TERRA BOREALIS

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The Institute for Environmental Monitoring and Research (IEMR) has the mandate to oversee the environmental effects of allied flight training conducted from the Canadian Forces Base at Goose Bay, over areas of Labrador and northeastern Québec. The Institute conducts multidisciplinary research on the effects of military activities on the natural and human environment and fosters the inclusion of aboriginal environmental knowledge and cooperation in research and monitoring amongst government agencies, universities, and private organizations.

Institute for Environmental Monitoring and Research
P.O. Box 1859, Station B
Happy Valley – Goose Bay
Labrador, Newfoundland
A0P 1E0

Phone: 709-896-3266
Fax: 709-896-3076
E-mail: iemr@hvgb.net

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Preface

The Canadian government established the Institute in December 1995 to oversee the environmental effects of allied flight training conducted from the Canadian Force Base at Goose Bay over areas of Labrador and northeastern Quebec. The decision to create an Institute dedicated to the study of low-level flying on the natural environment was made in response to an earlier recommendation by an independent Environmental Assessment Panel appointed to review military flight training activities. A Board of Directors representing aboriginal and municipal groups in the region serve as the governing body for the Institute. The Institute also has an independent Chair and non-voting members representing federal and provincial governments.

The Institute conducts multi-disciplinary scientific research on the Labrador and northeastern Quebec ecosystems affected by the low-level flying program. It also conducts research on the social and economic effects of low-level flying.

A great number of research programs were undertaken during the 1970's and 1980's to determine the possible potential effects of military jet aircraft on the environment, focusing primarily on the effects on humans due to public fear of adverse ecological impacts. However, the knowledge gained from this research is not readily transferred to wildlife that inhabit areas overflown by aircraft at low altitude. Although scientists have researched some effects of noise on animals, many data gaps still exist on the overall effects of aircraft noise. In addition, perceived inadequate or inaccurate analysis of the effects of aircraft noise on wildlife by the general public remains an important concern, particularly for aboriginal groups who maintain a close dependence on the land for their well-being and survival.

A solid information base on the effects of aircraft noise on various animals species is necessary to assess potential impacts to wildlife populations from proposed military flight operations. In order to help the Institute to better understand the impact of noise on wildlife populations, we hosted this conference on wildlife and noise to provide members with an overview of current knowledge. This publication brings together the presentations from 16 international experts in the field of noise and wildlife.

The Institute is grateful to the scientists and participating members for their expertise and guidance. We will endeavour to develop a research program that aims at filling the knowledge gaps that confront those of us who are dedicated to ensuring that we carefully understand the impacts of our actions. We remain constant and vigilant in the development of mitigation programs which will ensure that wildlife and humans are protected from the possible impacts of low-level flying.

Louis LaPierre, Ph.D.
Institute Chair

Acknowledgements

The Institute for Environmental Monitoring and Research would like to gratefully acknowledge all of those who helped make this conference a success. Universal Helicopters and Hickman Equipment for their generous donations of nutrition breaks. Local crafters and artists for providing items for the silent auction that raised money for the Paddon Memorial Home sunroom. The staff of Maxwells, the Royal Canadian Legion, Midway Garden, and Doris Patey for preparing wonderful meals throughout the conference. To Morris Tours, The Labrador Inn, Aurora Hotel, and the Royal Inn for excellent service. Mr. J. C. Bourque for providing continuous language translation throughout the conference. Finally, to the KILAUTIk Drum Dancers, Acting Up Entertainment, Beatrice Hope, Richard Neville, and Murphy's Law for great evening entertainment.

Thank you to all of those who spoke and contributed papers and information for these proceedings. We give special thanks to all members of the Steering and Logistics Committees for their hard work and dedication. A special mention to the Institute staff for their dedication and commitment.

Conference Program

Monday, August 21, 2000

Welcoming Reception — Maxwells Lounge

18:30 – 20:30 Entertainment by:
Beatrice Hope
Richard Neville
Murphy's Law

Silent Auction: Proceeds to the Paddon Memorial Home

Tuesday, August 22, 2000

08:00 – 08:45 *Registration*

08:45 – 09:00 *Introduction* and *Welcome*
Louis LaPierre, Chair of the Institute

09:00 – 09:15 *Welcoming Addresses*

Wally Anderson, MHA, Torngat Mountains

Judy O'Dell, Deputy Mayor, Town of Happy Valley – Goose Bay

Peter Penashue, President, Innu Nation

PART 1 PLENARY SESSION

09:15 – 10:00 *Overview of Research on the Effects of Noise on Wildlife*

Lex Brown, School of Environmental Planning, Griffith University, Australia

10:00 – 10:30 Nutrition Break – Sponsored by Universal Helicopters

10:30 – 11:15 *Utilizing Indigenous Knowledge in Environmental Research and Assessment*

Michael Ferguson, Department of Sustainable Development, Government of Nunavut, Canada

Aboriginal Discourse and Knowledge Concerning Industrial Impacts on the Environment

Daniel Ashini, Innu Nation, Labrador, Canada

11:15 – 12:00 *The Effects of Aircraft Noise on Animals: General Principles and Approaches*

Ann Bowles, Hubbs Sea World Research Institute, USA

12:00 – 13:15 Lunch – Midway Gardens

PART 2 NOISE MEASUREMENT TECHNIQUES AND PROCEDURES

13:15 – 14:00 *Defining Auditory Thresholds for Animal Species*

Larry Pater, U.S. Army Construction Engineering Research Laboratories, USA

14:00 – 14:45 *Department of National Defence Noise Prediction/Propagation Model*

Neil Standen, Urban Aerodynamics Limited, Canada

PART 3 RAPTORS

14:45 – 15:30 *Responses of Peregrine Falcons to Military Jet Aircraft*

Stephen Murphy, ABR Inc., USA

15:30 – 16:00 Nutrition Break – Sponsored by Hickman Equipment Ltd.

16:00 – 16:45 *Summary of Osprey Research Relating to the Low-Level Flying Program in Labrador and Quebec*

Peter Thomas, Environment Canada
Perry Trimper, Jacques Whitford Environment Ltd., Canada

Banquet College of the North Atlantic

18:30 – 21:30 Entertainment by:
KILAUTIk Drum Dancers
Acting Up Entertainment

Wednesday, August 23, 2000

PART 4 WATERFOWL AND OTHER BIRDS

08:30 – 09:15 *The Effects of Aircraft Operations on Passerine Reproduction*

Don Hunsaker, Hubbs Sea World Research Institute, USA

09:15 – 10:00 *The Effects of Sonic Booms on Animals: A Review of Effects Research*

Ann Bowles, Hubbs Sea World Research Institute, USA

10:00 – 10:30 Nutrition Break – Sponsored by Hickman Equipment Ltd.

10:30 – 11:15 *An Overview of Studies to Assess the Effects of Military Aircraft Training Activities on Waterfowl at Piney Island, North Carolina*

James Fleming, U.S. Geological Survey, USA

11:15 – 12:00 *Response of Geese to Aircraft Disturbances*

David Ward, U.S. Geological Survey, USA

12:00 – 13:00 Lunch – Royal Canadian Legion

13:00 – 13:45 *The Response of Sea Birds to Simulated Acoustic and Visual Aircraft Stimuli*

Lex Brown, School of Environmental Planning, Griffith University, Australia

PART 5 MAMMALS

13:45 – 14:30 *Effects of Overflights by Jet Aircraft on Activity, Movements, Habitat and Terrain Use of Caribou*

Julie Maier, University of Alaska Fairbanks, USA

14:30 – 15:15 *Movements and Site Fidelity of Woodland Caribou of the Red Wine Mountains Herd in Relation to Low-Level Aircraft Training in Labrador*

Tom Jung, Institute for Environmental Monitoring and Research, Canada

15:15 – 15:45 Nutrition Break – Sponsored by Universal Helicopters

PART 6 SPECIAL TOPICS

15:45 – 16:30 *Managing Low Level Jet Aircraft Noise*

Maurice Pigeon, National Defence Headquarters, Canada

16:30 – 17:15 *Overflights and National Parks*

Steven Opperman, National Parks Service, USA

17:15 *Closing Remarks*

Louis LaPierre, Institute for Environmental Monitoring and Research

Dr. Louis LaPierre

Chair, Institute for Environmental Monitoring and Research

I would like to welcome each of you to this conference. The Institute for Environmental Monitoring and Research was created by the Canadian government to oversee Allied flight training at the Canadian Forces Base here in Goose Bay in response to an Independent Environmental Assessment Panel.

Our goal is to hold conferences periodically to learn and to share our experiences. The first conference held by the Institute was on Traditional and Western Scientific Environmental Knowledge. The purpose of this second conference is to bring the experts together to share knowledge on noise and wildlife. Most research on noise has been done on humans; however, animals are now entering the picture. As the Institute is beginning to look at its research agenda, we want to look at the research that has been done in this area.

We need to understand and share with those involved in the field. Our goal is to bridge the gaps and establish a network between those in the field in order to gain appreciation for the work done and not to repeat the mistakes. This conference is an opportunity for our Board members to gain an understanding and learn. It is my hope that this conference will provide an opportunity for learning and sharing in both formal and informal activities, and I ask you to take advantage of the opportunity to network.

Every time I come to Happy Valley – Goose Bay, I learn. The people of this area have collected important information to help them survive on this landscape. I invite you to enjoy and explore the pristine natural environment of Labrador.

Wally Anderson

Member of the House of Assembly, Torngat Mountains

On behalf of the province, I welcome you to Labrador and wish you success with your conference. Low-level flying is important to Labrador as it provides income and employment. The Innu and Inuit people have been here a long time and have a passion for Labrador. Through good discussions we have seen an increase in flying and welcome the Italians. This has been done in consultation with the Innu and Inuit. It is only when you go to the northern regions of Labrador that you will see the true Labrador. You need to see the caribou, the char, the hare, and see how the people depend on the land.

