welcome. They should be addressed to a regional correspondent or to a member of the editorial board.

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CONTRIBUTION

Vous êtes invités à faire parvenir des articles en anglais ou en français. Prière de les adresser à un correspondant régional ou à un membre de la rédaction.

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(suite au recto de la couverture inférieure)

CONTENTS/TABLE DES MATIERES

NOISE/NEWS

The Canadian Acoustical Association has become a Corresponding Society of NOISE/NEWS. NOISE/NEWS is a bimonthly newsletter published by the Institute of Noise Control Engineering (P.O. Box 3206, Arlington Branch, Poughkeepsie, N.Y. 12603) and contains news items, editorials, notices of meetings, contract information, etc. of interest to noise control engineers. T.E. Siddon has been appointed corresponding Editor for the Canadian Acoustical Association and material for possible publication in NOISE/NEWS should be sent directly to him. Subscription rates to NOISE/NEWS for members of their corresponding Societies or ASA are $9.00/year.

ACOUSTICS SECTION - NRC

E.A.G. Shaw has taken over as head of the Acoustics Section, Division of Physics, National Research Council effective 2nd June 1975. G.J. Thiessen, at his own request, has relinquished administrative chores in order to devote more time before retirement to his research, especially the effect of noise on sleep.

RESTORATION AND SELECTION PROCESSES IN LISTENING TO SENTENCES WITH PHONEMES DELETED

J.M. Kennedy, L.D. Chattaway and E. Chattaway
Scarborough College, Toronto

Summary of a paper presented at the Canadian Acoustical Association Conference, Edmonton, 1974.

INTRODUCTION: See Conference Abstract

Materials: Recorded speech: "Unable to move their tents in the snow-storm they pulled their sleds in*ide and slept on top of them." In place of the * (a deleted s, a 300 msec gap), subjects were given:

1. A TONE THROUGHOUT the sentence
2. A TONE in the WHOLE GAP
3. The tone's ONSET IN the GAP, the tone continuing to the end of the sentence
4. The tone's OFFSET (termination) IN the GAP, the tone beginning at the start of the sentence
5. No tone - SILENCE - accompanying the sentence.

Also 6. The length of the tone in the gap, in condition 2, was varied from 50 msec to 75 msec, 100 msec etc., up to 300 msec, i.e. throughout the gap. (TONE IN GAP).

7. The length of the tone in the gap, in condition 4, was varied from 50 msec to 75 msec, 100 msec etc. up to a duration which filled the gap, all of these continued to the end of the sentence.

Reports: Subjects reported any speech sounds heard in in*ide.

Results:

A. Variation between conditions 1-5 was significant at the 0.025 level, with the ONSET IN GAP condition resulting in more speech sounds reported than conditions 1, 4 and 5.

B. Variations in conditions 6 and 7 were not significant, but all except the one of the 10 TONE IN GAP conditions resulted in fewer speech sounds reported than the TONE IN WHOLE GAP condition (significant at the 1% level).

FISH DIVERSION BY UNDERWATER SOUND AT DISCRETE FREQUENCIES

S. Buxcey

formerly Associate Professor of Electrical Engineering,
Royal Military College of Canada.

1. Reasons for the studies.

Ontario Hydro has been experiencing some difficulties at Thermal Generating Stations due to fish entering the cooling water intakes and passing through the screens in sufficient numbers to clog cooling tubes. Since these fish tend to be of the same species and size, e.g. alewife schools, it appears possible that sound at a discrete frequency, possibly resonant, might prove a deterrent to their entrance and reduce their effect on plant performance. Therefore funds were made available for the research projects which are described briefly below.

2. General Background.

A long term problem associated with the generation of hydro-electricity has been that of providing for the safe passage of migratory fish around high dams and preventing losses due to turbine and spillway hazards. Various sound sources were investigated (1, 1953; 2, 1956) for the U.S. Fish and Wildlife Service and the results found to be discouraging.

Later papers by H. Kleerekoper and T. Malar (3, 1968), who worked as the fish behaviourist in 1972, and R.R. Fay (4, 1969) reported fish responses within the acoustic field and encouraged further investigation.

Meanwhile D.E. Weston (5, 1966) with P.A. Ching (6, 1969) had postulated that "Fish very often have a gas-filled swim-bladder which controls their low frequency acoustic properties and there is typically a resonance in the kilocycle region". The basic relationship is

$$L = \frac{8\sqrt{P_o}}{f_o}$$

where L = fish length in cms.

P_o = effective bladder pressure in atmospheres

and f_o = resonant frequency in kHz.

This swim-bladder resonant frequency appears to identify a sound which can be determined experimentally, to which fish will probably be sensitive, and which may cause discomfort leading to diversion.

In later conversations Dr. Weston expressed the belief that the power levels at which his projectors were working were such that fish would have been killed had they remained nearby. Since dead fish were not observed it may be inferred that live fish had moved out of the dangerously insonified volume of water. Unfortunately such movement was neither looked for nor observed accidentally so that no direct confirmation was available.

3. Field experiments in 1972.

A site was selected in which the water depth was about 6 ft. and which was sheltered from the normal prevailing winds and within reasonable distance from Glenora Fisheries Station and the Royal Military College.

The fish enclosure was 20 ft. long, 5 ft. wide and 6 ft. deep and was placed about 100 yds. from the shore. The sound projector and hydrophones were placed on the long axis of the enclosure with the projector 10 ft. from the near end at which hydrophone, H_1, was placed. Hydrophone, H_2, was at the centre of the enclosure and hydrophone, H_3, at the distant end. At all frequencies the output of H_1 was treated as standard and the outputs of H_2 and H_3 referred to it.

The T.V. camera was placed at the end of the enclosure nearest to the projector and observed a water column of smaller volume than was desired. Nevertheless the quantity of data video-taped was so great that its rapid analysis proved difficult.

When four species of the family Centrarchidae were introduced into the tank a well defined maximum attenuation at 1.15 kHz was shown. Attenuation effects below 0.5 kHz were only observed on one occasion (during the late evening) when they decreased with time and increasing frequency of applied sound. Due to poor and deteriorating light conditions fish behaviour could not be monitored during this time. Since resonant attenuation occurred at a much higher frequency it is considered probable that the fish were initially clustered at the end of the enclosure nearest to the projector, which faced the setting sun, possibly as a response to light orientation and intensity, and later dispersed as the light failed. It is also possible that the increasing frequency of the sound encouraged this dispersal.

Analysis of the video-taped data indicated that these fish were normally undisturbed by single frequency sounds between 0.2 and 20.0 kHz.

The most interesting results were obtained with alewife supplied by Glenora Fisheries Station. Sufficient data was available to use Weston's equation which gave f_0 as 0.82 kHz. This was in good agreement with the experimental results.

Despite a shortage of data points, due to deteriorating weather conditions, considerable attenuation was shown at 2.0 kHz and school position and sound pattern appear to be related at this frequency, since H_3 produced its maximum output when the school could be observed by the T.V. camera. At this frequency the video-tape analysis indicated decreased school activity.

It was not unreasonable to regard the school as moving slowly from one end of the enclosure to the other with the movement either due to or causing the variations in sound pressure level at the end away from the T.V. camera.

From these experiments it was concluded that:-

1. No broad band acoustic source is likely to be effective in modifying the behaviour of fishes since their acoustic environment is also one of broad band noise.
2. The resonant frequency of a sufficient sample of fishes can be determined.
3. Fish response to sound at an appropriate frequency may be indicated.
4. Work in lakes is difficult and may be useless because too many variables are beyond control or compensation.
5. Experimental work should be completed before the end of June to avoid fish problems due to July's high temperatures.

4. Laboratory experiments in 1974.

The tank size was limited by the space available in the Power Laboratory of the Electrical Engineering Department at the Royal Military College. It was 60 ft. long, 2 ft. wide and 2 ft. deep, constructed of wood and first lined with plastic sheeting to retain water and then with acoustic damping material.