I do wish you success in your conference. Through discussion I hope you walk away with an understanding that we must work together to provide employment and maintain Labrador's culture. Welcome.

Judy O'Dell

Deputy Mayor, Town of Happy Valley – Goose Bay

First of all I want to welcome you to our town and say that Wally is always a hard act to follow. I came to Labrador in 1979 for three months, and I am still here. I feel we are very fortunate and must protect what we have. We must protect the wildlife and low-level flying. Last week we had Allied Appreciation Week. Yes, we want to protect our wildlife while working in harmony to keep our youth employed and ensure that the town of Happy Valley – Goose Bay thrives as a community. We are on the leading edge when it comes to housing. We are a proactive community. I welcome our aboriginal brothers here. Please feel free to speak and share your ideas, and I wish you a successful conference.

Peter Penashue

President, Innu Nation

I would like to welcome you to this conference. It will be a good opportunity to discuss the effects of low-level flying, particularly the effects of noise.

Low-level flying came here 20 years ago. I remember that in 1978-1979, local leaders talked about a new industry coming to Labrador – flying low over the land. But what was being proposed was difficult for Innu people to conceptualize at first, until we experienced its effects first hand. It was intrusive to our way of life. I remember the meetings, the protests, and all of the controversy that the flights brought to Labrador. I suppose they also brought great benefits to the area. The Innu experienced the impacts, but none of the benefits. In many ways, we were considered to be secondary.

Another element that was considered secondary in terms of priority was the impact of noise as it affects the people on the land. Not the people in the communities, for there was a great deal of attention paid to the issue of noise here in town, but the people on the land, who were practicing a way of life thousands of years old, were really left out of the picture as the military and the supporters of the project saw it.

Some of you have been to our communities, and seen something of the despair and the poverty that we live with there. But out on the land, we have our pride. There is joy and the sound of laughter.

All of these things should be treasured. The Innu are one of the last hunting and fishing peoples in North America.

Many of us go to the land for several months as a way of life. When low-level flying was proposed, it became a very emotional issue for us. It challenged us to defend what was most important to us and we fought to discourage low-level flying because of the effects that it had on our way of life.

We made a lot of noise. Had it not been for the Innu, I think there would have been a NATO base here in Goose Bay. Because of our opposition, the government felt they had to do something, so they gave us an environmental assessment to collect data. Because of our position, and the time that it took to do the environmental assessment, there was a long delay in going ahead with the NATO base. By the time the environmental assessment ended, the Cold War had ended, and there was also a change in the political landscape. It no longer made sense to build a NATO base here and it might not make sense to continue low-level flying at all.

My point is that our efforts changed the course of development here. I think that if a NATO base were built here, it would have been one of the many things that would have discouraged Innu from living our way of life. Low-level flying does not help Innu; it actually puts more pressure on our community. We are struggling to gain some control over our land and our lives, and low-level flying has contributed little to this struggle.

Last week we were in court. The Department of National Defence wanted to conduct supersonic test flights using Dutch aircraft. We went to court because this was not part of the Environmental Impact Statement, not part of the project that the government approved in 1994, and not something that we had been consulted on. We have serious concerns about the effects that supersonic noise might have.

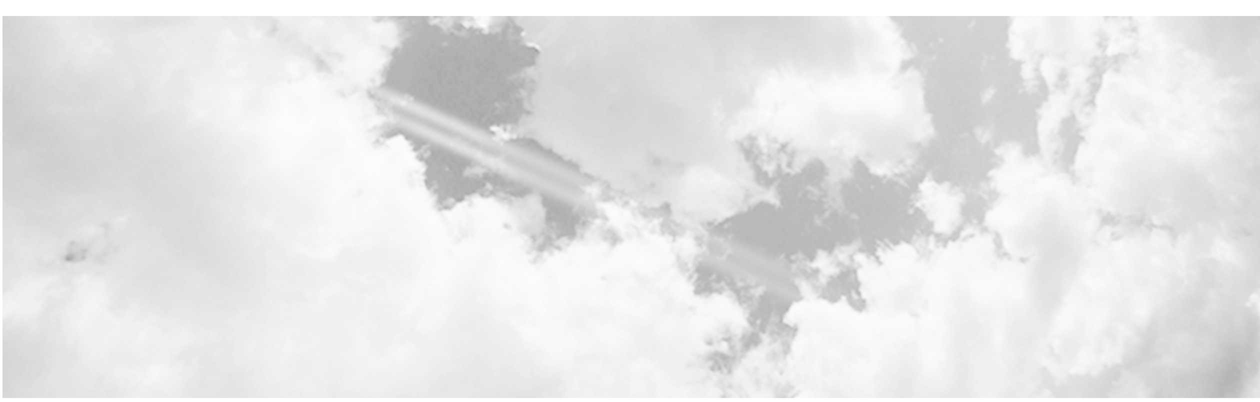
So we went to court. And at the last minute, DND backed off. But then we heard rumours that they were looking at pursuing supersonic flights with Canadian CF-18s, which we couldn't fight in the courts, but we were convinced that we could win in the courts of public opinion. We didn't believe that the Canadian public would allow DND to trample over our rights. In the end, and after some serious discussions with the Innu, DND has agreed to abandon their plans until next year. In the meantime, we will all bring in our own scientists to review the proposal, and help us get a better sense of the impacts of supersonic flights.

It must be remembered that the Innu are the main users of the land where the proposed supersonic flights will occur. DND has told us not to be concerned, however, because the sound of a supersonic jet is equivalent to thunder. If this is so, why don't they train over the cities which could withstand such noise? Perhaps because the last time that a CF-18 went supersonic over Ottawa, it damaged buildings and even blew the doors off a car dealership.

In any event, when we next sit down to talk about noise and supersonic flights with DND, we will bring our own experts to the table. The next step may be an Environment Assessment. If that is the case, we think that the Institute will have an important role to play in helping us understand the potential impacts of these proposed flights.

The fact remains that Innu were concerned about noise in 1979, and, in 2000, we still have the same concerns. However, the world has changed. I think that it is an open question as to whether supersonic flights and helicopters will come here to train, but one thing is for sure, the Innu won't be just watching as the events unfold over the next five years.

On that note, I'd like to bid a warm welcome to all. This session should be informative and, if we take the time to listen, there is wisdom here for all of us, including ourselves. It is my hope that we can all share in it, and use it to help us make the hard decisions that we will need to make in the years to come.



Overview of Research on the Effects of Noise on Wildlife

Professor Lex Brown
School of Environmental Planning
Griffith University, Brisbane 4111
Australia

It is widely acknowledged that there is need to assess the influence of noise on animals, but overall, there has been relatively limited research undertaken in these fields; and the scientific evidence addressing the issue of human noise and wildlife is still rather meagre. This paper provides an overview of this research activity, and the contexts and management areas in which it has been carried out. It illustrates different categories of research undertaken and identifies some limitation in current work and avenues for further research.

The effect of noise on humans has been the subject of quite extensive research for much of the twentieth century. There is now a reasonable knowledge of its damaging effect on human hearing at high energy levels, and its effects on human sleep, on human communication, and on human mental activities and well being at lower energy levels. Noise, to humans, is recognised as a stressor, and considerable effort has gone into quantification of the relationship between noise levels and human stress, and determination of what might be "safe" levels in different settings. In contrast, the effect of noise as a stressor for wildlife and for captive/domesticated animals has received far less attention (Radle, 1998). Research into the effects of noise on disturbance to individual animals, their habitat and the ecosystems in which they reside, is required to determine "safe" levels of exposure to protect wildlife values, for management of anthropofaunal conflict and for sustaining animal productivity.

Research into the effects of noise on animals has been in two situations: animals in the wild and captive/domestic animals, and this paper concerns the effects of noise in the wild. Much of this research deals with the impact of the noise from military ctivities on wildlife, particularly low-level aircraft overflights, sonic booms and helicopter movements. Another focus of research has been the impact of exploration and exploitation of mineral resources including marine and land-based seismic activities, transport of both people and materials from mines and oilrigs, and the mining operations themselves. This is not surprising given that both military and mining operations tend to occur in areas remote from major areas of population activities where wildlife has previously suffered little disturbance, and both are associated with high levels of noise, often explosive in nature. Increasingly, tourism operations are using scenic flights by light, fixed-wing aircraft and helicopters over remote areas, require the use of off-road vehicles for remote access, or focus on viewing concentrations of wildlife – whale watching or Antarctic tourism are examples – and research has been directed at the effects of these activities on wildlife. In some instances research activities themselves, as in the use of helicopters for wildlife surveys, or projects such as the Acoustic Thermometry of Ocean Climate program that involves creation of underwater acoustic signals for climate change research, have been the sources of noise and have prompted related studies of their effect on animals.

Noise from all forms of motorised transport has also been the subject of some studies. In addition to noise causing unwanted effects, there is also considerable literature on the use of noise to deliberately haze wild animals –primarily for the protection of human safety at airports and the protection of crop production by the use of bird and animal scares.

To a large extent, much of the research has been uneven and uncoordinated, with most of the funding being directed at specific situations, particularly military situations, or reported with respect to the impacts of development projects, and often in the grey literature of government contract reports or environmental impact statements. While there has been some very good work conducted by individual researchers, one would have to conclude that we have barely scratched the surface in our understanding of the effect of noise on wildlife. Larkin (1996) in a recent review of the effect of military noise on wildlife has observed that, Research is hampered by a preponderance of small, disconnected, anecdotal or correlational studies as opposed to coherent programs of controlled experiments ... Comparability among studies is complicated by terms lacking generally-accepted definitions (e.g. "disturbance") and by species difference.

How does noise affect wildlife? Put simply, animals depend on acoustic signals in nature for a wide range of essential functions: for communication, for navigation, for mating, for nurturing, for detection of predators, and for foraging functions. There are some measurements of off-road vehicle noise impairing the hearing of small desert animals, but this is probably not common. More importantly, noise can mask these natural acoustical signals and can impair satisfactory performance in any of these functions. To assess if masking may occur, one needs information on the hearing capabilities of the particular species investigated, good details of the frequency spectrum, the level and the temporal variation of the intruding noise, similar detail of the natural acoustic signals that need to be detected, and reliable measurement of the natural background sound levels on which the signals to be detected are superimposed (wind in trees, waves, biological background levels etc). We lack most of this information for most species and most localities. However, quite apart from its masking effects, noise can be postulated as a stressor for animals, particularly where they cannot escape the noise, say when bound to a location through their breeding and nurturing activities, or where the whole of their habitat range may be affected.

How are noise effects on wildlife measured? Observations of the effect of noise on wildlife have mostly been made in two ways: observation of specific behavioural effects or observation of physiological effects. Behavioural responses have been measured in terms of gross response – things such as trotting short distances, walking around flapping wings, panic and escape behaviours, temporarily abandoning nests or young, or avoidance of specific areas. Sometimes these gross measures have been on the behaviour of whole herds or colonies or schools, all birds being flushed from a lake for example, or alternatively of individual animals or pairs. Other measures of behavioural response have been more subtle, things such as head raising and body shifting, small alterations in feeding patterns or similar, and these require very detailed recording of individuals, usually by videotaping. More recently, much research has focussed on individual's physiological response such an increase in heart rate, changes in metabolism, temperature and hormone balance. Many of these have to be quite invasive, requiring capture and release with potential strong experimenter effects, but modern instrumentation allows remote assessment using, for example, telemetric monitoring of heart rate devices fitted to individuals or under eggs.

The presence, sometimes the absence, of behavioural and physiological responses when exposed to noise, has all been measured in different species in different studies. So what? In some cases one can observe, in others postulate, that the noise has the potential to cause injury, energy loss through movement away from noise source, decrease in food intake, habitat avoidance and abandonment, and reproductive loss. If birds are flushed by noise, eggs can be broken and young exposed to injury and predators. Young mammals have been trampled on avoidance of noise. Some changes in mortality rates have been observed.

But overall our knowledge of noise as an ecological disturbance is limited.

Research on the effects of noise on wildlife needs to be undertaken within a theoretical framework of the ecology of disturbance of animals (Hulsman, 1997). Such a framework incorporates various existing ecological models for concepts such as tolerance, range, niche, habitat and life-history strategies to provide a rigorous basis for the study of noise as ecological disturbance. We need to define how the complex disturbance characteristics of noise alter the existing habitat of an organism and how well that new habitat meets, or does not meet, that organisms' requirements of the habitat. To research what levels might be "safe" for wildlife, not only must the dose of the acoustic disturbance be fully understood e.g. nature (type of noise – aircraft noise, etc.), intensity, spectral frequency, duration, frequency of occurrence (how often the target organism is exposed in a given amount of time), predictability, combination with another stimulus (e.g. visual stimuli), timing of exposure (time of day), but so too must the organisms' characteristics e.g. tolerance level, physiological state, timing (in terms of life-history stage exposed), powers of dispersal and behaviour, etc. It is vital to note that characteristics of the disturbance do not act independently of one another in producing an impact. And while we are likely to be severely constrained in what we can observe experimentally of an organism's response to noise exposure, in the long run, the critical measures of wildlife response to noise disturbance are the individual's, colony's, and the species' chances of survival and reproduction as a result of the exposure to the disturbance. Does wildlife abandon territory or have less reproduction success as a result of noise exposure? Some species have become threatened or endangered because of loss of habitat, and further relocation as a result of noise disturbance is not possible (National Parks Service, 1994). Gathering such extensive ecological information to determine safe doses for all species, in all habitats, of interest is going to be difficult to achieve. Prudence is going to require application of the precautionary principle in most management regimes.

Most of the studies on noise and animals can be placed into categories: field observations, field-based experiments and laboratory-based experiments. In addition, studies that attempt to describe the acoustic baseline in natural environments are an important contribution to our understanding of the effect of noise on wildlife, providing a base against which levels of intruding noise can be assessed. While I am unaware of any reported studies, it is probable that traditional knowledge can make a major contribution to our understanding of the effects of noise on wildlife in wilderness areas.

Two very important dimensions in these studies are how the noise stimulus is measured and/or controlled together with the range of the stimulus used, and how the response of wildlife to the noise stimulus is observed and measured. In the past, much research has used surrogate information to describe noise events in field studies. For example, noise exposure was often measured at an observer location far removed from the animal under study, or inferred from the presence of flyovers. Devices can now be worn by animals, on collars or similar, that can monitor direct animal exposure.

Much of the literature reports research based on field observations, and while this has provided valuable insights, the general absence of control over the acoustic stimulus and little other than gross measures of response (for example, observing gross fly off, or observing "no visible response") means that these studies have little chance of replication. These can be improved by careful monitoring or modelling of the exposures and by sophisticated recording and measurement of response. Field experiments, controlling or simulating the stimulus, and/ or making detailed measures of response, are quite difficult to conduct, and this presumably explains their paucity in the literature. However, manipulation of the experimental stimulus provides the opportunity to define the dose-response relationship for individual species and the safe floor of noise exposure. Both field experiments and field observations may be conducted on naïve or chronically exposed animals to provide an opportunity to assess the effects of habituation to noise stimuli.

Laboratory experiments are far simpler, but of course raise questions of applicability of their results in the field, particularly given the complexity of the ecology of disturbance. Baseline studies, while not measuring effect, provide critical information on natural acoustic environments in which organisms live and against which measures of intrusive human generated noise can be assessed. For example, McCauley [19] provides a thorough documentation of the ambient noise in marine habitats of Australia comprising both biological (e.g. invertebrates, fish and marine mammals) and non-biological sources (e.g. marine transport noise, wind, rain and earthquakes). In the context of the ecology of disturbance [40] these data provide a description of the acoustic habitat characteristics. He then reviews the potential disturbance characteristics, seismic survey sounds, and goes on to comprehensively document the characteristics of marine organisms and their various life-history strategies which make them more susceptible to impacts resulting from noise exposure, and reviews the pathological and behavioural effects of seismic exploration noise among the various taxa. McCauley [19] defines various zones of influence of marine acoustic disturbance that include audibility, masking, behavioural response, avoidance, pathological effects and lethal effects. A zone refers to the radius from a point source within which organisms exposed are susceptible to a certain effect. Under each of these zones he addresses the effects on various marine fauna and identifies existing gaps in the knowledge. He also ranks the significance providing a framework for the effects of noise as ecological disturbance, and presents the long term implications of seismic exploratory activity and a template to assess noise effects in marine habitats.

Conclusions

There are many examples of excellent work regarding the effects of noise on wildlife in which either behavioural responses or physiological response to noise have been observed, measured, and in some cases shown to be absent. They contribute to our understanding of the problem.

However, review of the literature indicates that, overall, work in this area is still sparse and sporadic (and much of the information is only available in unpublished documents and government reports). Much of the literature deals with the impact of military activities, seismic and other exploration activities and the influence of transport noise.

The use of uncontrolled stimuli and the measurement of gross disturbance responses such as flushing or escape accentuate difficulties in replication of research into effects of noise on animals. Though such studies are useful as pilots, critical examination of a particular response to a pre-defined stimulus is vital for future noise management. Both careful control over the stimulus and detailed measurement of response are pre-requisites for investigation.

Very few studies in this field have designed experiments with a level of precision that can identify a threshold stimulus below which the target animal is unlikely to experience detrimental effects.

Habituation to noise could enable animals to increase tolerance but, as with humans, anecdotal evidence of habituation is inadequate, and will need to be tested by appropriate studies. The influence of habituation, and overall tolerance to acoustic disturbance, are areas that require further investigation.

There is still an absence of understanding how observed behavioural and physiological effects translate into ecological consequences for wildlife.

Finally, the long-term effects of noise on wildlife are unlikely to be revealed in the near future because of the magnitude of the effort required. In this area, perhaps, there is potential for use of traditional knowledge. Given the difficulties of much of this experimental work in wilderness areas, there must be considerable opportunity for utilisation of traditional knowledge on changes in the abundance, and changes in the movement behaviour of wildlife to help assess its disturbance by human sounds.

In addition to concern for wildlife in the presence of noise, we also must be concerned with humans in wilderness. As Paul Matzner from the Nature Sounds Society has pointed out, wilderness is an area that has outstanding opportunities for solitude. Auditory solitude, or quietude, is an important component of wilderness, and of wilderness management and, I would hazard a guess, maintenance of cultures. Perhaps to some extent we can use "humans" as the "management indicator species" for much management of the effects of noise on wildlife?

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Utilizing Indigenous Knowledge in Environmental Research and Assessment

Michael A.D. Ferguson, Ph.D.
Department of Sustainable Development
Government of Nunavut
Pond Inlet, Nunavut, X0A 0S0

The indigenous knowledge of aboriginal peoples in North and South America has been used to varying degrees by Europeans, others and their descendants over the past 500 years. In northern Canada, a few explorers readily acknowledged the contributions of Inuit and other aboriginal peoples (Hall, 1864, 1873). Although naturalists and biologists undertook many Arctic expeditions, most seemed oblivious or indifferent to the abundant relevant knowledge of aboriginal peoples (Hantzsch, 1977).