Ideally, all experiments would have been carried out with healthy fish which had become accustomed to their surroundings. Unfortunately this condition was never achieved so that the results were obtained with dying and/or shocked fish.

a) Guppies

Despite the considerable precautions taken before the guppies were introduced into the tank, sudden and considerable deaths occurred after less than 48 hrs. so that it was necessary to proceed immediately with response experiments. Since the surviving guppies were clustered at the end of the enclosure nearest to the projector the standing wave pattern made any movement difficult to interpret.

The theoretical average resonant frequency was 5.4 kHz. No direct attenuation measurements were made but anomalous hydrophone outputs were obtained at 2.5, 5.0 and 6.0 kHz.

Below 10.0 kHz it appeared that guppies would respond to sound at any frequency by agitated swimming once a lower threshold of sound pressure level had been crossed. This threshold level was lower at 2.5, 5.0 and 6.0 kHz than at 0.70 kHz, the only other frequency at which the input drive to the projector was varied.

b) Shiners

Survival problems were not expected since lake water was being pumped into the tank at one end and out at the other. 120 fish were placed in the tank on Wednesday, 3rd July and the main series of experiments planned for Saturday to permit the fish to become accustomed to their surroundings and to ensure that there was no other activity in the laboratory. By that day the shiners had started to die at an increasing rate, possibly due to a combination of previous rough handling and high water temperatures. No responses were observed when systematic experiments were carried out.

A brief test on Wednesday evening in which the frequency was increased from 0.20 to 20 kHz indicated increased fish movement at 1.0, 1.5 and 2.0 kHz. This was the range over which discomfort due to swim-bladder resonance might be expected since the theoretical average resonant frequency was 1.4 kHz.

c) Alewife

Approximately 30 cu. ft. of ice cubes were needed to reduce the tank water temperature below the recommended upper temperature limit of 20°C. In view of this cooling problem and the known delicacy of alewife the main acoustic experiments were performed after the alewife had been given only 90 mins. to become accustomed to the tank.

The theoretical average resonant frequency was 0.92 kHz and increased activity was observed at 0.80 and 1.5 kHz.

When the water temperature was 19.5°C the healthy alewife appeared to avoid the sound source while the dying ones were stimulated into violent flapping. Whatever question there may be about the avoidance of the source by healthy fish, there is no doubt that sound at 0.80 and 1.5 kHz stimulated nearly dead fish into violent activity. When sound at 10 kHz was used the healthy fish appeared to swim more actively but there was no response from the nearly dead fish.

5. General Conclusions

1. Some species of fish react to sound at a discrete frequency once a lower threshold of sound pressure level has been crossed. These reactions appear to be most vigorous around the swim-bladder resonant frequency.
2. Experiments under fully controlled conditions are needed to determine the frequencies at which fish responses are clearly interpretable and the sound pressure levels and gradients at which they occur.
3. Such experiments would require the long term funding of an interdisciplinary research team containing at least a fish behaviourist and an underwater acoustician. An anechoic tank in which fish could be maintained in good condition for long periods of time would be necessary.

6. Acknowledgements

I am most grateful to Professor F.E. Hetherington and the staff of the E.E. Department, Royal Military College, Dr. W.R. Effer and Mr. C.J. Barnett of Ontario Hydro, Mr. J.W. Christie of Glenora Fisheries Station and Dr. P. Colgan of the Biology Department of Queen's University. Without their help and that of their organizations these studies could not have been carried out.

7. Bibliography

This paper summarises three Royal Military College Electrical Engineering Technical Reports. These are:-

73/2; S. Buxcey and T. Malar, Fish response to underwater sound at discrete frequencies.

74/1; S. Buxcey, Fish response investigations in 1973.

74/6; S. Buxcey, The responses of three types of fish to underwater sound.

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AUDITORY ACUITY OF NATIVE POPULATION AT IGLOOLIK, KEEWATIN, N.W.T.

T. Cummings and J.R. Brown
Dept. of Preventive Medicine & Biostatistics,
University of Toronto.

ABSTRACT

The use of snowmobiles on a routine basis by Eskimo hunters has led to some concern regarding potential risk to hearing.

Noise levels of snowmobiles were measured, under representative operating field conditions.