During the last half of the 1900's, countless migratory biologists and other "Western" researchers visited Canada's remote northern regions to gather "new" information, mainly through numerical quantification. Over the past 10 years, some have become curious about the knowledge of aboriginal peoples. However, this curiosity has come largely as a response to political, legal and negotiated efforts by aboriginal peoples (Usher, 2000).

Several non-aboriginal persons and organizations (Usher, 2000) have stated that "traditional ecological knowledge" or "indigenous knowledge" must be defined, probed and tested. Such intensive examination is largely unnecessary within aboriginal cultures, because indigenous knowledge is continuously verified, updated, adaptive, aggregated, intergenerational, multifaceted and iterative (Thorpe, 2000). The cultural paradigm that makes such intensive questioning valid comes largely from the adversarial and advocacy traditions in Western science, law and politics. Perhaps the primary question at issue for aboriginal communities is: To what degree, when and how will indigenous knowledge adequately influence the outcome of a given environmental assessment or wildlife management regime?

To force any particular knowledge system into another cultural paradigm, risks changing the integrity of the system. Non-oral recording of indigenous knowledge may lead to the loss of the mental discipline and lifetime of training required for the detailed, accurate and precise recollection and retelling of information (Hall, 1864; Arima, 1976; Woodman, 1991; Freeman, 1993; Ferguson and Messier, 1997). Such characteristics of indigenous knowledge systems may not be preserved if holistic, deductive knowledge and consensus decision-making of indigenous peoples are transformed so they can be comprehended and utilized within Western processes. Therefore, different efforts and protocols are probably required to meet the differing knowledge needs within aboriginal communities themselves, and the cross-cultural needs of Canadian governments, science, law and general public.

Both indigenous and non-indigenous persons are developing methods to collect and document selected indigenous knowledge for the cross-cultural context (Walker et al.,1997; Williamson, 1997; Ferguson and Messier, 1997; Thorpe, 2000; Usher, 2000). Common elements of these methodologies include:

- cooperation and trust within aboriginal communities;
- consensus on research issues, priorities, objectives and methods;
- selection, orientation and training of both local and external personnel in objective repeatable protocols;
- locally based selection of informants and strategic scheduling of interviews;
- recognition of informants' intellectual property rights, with explicit limits on use of information;
- collection of observations, inferences, values and predictions through semi-structured, semi-directed interviews (Ferguson and Messier, 1997; Huntington, 1998; Thorpe, 2000);
- detailed initial analysis and interpretation of interview materials;
- follow-up interviews to correct misunderstood information and fill gaps;
- production of draft summaries for review by informants and the aboriginal community;
- production of final reports and materials for both aboriginal and non-aboriginal groups.

Methodological development is still evolving and no standard prescription is yet available. Over the long term, such a prescription is unlikely because of the diversity inherent between and within aboriginal cultures (Damas, 1968), differing needs that various non-aboriginal forums and institutions may have or perceive, and other factors. Despite current limitations of European and North American copyright laws, gradual evolution of appropriate methodologies will probably be influenced by protection of community-based indigenous knowledge, processes and products recently afforded through international conventions and agreements (Kothari and Anuradha, 1999).

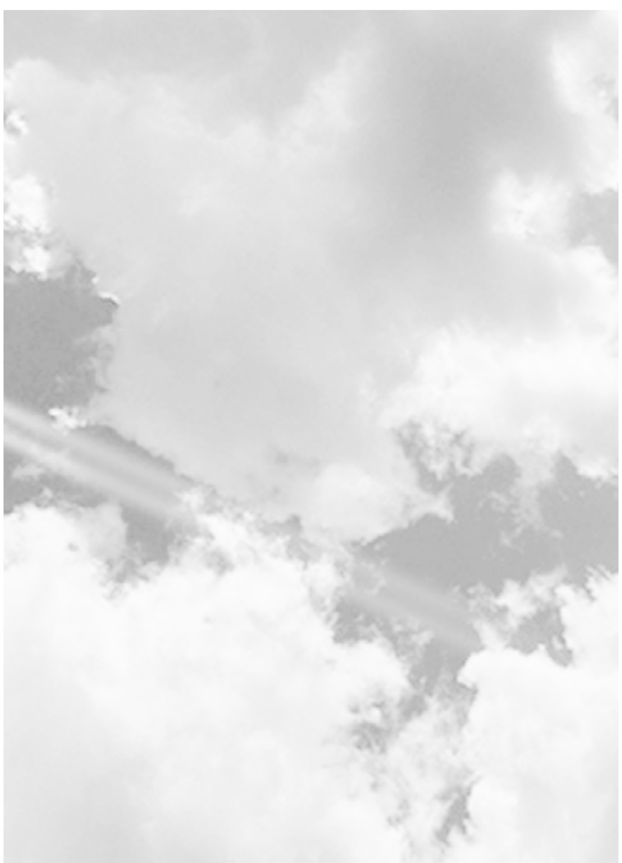
The limits of indigenous knowledge in environmental assessment processes are not currently known, partly due to inadequate cross-cultural understanding. For example, although indigenous knowledge is commonly viewed by scientists as non-quantitative, this misconception ignores the obvious historical need and ability for aboriginal peoples to quantify their resource needs, animal abundance and a multitude of environmental factors (Freeman 1993). Attempts to translate aboriginal quantification for use in Western science have been rare (Ferguson et al., 1998). Perceived limitations in using indigenous knowledge may largely lie in the current difficulty of such cross-cultural translation.

Currently the strength of indigenous knowledge most recognized by non-aboriginal researchers is in its observational accuracy, detail, and geographical and temporal extent (Johnson, 1992; Reid et al., 1992; Freeman, 1993; Ferguson et al., 1998; Thorpe, 2000). A largely unrecognized strength is the capability of indigenous people to monitor a wide array of environmental factors simultaneously, even those not specifically related to the wildlife that hunters might be pursuing (Thorpe, 2000). Inuit on southern Baffin Island are aware of many environmental factors that can cause varying impacts on wildlife from any given human activity (E. Keenainak, pers. comm.).

One difficulty in accepting indigenous inferences and predictions comes partly from differing cultural values (e.g., different views on the acceptability of live animal capture and marking). A second problem originates from an inherent weakness of modern scientific research when it attempts to corroborate indigenous knowledge. Updated by active Inuit hunters, elders synthesize complex interrelationships that occur over time and space at many scales, and then provide advice and predictions about the environment. The massive array and nuances of historical and current information and knowledge synthesized by expert elders cannot yet be duplicated in scientific study. As a result, valid indigenous concepts and predictions may remain uncorroborated by science for many years.

Despite these current cross-cultural limitations, I see a great opportunity for advancement of science and the predictive capability of environmental assessments and wildlife conservation. By working closely on an on-going, progressive basis with aboriginal groups, we could develop complex predictive models and decision-making tools built on the holistic knowledge and ecological concepts of aboriginal peoples. The generalized deductive conceptual models within indigenous knowledge systems could be examined for critical interrelationships and testable predictions (Ferguson and Messier, 2000; Thorpe, 2000). Significant advances have been made in the development of computerized knowledge bases of complex ecological relationships understood within six Asian and African indigenous cultures (Walker and Sinclair, 1998).

Once conceptual ecological models used within indigenous knowledge systems are better understood by Western scientists, reductionist scientific methods could begin to numerically quantify complex ecological factors and relationships to enhance the predictive capacity of indigenous systems, and make it available in Western conservation and environmental assessment and mitigation. Such an effort is currently underway in the development of a comprehensive predictive management and research plan based on historical Inuit knowledge and elder's predictions for the future of the South Baffin caribou population (Ferguson et al., 1998).



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Aboriginal Discourse and Knowledge Concerning Industrial Impacts on the Environment

Tanien (Daniel) Ashini
Innu Nation
Sheshatshiu, Labrador, A0P 1M0

Good morning to everyone, and thank you for attending this conference. I'm certainly looking forward to the presentations and the discussions today and tomorrow. I'd also like to thank the Institute for Environmental Monitoring and Research and the conference organising committee for all the hard work they put into bringing us all here.

I've been asked to make a presentation today on "aboriginal discourse and knowledge concerning industrial impacts on the environment." Well, let me tell you this is a complex issue and there's no easy way to go about it. I'll start by relating a story about the nature of aboriginal knowledge.

In 1978 and 1979, Alex Andrew, George Gregoire and Brenda Sakauye conducted interviews in Sheshatshiu and Utshimassits for an Innu land use and occupancy study. One of the people interviewed was Joachim Nui, a respected Mushuau Innu hunter. Joachim provided detailed information on several different animals.

Joachim described the mating ritual of caribou, that one male will protect 7 to 8 females, and that the people never actually see the caribou mate, so that may take place at night. He understood the concept of delayed implantation in Black Bears (since the foetus is not always found in the spring, after breeding has taken place), and that rabbits breed in April or May, gestate for three months and have 6 to 7 offspring. When asked about porcupines, he replied, "well, one of them probably turns over to breed." Aboriginal knowledge may have a sense of humour, but it should not be treated as a joke.

What is aboriginal knowledge? There are many formal definitions, but to me it is the sum total of what we, as Innu, know and believe in based on our experience and our ancestor's long experience living as hunters living and travelling on the land. It's our world-view, what has enabled us to survive for generations. It based on both spirituality and practicality. It is at the same time a part of our culture and the overarching principles that govern all life on earth – in other words, it defines us as a people yet we are the ones who define it. It is used to understand, explain and enable life. On many levels Innu knowledge and western scientific knowledge have a lot in common, but in many respects the two knowledge systems are completely incompatible.

Whatever definition of aboriginal knowledge you use, I think that most of you would agree that it can be a valuable, and from my perspective vital, part of scientific research or impact assessment. In case there are any nay-sayers out there, I'll go over some of the advantages of aboriginal knowledge.

1. Aboriginal knowledge is based on a long term relationship with the land. Our knowledge extends back for generations. We even have a word for

Woolly Mammoth in our language: Katshitoshk. This long term knowledge is especially helpful in archaeological studies or other historical studies.

2. Aboriginal knowledge is not a snapshot. We don't study a certain animal for only short periods of time then leave when the funding for our study runs out or when winter comes. We are constantly on the land, making observations and reporting them to our friends and family.

3. Many people (there are over 2,000 Innu in Labrador) can make many observations over a wide area. As I just mentioned, these observations are reported to our friends and families through telling stories of our travels and experiences living on our land.

4. The information we have is specific to the area we live in. I'll give an example here: the 1998 EIS of the Voisey's Bay Mine/Mill Project states that the Black Bear's mating season starts in early June, which is based on study done in Michigan. However, our elders know that in Labrador the Black Bear mating season in the Voisey's Bay area starts some time in July – a full month later than was stated in the EIS.

5. Our view of the environment is a holistic one: that everything depends on everything else. This is what most of you would call an ecosystem based approach. We also understand many of the links of our ecosystem. This helps us in identifying impacts that others may not see.

There are also some important differences between Innu Knowledge and scientific knowledge, and if these are ignored then there will be problems in incorporating Innu Knowledge into a scientific study or scientific knowledge into the Innu world.

Innu knowledge has a different baseline than scientific knowledge. In the scientific world, there is the atmosphere, biosphere, lithosphere, hydrosphere and cryosphere, and everything on earth is contained in those five 'spheres.' In Innu knowledge there is also a deep and rich spiritual world, which is as real to us as the chairs you are sitting on are real to you.

The different spirits can support us just as your chair is supporting you. If we are careless with the way we treat the animals, then the spirits will let us down, just as your chair will let you down if you are careless and tip too far back on your chair. To my knowledge, there is no way of incorporating the Innu spiritual world into the scientific way of thinking.

I'll give you a further example of this. There are people living deep within Nutshimit, or the country, called Kakemashesheut, or "the sneaky ones". Kakemashesheut usually only reveal themselves in foggy conditions or during the night. They are often feared, as they have been known to kidnap sleeping children from tents. Whenever we have to make a decision regarding industrial developments, we have to consider Kakemashesheuts as well – how would they react to having a mine on their land? How are they affected by military flight training? And how will they relate to us if we make the wrong decision on their behalf? Will they retaliate or will they abandon us?

With the assimilation we have already undergone, we ourselves have trouble communicating with Kakemashesheuts, or spirits such as Kanapinikasiueu, the caribou spirit. The shaking tent ceremony, our principle means of communicating with the animal spirits, has not been performed in decades. When scientists say that industrial developments, such as military flight training, a hydro project or a mine, have no impact, or that all the impacts can be mitigated, we get extremely frustrated because we know that while they have conducted certain tests, they have not studied the effects on Kakemashesheuts or Kanapinikasiueu. They have not done this because they are not capable of doing it. Even worse, we have been the victims of ridicule and racism for standing up for our beliefs in public. This was most certainly the case when Pien Penashue, one of our most respected elders, was not allowed to testify in court on the impacts of military low-level flight training on the environment because the judge decided that he was not an expert. Pien left the court that day shaken and disillusioned with Akeneshau world.

So, I guess when the question what does aboriginal knowledge have to say about industrial impacts on the environment is asked, I would have to answer that we have to be accountable to many things. We have to look at ecological impacts as well as impacts on individual plants and animals. We have to consider our long history as well as our future. We have to look at physical impacts as well as spiritual impacts. We have to consider the words of our elders very carefully, such as those of Edward Piwas in talking about the impacts of a proposed mine at Voisey's Bay (often called Emish by the Innu):

"There will be no fish, caribou, ducks, geese at Emish after the mining starts. The bear is different. The bear is like the white man, but he can't live with them in the winter. He will walk around in the Emish camp. He will eat at the white man's table because the Akeneshau has killed the fish in the river. The white people will keep the baby animals for pets and these animals will starve – they will not know how to hunt for themselves. Take for example the goose that was seen at Black Ash. It was lost and didn't know its migration route. Even the moose – he is the brother of the Akeneshau. He will walk down the streets of Emish with a tie. The Akeneshau has three friends – bear, moose and raven, but he can't be friends with squirrel because it steals from them. The smog from the milling plant will kill the plants and animals. And it will float into our community. We will not see the smog – it will slowly kill the animals and us. They will probably not drill in one place – they will drill all around us. The wildlife officer will know when he can't find any animals. He will blame us for the lack of them but he will not think about the drilling."

Edward identifies many impacts in his words. He talks of changing communities and changing behaviour. He talks of visible and hidden pathways. He speaks from an ecosystem based perspective. He talks of creeping, long term impacts when he says that smog will slowly kill the animals and the Innu – impacts that may be missed in a scientific study. When I heard these words, they really struck a chord with me. It's depressing to think about, but I think that the slow death of a pristine environment and our relationship with it is the most important impact that Innu knowledge can identify and bring to the forefront of our discussion.

If we are denied access to our land by roads, recreational ski-doo trails, flooding, mines, sport hunting and fishing camps or military training activities, then we will slowly but surely loose our relationship with the land, our culture and our knowledge. If we are lured by Ministers and CEOs into trading our way of life for jobs and economic development, much like the way priests and government officials lured us into communities in the late 1960s, then we will not have time to live in the country and pass our knowledge on to our grandchildren. We will loose our knowledge and our culture.

Some will call this assimilation; others will call it cultural genocide. In my mind, if we allow this to happen, it is the biggest, most certain and by far the most disturbing impact industrial developments can have on our land.

Tshinishkamitun.

Defining Auditory Thresholds for Animal Species

Larry Pater, Ph.D
US Army Construction Engineering Research Laboratories
P.O. Box 9005
Champaign, Illinois, 61826, USA

Insufficient information about noise impact on an animal species may result in conservative rulings by regulatory agencies or the courts. Such rulings can affect commerce, military readiness, recreational activity, and the public attitude toward the protected species. An informed decision based on adequate data may minimize restrictions on activities while preserving wildlife and domestic animal resources.

The study of noise impacts on animals requires expertise in both biology and acoustics. A study that uses impeccable procedures and metrics in one discipline, but is inadequate in the other, yields conclusions that may be misleading or incorrect and which cannot be extrapolated to other locations or even to the same location under different noise conditions. Anecdotal information can result in interpretations or conclusions that conflict with the findings of controlled thorough studies.

Acoustics is the science of sound, including its production, transmission and effects. Noise is usually defined as unwanted sound. Pierce (1989), Harris (1991) and Crocker (1998) are a few of many references that present detailed information on the fundamentals of acoustics. The American National Standards Institute (ANSI) in the United States, and the International Standards Organization (ISO) worldwide, standardize acoustical terminology and methodology. The International Bibliography On Noise (IBON) is a bibliography of publications on noise effects on humans, animals and structures.

A noise metric, a parameter used to characterize and quantify a noise event, is chosen to measure noise dose in a way that correlates with subject response. Response to noise can depend on noise level, duration, number of events, frequency distribution of noise energy, variation in level with time, rate of onset, presence of pure tones, and existence and level of background noise. Appropriate noise metrics and frequency weighting are essential to adequately quantify noise impact for each type of noise. Measurement of some metrics requires specialized instrumentation.

For more-or-less steady noise such as traffic on a busy road or ambient outdoor noise, a measure of average noise level is appropriate. One such metric is sound pressure level, which is a measure of root-mean-square sound pressure (ANSI S1.1, 1994). Low-pass filters are often used to smooth out the instantaneous fluctuations so that the meter is easier to read, and their use should always be reported as part of the sound measurement. A similar metric, available on modern microprocessor-based digital instruments, is the time-average equivalent sound level, sometimes abbreviated as LEQ.

For more complex variable or transient noise events, a simple measure of average sound level is not adequate because the choice of measurement period affects the reading. A metric that is used to characterize very brief transient events such as blast noise from guns, explosions and mechanical impacts is the sound exposure level (SEL), which is defined as the time integral of the square of the acoustic pressure. This metric is generally (though sometimes incorrectly) taken to be indicative of the total acoustic energy of the event. For transient noise events of a few to several seconds duration, a popular method is to divide the event duration into short time increments, measure the metric during each increment, and report the maximum value that occurs in any increment. For this purpose, time is often divided into _- or one-second increments. For aircraft and helicopter flyby noise, two metrics are typically used; SEL and the maximum _-second equivalent average (LEQ) level, since both are good candidates for correlation with response. Measurement of these metrics requires sophisticated instrumentation.

An adequate characterization of a noise stimulus often also requires a spectrum or spectrogram to show how the magnitude of a noise metric varies with frequency (pitch). A closely related concept is frequency weighting, which discriminates against sound which, while easily measured by microphones and electronic instrumentation, is not heard by the study subjects. This is accomplished by means of frequency-dependent attenuation which mimics the hearing sensitivity and range of the study subjects. An example is the familiar "A" weighting, which filters noise energy according to human hearing range and sensitivity at ordinary noise levels. An audiogram describes hearing range and sensitivity. Weighting systems developed for humans, such as "A" weighting, will in general not be appropriate for other animal species that have significantly different audiograms. It will be useful to obtain the audiogram for the study species and use it to derive an appropriate weighting function or to guide interpretation of noise response data.