Audiograms of hunters and of the general native population were obtained. Composite audiograms were prepared. Preliminary results indicate that: (a) the general native population presents a normal response pattern (b) the Eskimo hunters demonstrate a typical noise induced pattern of hearing loss.

The following survey was carried out by the Department of Environmental Health, University of Toronto, at the request of the Federal Department of Indian and Northern Affairs.

Concern has been expressed about the loss of hearing in native populations residing in the circum- and sub-arctic regions. Surveys have been carried out by Baxter and Ling (1)(2)(3).

Whereas snowmobiles are used for recreational purposes throughout most of the North American continent, they are now widely used on a day-to-day basis in the Arctic regions. In many Eskimo settlements these vehicles have largely replaced dog teams as a means of transportation. Eskimo hunters may be exposed to snowmobile noise for periods ranging up to 12 - 14 hours/day. Results from this study indicate that noise levels at the snowmobile driver's ears may range from approximately 90 to 115 decibels A-weighted network. These levels are in excess of present accepted criteria for hearing conservation (4).

Effects of noise on hearing

The effects of noise on hearing have been extensively reported in health literature over the last twenty years. The loss of hearing is attributed to irreversible changes in the hair cells located in the inner ear. At the onset, hearing thresholds at 4,000 and 6,000 Hz are normally the first to indicate significant change. With continued exposure, one normally finds increased losses at these frequencies. The loss is often referred to as the 4,000 cycle notch. However, with continuing exposure to noise, the speech frequencies of 500, 1,000, 2,000 and 3,000 Hz become involved. The recognition of the 3,000 Hz area as a significant factor in the understanding of speech is a recent development. Eventually the degree of loss in the speech frequencies becomes such that the subject starts to experience difficulty in voice communication.

Survey:

The Eskimo settlement of Igloolik is located on a small island between the north-west tip of Hudson Bay and Baffin Island. Approximately 40 hunters provide food for the settlement of 360 people.

This study consisted basically of two parts:

1. measurement of hearing thresholds of the hunters and of the general population; and
2. measurement of snowmobile noise and an estimate of exposure pattern.

1. Hearing Threshold

A. Audiometer

Hearing thresholds were obtained using a manually operated pure tone audiometer. The instrument was calibrated (I.S.O. 1964) on the first morning of the survey. A biological check was carried out each morning thereafter.

B. Otoscopic examinations

Otoscopic examinations of the ear were carried out in order to detect any major occlusions of the canal or damage to the membrane which might influence the hearing testing results. The subjects were questioned concerning any hearing damage or disease.

C. Test room

The tests were carried out in a frame building belonging to the Northern Laboratory of the Ministry of Indian and Northern Affairs. Ambient noise levels in the test room were measured with the following results.

TABLE 1

Noise Octave Band Mid-Frequency (Hertz)	Noise Level (Decibels)
250	30
500	22
1,000	20
2,000	< 20
4,000	< 20
8,000	< 20

results were obtained with:

a) door to test room closed;
b) no conversation in adjacent room
c) building furnace switched off.

These levels lie well within the limits in the proposed CSA Standard Z107.4, "Pure Tone Audiometers for Limited Measurement of Hearing and for Screening.

D. Subjects

The audiometric test procedure was explained in some detail to our interpreter following which he received the first test. He then operated the various audiometer controls on a demonstration run. His subsequent explanation and instructions to the subjects appeared to be readily understood. In almost all cases the tone presentation-response pattern indicated successful testing.

Audiograms from a sample of 79 people of which 30 were hunters, 45 general population, and 4 diesel driver/mechanics, were obtained. In view of the high noise levels associated with the use of diesel equipment the diesel operators were excluded from the general population and reported separately. Four subjects, including one hunter, were excluded from the results due to the presence of aural pathology.

Snowmobile noise levels

The results are given in Table 2. We failed to observe any snowmobiles other than SKI-DOO models in use at the settlement. The Igloolik results are compared with previous results from other results involving SKI-DOOS in Table 2.

It would seem reasonable to assume that the noise level at the driver's ears could range from about 90 to 115 dBA. Some Eskimos reported having driven their machines for some time, either with broken or missing mufflers. Noise levels under these circumstances are not available, but one might speculate that they would be significantly higher than those listed.