Sound levels vary with distance from a sound source due to several factors, including distance, atmospheric attenuation, terrain, ground cover, wind and weather. These factors can combine to yield larger or smaller changes in sound level with distance. The received sound level can vary widely, sometimes by as much as 50 dB, for a given receiver location and a given source. This means that in general each noise stimulus event must be measured during response observations. Noise measurements should be taken in the same habitat, at the same height above the ground, and preferably in the same individual location, as occupied by wildlife impacted by the noises. Noise models exist that can help define noise exposure for a population. Parameters of interest include the number of animals exposed and the noise exposure type, level, time frame and number of repetitions.

Selection of impact criteria is a critical issue. Criteria for noise impact on humans include annoyance, sleep disturbance, and hearing damage. For domesticated species the issue may be damage to individual animals or impacts on production and profits. For threatened and endangered wildlife the primary issue is survival of the species. In this case the challenge is to determine or infer long-term impacts on the total population in a relatively short-term study.

Response to noise can be characterized in terms of proximate effects, that is the direct and immediate response of the animal to the noise stimulus. A proximate effect could be a behavioral (e.g. flight) or a physiological (e.g. change in heart rate) response. A dose-response relation between stimulus severity and response level will typically not be obtained for the entire range of potential interest, since extremely high experimental noise levels are not permitted in practice for either humans or endangered species. Threshold for response can usually be obtained and will provide a delineation of the variation of response with noise level over the range of practical interest. Or, in the event that no proximate responses are obtained at typical training noise levels, a useful result will be the noise level below which no responses occurred.

Distance is often a useful surrogate for noise levels, but distance measurements are specific to a particular noise stimulus situation, whereas noise levels in units of decibels are more universally applicable.

It is important to consider whether an animal is responding to noise or to some other aspect of a potentially disturbing activity. Establishment of a dose-response model should also include consideration of habituation, that is, reduced severity of response as the animal becomes accustomed to the noise. Temporal factors are also a consideration for evaluating response, for example the season of the year or the time of day. Similarly, animal activity and location will also affect response to noise. Individual characteristics and temperament such as age, sex, breeding status and last feeding can also influence response. One important variable to consider is whether the noise source is an actual noise event or a simulation. Simulated noise sources are limited in their ability to explain animal responses to the actual disturbance events due to differences in the visual (e.g. aircraft simulated noise over a loudspeaker versus the real overflight event), spectral content, and temporal aspects (e.g. suddenness of onset). Experience with humans has shown that the dose-response relation is different for each type of noise. It is reasonable to expect that each animal species may respond differently. Thus the dose-response model may be different for each combination of noise type and animal species.The ultimate level of effect is often whether the stimulus causes significant changes in the number of individuals in the population. The connection between proximate effects and population effects can be made by means of an intermediate level of effect, which is typically evaluated in terms of mortality or reproductive success as a function of stimulus level. As a specific example, consider that a bird might flush from a nest (a proximate response) as a result of noise. It is possible that this could lead to failure of the nest, especially if it occurred repeatedly. Monitoring is required to determine reproductive success of disturbed and of undisturbed nests. A population model is required to determine if failure of some percentage of nests has impact on survival of the population.

Ideally, noise impact studies will result in information that delineates responses with sufficient detail and reliability to effectively guide development of management protocols for the species and/or the noisy activity. For example, Delaney et al. (1999) reported no significant impact of helicopter overflights on Mexican spotted owl proximate response or reproductive success when the helicopters did not approach closer than 105 meters. Grubb et al. (1998) reported distance and noise level measurements that did not evoke any response of northern goshawks to logging trucks. Pater et al. (1999) and Delaney et al. (2000) reported data that defined the effects of types of military noise on the proximate response (flush probability, return time, etc.) and reproductive success of the red-cockaded woodpecker (RCW). These data showed that while sufficiently high noise levels evoked a flush response, the birds quickly returned to the nest, and even rather severe noise exposure did not result in a statistically significant impact on reproductive success. Such data provide the scientific data that is needed to effectively and objectively assess impacts, guide the evaluation of management options, and develop mitigation procedures.

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Department of National Defence Noise Prediction/Propagation Model

Neil Standen
Urban Aerodynamics Limited
3266 Kodiak Street
Ottawa, ON, K1V 7S8

I owe a deep debt of gratitude to Lex Brown, Ann Bowles, and Larry Pater for their previous talks on this subject because they have set the stage very well for what I want to present. Lex and Ann both outlined the requirements, from their perspective and expertise, to examine the effects of noise on animals. Ann and Larry both dealt in great detail on the nature of sound and the composition of sound.

I think of noise and its impact as an equation. On one side of the equation is the noise level and the physical characteristics of noise. On the other side of the equation is the effect of noise on the receiver, whether the receiver is a human being or wildlife. Most of you are experts in the area of animal response to various impacts or stimuli. My side of the equation is the noise side. I would like to present to you this afternoon the work we have been doing on behalf of Department of National Defence (DND).

DND has a mandate to mitigate noise impacts in the military training area in Labrador. In order to mitigate noise effects, it is necessary to know the level of the noise being experienced as well as how much noise can be tolerated by the receiver. Mitigation is simply the difference between the two. To know how much noise is being created in the Military Training Area, there are two options. One is to measure noise throughout the entire training area, which comprises a very large territory heavily covered in terms of flight tracks but not necessarily in terms of numbers of aircraft. An incredible amount of equipment would be required to undertake noise measurements and noise monitoring over this area, and a large amount of time would be needed to analyze the noise data coming from the monitoring equipment. I have conservatively classified this approach as highly impractical. I think it would be only a small exaggeration to say that it would be impossible to accomplish. Therefore, the only way practical way to determine the noise levels that are impacting from the flight-training program is by calculation, and this requires a noise model. Over the past several years we have been developing such a noise model for use by DND in order to account for sound propagation from aircraft flight tracks in the training area. I would like to explain the details of this model in terms of what it is capable of doing and how it performs this.

Labrador Military Training Area Low-level Flying Noise Propagation Model

Purpose

- Mitigation of Noise Effects requires that Noise Levels caused by aircraft operations be known anywhere in the training area.
- Measurement of Noise Levels throughout training area is highly impractical.
- Noise Levels can be obtained by calculation using adequate Noise Propagation Models.
- A Noise Model for the Military Training Area has been developed, based on current knowledge about the physics of sound propagation, and terrain conditions in the MTA.

Basics of Model

- General Expression of Noise Algorithm is:

  Lr = Ls + Ad + Aa + Ac

  where

  Lr = Noise level at Receiver

  Ls = Noise level of Aircraft at Reference Distance

  Ad = Attenuation due to Separation Distance

  Aa = Attenuation due to Atmospheric Absorption

  Ac = Attenuation due to:
    - Ray interference
    - Terrain Barrier Effects
    - Upward Refraction Shadow Effects

- The model identifies the aircraft position (from flight track data supplied by user) relative to receiver location (any point on the ground identified by the user).
- The model then computes the relevant attenuation parameters, according to the following logic Flow Chart.

Model Structure and Data Requirements

In general, any model determines the noise at a particular receiver location based on the noise that is generated by the source itself and the attenuation of that noise over distance as it propagates from the source (in this case, an aircraft) to the receiver. The attenuation includes the atmospheric absorption of sound energy as it propagates across this distance, and additional attenuation that may be due to phenomena such as interference between sound waves from different pathways, terrain barrier effects, and refraction due to wind and atmospheric temperature effects.

Our model identifies the aircraft position either from flight track data supplied by the flight crew for impact assessment after the flight has occurred, or from planned flight tracks for avoidance planning. Avoidance planning means choosing a flight track that will reduce the noise level at a receiver location to an acceptable level. These flight tracks would normally be defined in the vicinity of a particular receiver location that may be of interest for noise impact assessment, such as a bird's nest or a wildlife concentration. The model then calculates the relevant attenuation parameters for each of the attenuation factors mentioned above, following a logic flow chart (Appendix 1). The flow chart indicates some of the complexity in the decision making process within the model required to determine what kind of conditions exist along the sound propagation path, and therefore the noise level at the receiver.

To operate the model, the user must supply certain data. Initially and fundamentally, the data that is required is the aircraft type, the flight track, the speed and the altitude of the aircraft. The model contains or will contain noise data for several different types of military aircraft: the CF-18, the Tornado and the F-16 in particular being the aircraft that are operating at Goose Bay. Of course, the user also must identify the receiver location, such as a wildlife site or a human habitation site, which is of interest for the noise impact assessment.

The user also has to specify atmospheric data because the model takes into account the effect of the atmosphere on sound propagation. The required atmospheric data include the vertical wind speed gradient and direction, the vertical temperature gradient and the humidity. The wind and temperature gradients are defined by specifying the wind speed and temperature at a certain altitude above the ground (typically 500 feet) and at ground level. These conditions are usually not known at any arbitrary location in the training range. Therefore, estimates have to be made of these parameters, either based on typical conditions for the time of year, or measurements taken at some other point on the training range and extrapolated from that point to the receiver location. Obviously, the less that is known about these parameters the less accurate will be the calculation provided by the model.

Finally, the terrain description has to be provided in terms of the elevation above sea level at grid points covering the training range, and the type of ground cover at each point. The terrain data along the aircraft track and lateral to the track for a certain distance is extracted by the model as a data subset. The terrain database is referred to as a Digital Terrain Elevation Database (DTED) file and is obtained from satellite imagery.

Data Required from User

- Aircraft Type, Flight Track, Speed and Altitude
- Receiver Location
- Atmospheric Data (Wind speed and Temperature at 500ft. altitude and at ground level, Wind Direction, humidity)
- Terrain Description (DTED file providing elevations at grid points, slopes of terrain)

Examples of Terrain and Atmospheric Effects on Propagation

The simplest case of noise propagation is flat terrain and no wind or temperature gradients. The receiver is located on the ground at some distance lateral to the flight path. Since there is no wind and no temperature gradient, the sound waves propagate along straight lines (Figure 1). There is one direct ray path traveling in a straight line from the aircraft to the receiver and another ray path that leaves the aircraft at the same time and travels to a point on the ground and then reflects back up to the receiver. There is a slight difference in the travel time between these two rays because the reflected ray has traveled a longer distance. The combination of the two rays at the receiver produces a different sound level at the receiver than would be obtained by the single, direct ray alone. This is due to the slight difference in travel times at the receiver plus the effects of the reflection

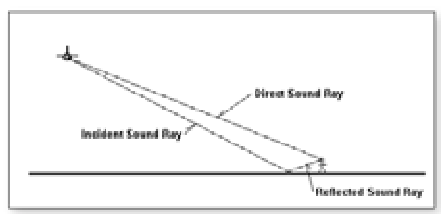


Figure 1: *Flat Terrain and No Atmospheric Effects*

off the ground, both of which produce a phase shift between the direct ray and the reflected ray. The reflection at the ground can either augment the sound that the receiver hears or can reduce the sound level, depending on the frequency content of the sound and the acoustic properties of the ground. These properties of the ground surface determine how much sound energy is absorbed by the ground and how the phase changes in the reflected ray. Generally, for low frequency sound there tends to be an augmentation at the receiver. For higher frequency sound, there is a reduction in sound level at the receiver. The effect of the reflection is that the spectrum of the noise at the receiver is different from the noise spectrum at the aircraft.

In addition, of course, there is reduction of the overall energy level at all frequencies because of the sound energy spreading out over distance and because of the atmospheric absorption that takes place over that distance.

The second propagation condition has a low hill located between the receiver and the aircraft, but still with no atmospheric effects considered. The hill is low enough that the direct ray passes over the top of that hill and still reaches the receiver (Figure 2). However, the reflected ray is now interrupted by the hill and does not reach the receiver, and as a consequence the receiver hears only the sound level from the direct ray. In this case, since there is no reflection to affect the noise spectrum, there is a different sound at the receiver than there would have been in the absence of the hill.

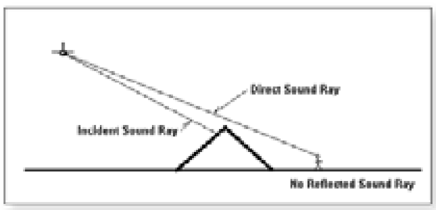


Figure 2: *Low Hill between Aircraft and Receiver; No Atmospheric Effects*

If the hill is higher, but still below the altitude of the aircraft, the line of sight from the aircraft to the receiver is now broken by the hill (Figure 3). The direct ray propagating from the aircraft to the receiver will be attenuated in much the same way as road traffic noise from a highway is attenuated by a noise barrier along the side of a highway.

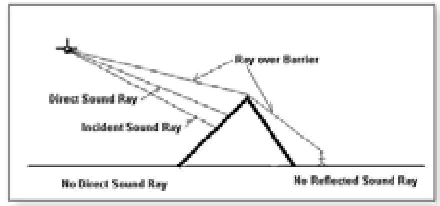


Figure 3: *Hill interrupting line of sight from aircraft to receiver: Barrier Effect*

Note that the receiver is still the same distance lateral to the aircraft flight path, and the aircraft is at the same altitude as in the previous cases. Both the direct ray and the reflected ray are now blocked by the hill. The receiver would now hear an even lower sound level because of the barrier attenuation effect.

The attenuation produced by the barrier effect depends on the height of the hill. If the hill is higher than the aircraft, so that the aircraft is essentially flying in a valley, the noise propagation distance from the aircraft to the top of the hill and then down to the receiver is much larger (Figure 4). The longer that path and the sharper the angle through which sound wave has to bend in order to get to the receiver as it passes over the barrier, the lower will be the sound level at the receiver. Even though the receiver is the same distance from the aircraft in all of these figures, the sound spectrum and level at the receiver depend significantly on the terrain features between it and the aircraft.

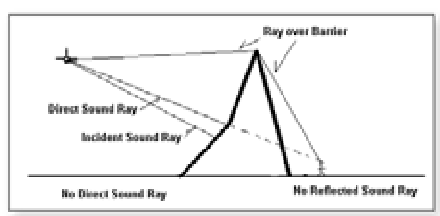


Figure 4: *Aircraft Altitude below Hilltop: Increased Barrier Effect*

The noise levels at the receiver were calculated by the model for the four examples just illustrated. Recall that in these cases there are no wind or temperature gradients. The calculation results are shown in Figure 5 in terms of the overall noise levels, represented by the sound exposure level (SEL) and the energy average level (LEQ). These are only two of the noise parameters available from the model. The data in the model are expressed in terms of the frequency components of the aircraft noise. Therefore, several other noise parameters involving spectral content are also available from this model. Thus, if it is determined that spectral information about the noise is necessary to assess impact on wildlife, then that spectral information is available from the program.

Figure 5 shows that the calculated SEL with flat terrain is about 105dB. The equivalent sound level (LEQ) is about 94dB. The second case (Figure 2) is represented by a hill that is 200 feet below the aircraft. In this case, the sound has been reduced somewhat because the reflected ray has been blocked by the hill. The attenuation relative to the flat terrain is not very large – only a matter of 2 or 3dB. A hill that is only 80 feet below the aircraft altitude blocks the line of sight from the aircraft to the receiver, as in the third case (Figure 3). Now the noise levels behind the hill are considerably reduced compared to the flat terrain; the SEL is now at about 91dB compared to 105dB. For a hill that is 100 feet above the aircraft altitude, (the aircraft is now flying in a valley, as in Figure 4), there is a significant reduction in the noise. The SEL is now 81dB as compared to 105dB.

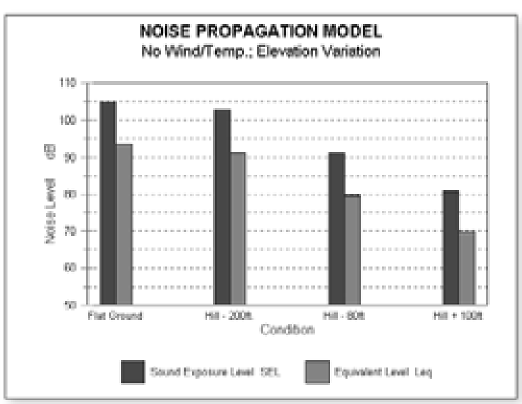


Figure 5: *Noise Propagation Model*

The effect of wind gradients and temperature gradients can now be examined. Both wind and temperature can affect the propagation path of the sound wave by refraction.

It is probably easier to visualize wind effects. If the wind direction is such that there is a component blowing from the aircraft towards the receiver, then as the sound waves propagate outwards from the aircraft in the direction of the receiver, the wind component in this direction will add to the sound speed. Because the wind at altitude is faster than the wind at ground level, the sound rays that are at higher altitudes will travel faster than the sound waves at ground level. The rays will therefore be refracted downwards. Consequently, if there is a hill located between the aircraft and the receiver, but there is wind blowing in the direction from the aircraft toward the receiver, the sound rays may curve over the top of the hill without being blocked by the hill. Since the direct path is no longer interrupted by the hill, there is no additional barrier attenuation provided by the hill (Figure 6).

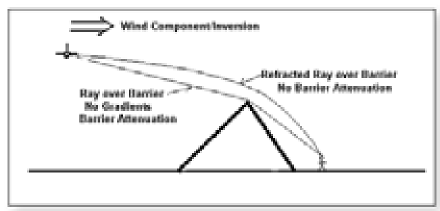


Figure 6: *Noise Propagation Path over a Hill with Downward Refracting Wind and/or Temperature Gradients*

If the wind is blowing in the opposite direction - from the receiver towards the aircraft - then the opposite effect occurs. Now instead of being refracted downward by the wind, rays are refracted upward (Figure 7). Rays that propagate downward from the aircraft become flatter, approaching parallel with the ground. Where these rays intersect the ground, they are still reflected upward. However, there is one particular ray that is parallel (tangent) to the ground at the reflection point, appropriately termed the tangent ray. All rays propagating from the aircraft below this tangent ray have a reflection point on the ground.

All rays propagating from the aircraft above the tangent ray never touch the ground. If a receiver is located closer to the aircraft than the ground intersection point of the tangent ray, the noise heard will be a combination of the direct and reflected rays, as with downward refraction. However, if a receiver is located farther from the aircraft than the tangent ray ground intersection, and is below the tangent ray, the noise level will be greatly reduced, and will be due essentially to sound-scattering phenomena. Such a receiver is said to be in the shadow zone. The noise attenuation in the shadow zone depends on the location of the receiver in that zone. Close to the point of contact of the tangent ray, the attenuation is relatively small. The attenuation increases very rapidly as distance into the shadow zone increases.

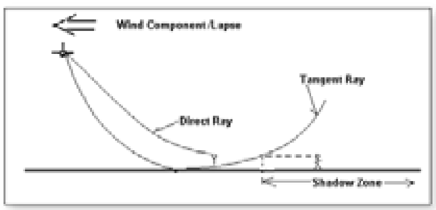


Figure 7: *Upwind Propagation and Shadow Zone*

The model was used to calculate the same noise indices (SEL and LEQ) but now including wind effects. Figure 8 compares the effect on noise levels due to a downward refraction over an intervening hill. The comparisons are with noise levels with no wind or temperature effects, first for a hill which is 80 feet lower than the aircraft altitude (illustrated in Figure 3) and second for a hill which is 200 feet lower than the aircraft (as in Figure 2). For these cases, Figure 5 indicated 92dB SEL and 80dB LEQ at the receiver beyond the higher hill (80 feet below the aircraft), and 103dB SEL and 91dB LEQ beyond the lower hill (200 feet below the aircraft). With downward refraction caused by the wind blowing from the aircraft to the receiver, Figure 8 shows the SEL is about 103dB and the LEQ about 91dB at the receiver. The wind blowing over a hill that is 80 feet below the aircraft results in the same noise level at the receiver on the other side of the hill as if the hill were 200 feet below the aircraft without any wind. The wind reduces the noise barrier effect of the hill by the equivalent of reducing its elevation by 120 feet. Wind effects can have a very strong and a very powerful effect on the noise levels that actually occur at a receiver site. In fact, they can be equivalent to a very significant change in terrain.