As noted previously, the hunters may be exposed to these noise levels for periods up to 12 to 14 hours/day.

TABLE 2

Noise Levels - Snowmobiles

Model	Noise Level - dBA near driver's head idling/slow - full speed	Reference
SKI-DOO 340 20 H.P. Twin	90 - 103	Igloolik
SKI-DOO 300 15 H.P. Single	98 - 114	
SKI-DOO 440 24 H.P. Twin	104 - 108	
SKI-DOO Nordic	113	(5) Information Canada Catalogue No. T46-173
SKI-DOO Elan SS 320	95 - 105	(6) Snowmobile Handbook 1974 Popular Science
SKI-DOO T'NT 440	95 - 106	
SKI-DOO	100 - 110	(7) Journal of Environmental Health Nov/Dec. 1971
Assorted mix of 10 snowmobiles	87 - 118*	(8) Sound & Vibration May 1973

*Measured at side of vehicle.

a) Noise levels measured close to driver's ear
b) Snowmobiles were driven on hard packed snow
c) Instrument used - Bruel-Kjaer S.L.M. 2205; Windscreen UA 0207
d) Ambient Temperature - approximately -10°F. (Sound Level Meter was returned to heated room between tests; and stored beneath parka between readings).

Discussion

With reference to the group audiograms of the hunters, the median follows the classical pattern of noise-induced hearing loss, showing a relatively slight loss at 500, 1,000 and 2,000 Hz, then sloping rather steeply to a threshold of 55 dB at 4,000 Hz. The upper and lower quartile lines illustrate the relatively wide range of values that one might anticipate when testing a group with a mixed experience of noise exposure, and ages ranging from 19 to 74. The upper quartile demonstrates the marked encroachment of the speech frequencies.

In contrast, the general population audiograms indicate a normal response pattern with the upper and lower quartiles lying mostly within 5 dB of the median, and displaying no significant loss at any frequency.

Each subject was questioned following the taking of the audiogram for the purpose of discovering any unusual "noise" experience or clinical history. In the case of the hunters, many reported incidents that occurred while hunting from small boats. During the summer, small groups of Eskimos hunt together in small (10' - 12') boats. During these expeditions rifles may be discharged within one foot or less of a neighbour's ear. About half of the hunters related, through the interpreter, that following such incidents they (a) could not hear in one ear for about two days, or: (b) heard noises in their ear(s) for some time following, or: (c) their ear(s) hurt for awhile. A review of the individual audiograms revealed that six of the hunters disclosed appreciable difference in hearing threshold from one ear to the other. This effect was more noticeable in the right ear. This is in contradiction to what one might expect from a group of right-handed marksmen.

The small boat episodes place serious constraint on any conclusions regarding the effect of snowmobile noise. The noise level of the snowmobiles and the duration of exposure on a routine basis, clearly suggests a resultant exposure to noise well in excess of present accepted hearing conservation criteria. However, one must assume that the effect of rifle noise complicates any effect of snowmobile noise on the individual and group audiograms.

A comparison of the median threshold of Eskimo hunters with sports hunters (9) is shown in Figure 1. A comparison is also made with industrial workers in Figure 1. Both comparisons show general agreement.

The hearing losses exhibited by the 4 diesel operators, ages ranging from 31 to 50, are unfortunately and predictably all typical of severe noise exposed hearing loss.

Whilst recognising the problems associated with the wearing of hearing protection under Arctic conditions, it would appear that the only hope of conserving what hearing remains within the hunter and diesel operator groups lies in the wearing of such protection. In the case of the hunters, hopefully, quieter snowmobiles will become commercially available. The problem of group rifle fire offers no ready solution.

It would appear that a more active programme of health education with regard to hearing conservation should be undertaken as soon as possible if deafness of native populations is to be avoided.

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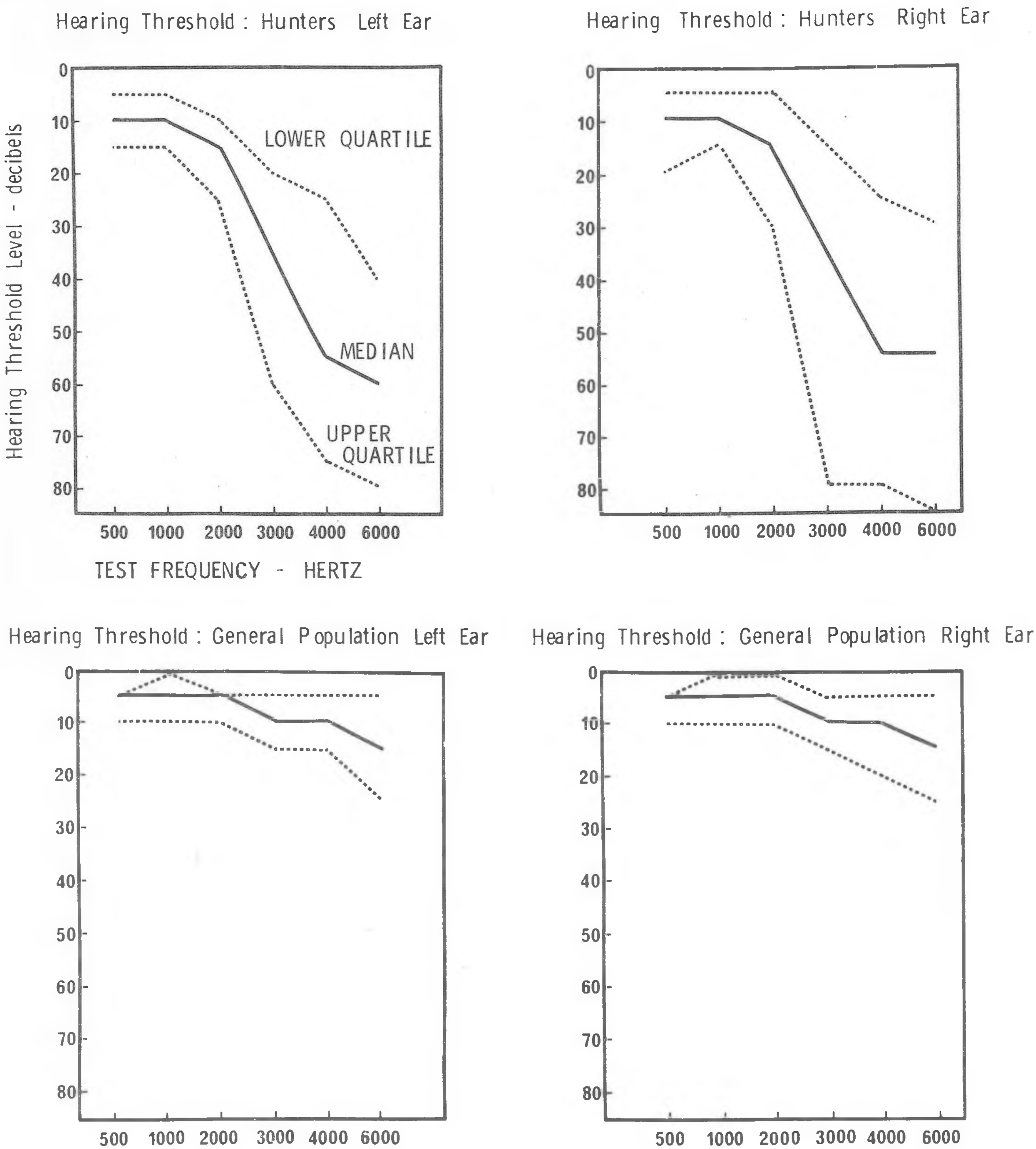

Hearing Threshold : Hunters Left Ear
Hearing Threshold : Hunters Right Ear
Hearing Threshold Level - decibels
0
10
20
30
40
50
60
70
80
LOWER QUARTILE
MEDIAN
UPPER QUARTILE
500 1000 2000 3000 4000 6000
TEST FREQUENCY - HERTZ
Hearing Threshold : General Population Left Ear
Hearing Threshold : General Population Right Ear

FIG. 1

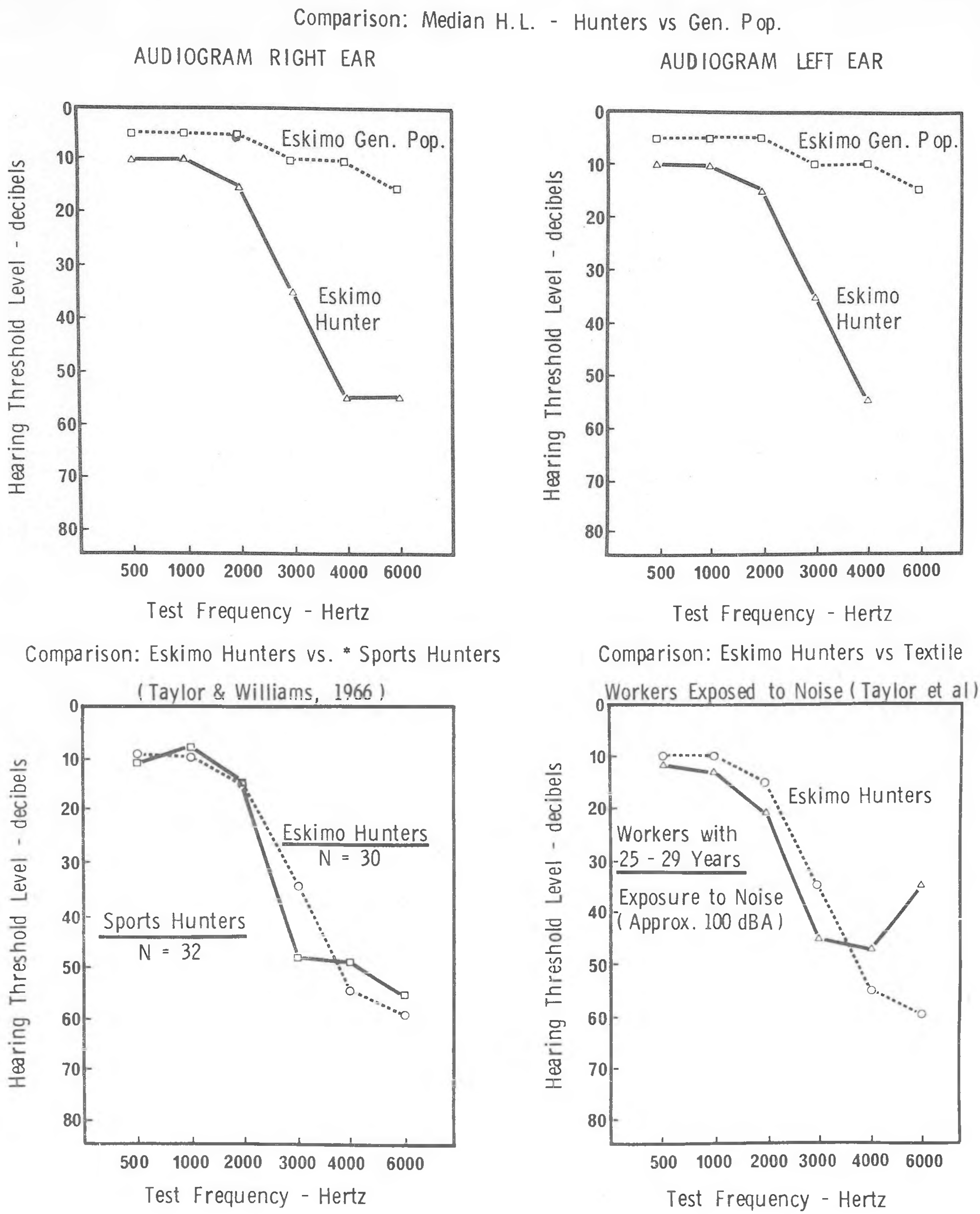
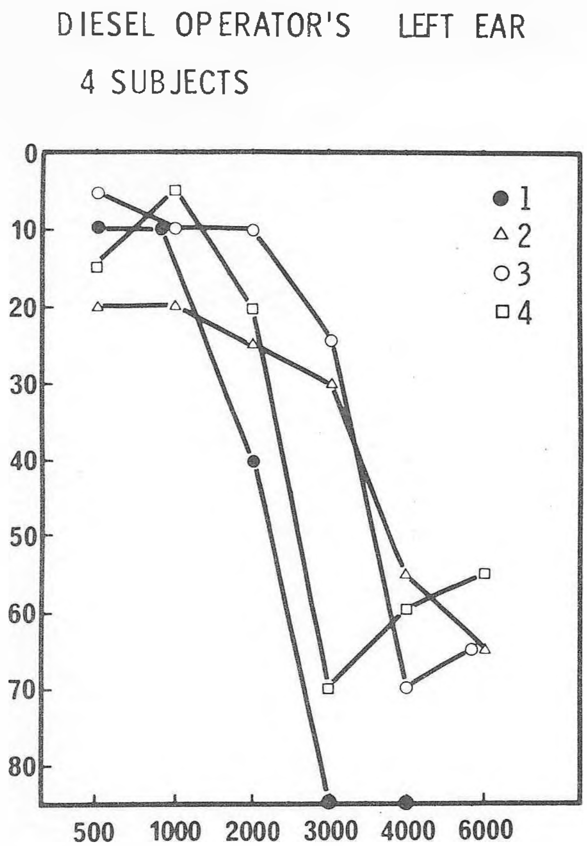

Comparison: Median H.L. - Hunters vs Gen. Pop.
AUDIOGRAM RIGHT EAR
AUDIOGRAM LEFT EAR
Eskimo Gen. Pop.
Eskimo Hunter
Hearing Threshold Level - decibels
Test Frequency - Hertz
0 10 20 30 40 50 60 70 80
500 1000 2000 3000 4000 6000
Comparison: Eskimo Hunters vs. * Sports Hunters
(Taylor & Williams, 1966)
Eskimo Hunters
N = 30
Sports Hunters
N = 32
Comparison: Eskimo Hunters vs Textile
Workers Exposed to Noise (Taylor et al)
Eskimo Hunters
Workers with
25 - 29 Years
Exposure to Noise
(Approx. 100 dBA)

FIG. 2


DIESEL OPERATOR'S LEFT EAR
4 SUBJECTS
0
10
20
30
40
50
60
70
80
500
1000
2000
3000
4000
6000
1
2
3
4

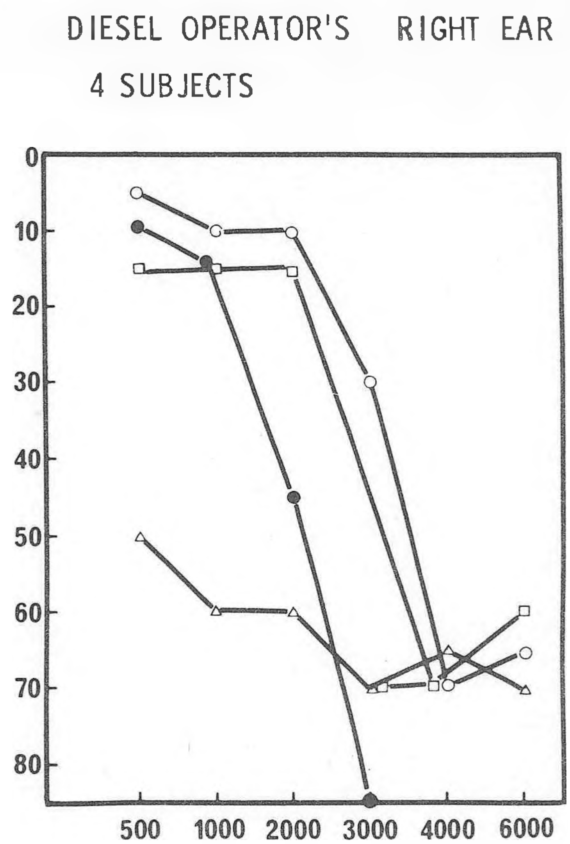

DIESEL OPERATOR'S RIGHT EAR
4 SUBJECTS
0
10
20
30
40
50
60
70
80
500
1000
2000
3000
4000
6000

FIG. 3