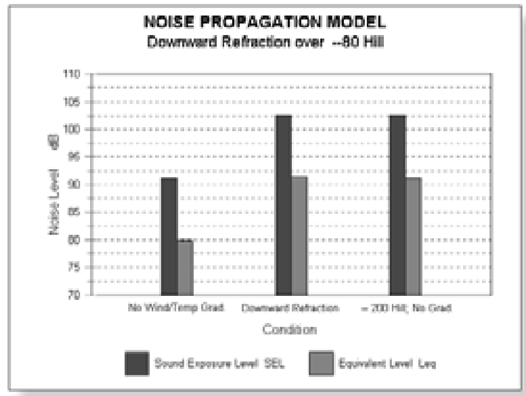


Figure 8: *Noise Levels behind a Hill with Downward Refraction compared to No Refraction*

Figure 9 shows the model calculation results for upward refraction. Again, the comparison is with a case with no wind or temperature effects. The comparison is for flat terrain (Figure 1) where the SEL is 105dB and the LEQ is 93dB (from Figure 5). If the receiver is located before (in front of) the shadow zone there is a decrease of about 1 to 2dB in both noise indices, a very small change due to the curvature of the rays at the ground reflection point. Just down-stream from the shadow zone there is a decrease of about 2-3dB in these indices. As the distance into the shadow increases, the decrease in noise level becomes very much larger.

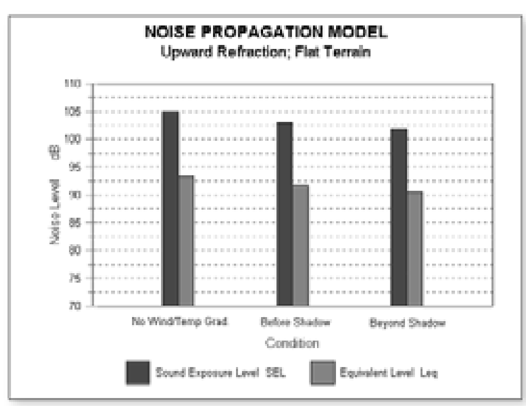


Figure 9: *Effect of Upward Refraction with Flat Terrain*

These model calculations currently provide only numerical values and numerical results. One of the model development efforts now is aimed at converting this numerical information into a visualization of the noise field around a defined aircraft flight track. Such a visualization would show the terrain in sequential cross sections about the aircraft flight track, depicting the noise level graphically as an overlay on the terrain. There are a number of ways currently being considered to accomplish this. The noise index to be displayed in this visualization could be any of the indices available from the model, including the SEL, LEQ, instantaneous peak noise level, or a similar index value for any of the frequency components of the noise spectrum. Figure 10 illustrates a conceptual visualization at one cross section.

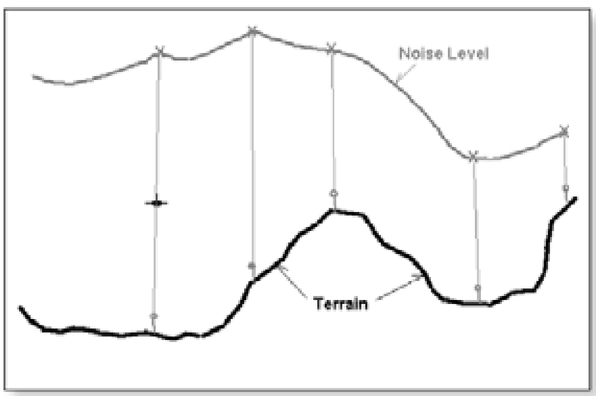
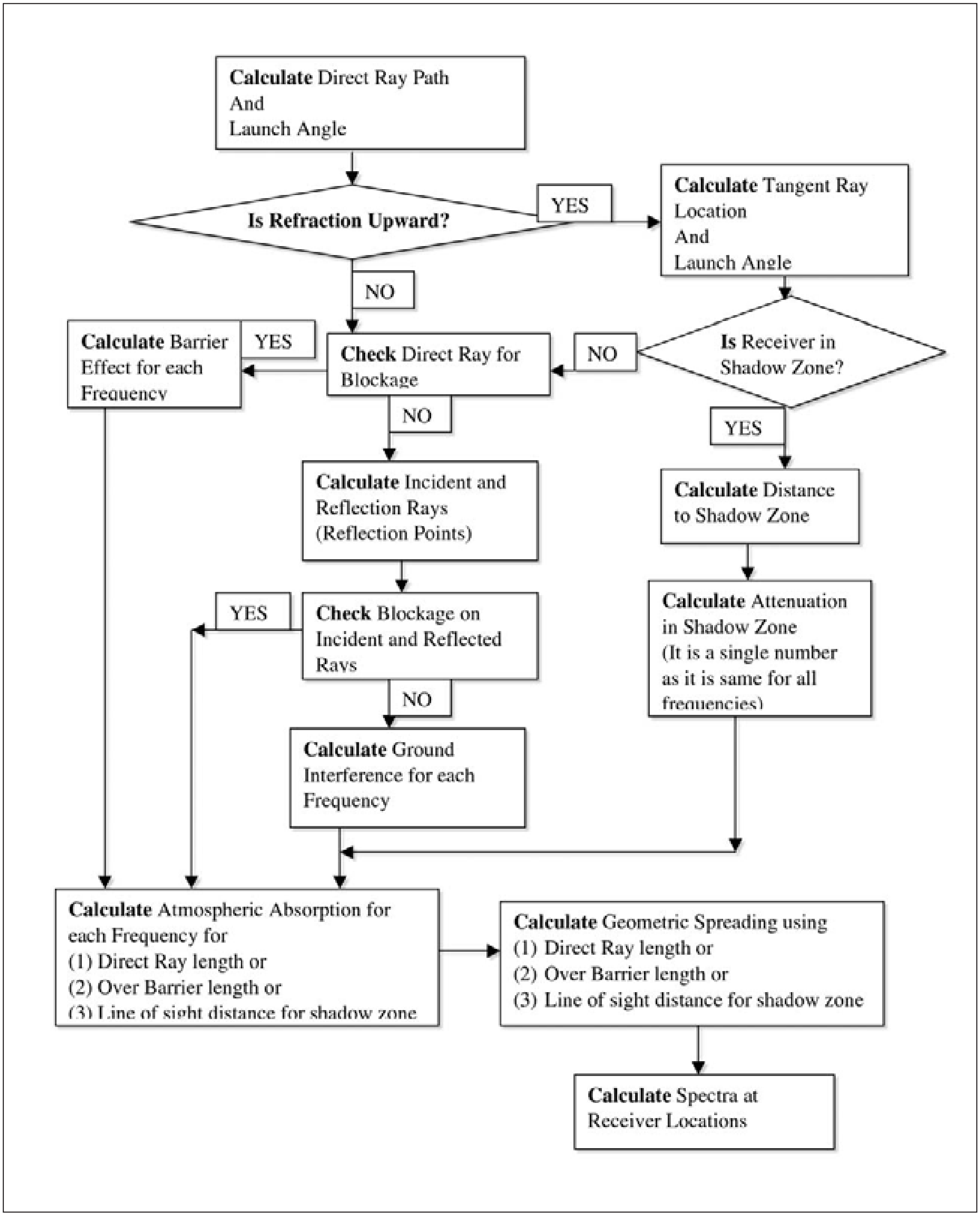


Figure 10: *Conceptual Display of Noise at Various Receiver Locations about Flight Track*

The model is now being programmed into an operational version. It has been functioning as a prototype for some time. We have compared the output of the program against measured data from the Goose Bay range. Those results were presented at several previous conferences: InterNoise 98, ICBEN 98, and the ASA/EAA/DEGA meeting in Berlin (March, 1999). The comparison between the noise calculated by the program and the noise measured by the sound level meters and monitors is satisfactory for the model at its current stage of development. It is now important to develop a rapid presentation technique that provides the maximum amount of information in a very perceptible way.

Appendix 1

Sequence of Calculations for Sound Rays



Responses of Peregrine Falcons to Military Jet Aircraft

Stephen M. Murphy
ABR, Inc.—Environmental Research & Services,
P.O. Box 80410, Fairbanks, AK, 99708–0410, USA

Robert J. Ritchie
ABR, Inc.

Angela G. Palmer
Oregon Cooperative Fish and Wildlife Research Unit
Oregon State University (OSU), Corvallis, OR, 97331–3803, USA/ ABR, Inc.

Dana L. Nordmeyer
OSU

Daniel D. Roby
OSU

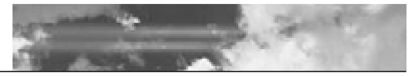
Michael D. Smith
ABR, Inc.

We conducted a 3-year (1995–1997) investigation of the effects of low-level military training exercises on behavioral reactions, nest attendance, time-activity budgets, provisioning rates, and productivity of nesting Peregrine Falcons (Falco peregrinus anatum) in east-central Alaska. Each year, we monitored instantaneous behavioral reactions to disturbance at 12 nests; nest attendance, time-activity budgets, and provisioning rates at 10–11 nests; and productivity at 58–102 nests. Noise levels and frequency of overflights were monitored with Animal Noise Monitors (ANMs), which are compact and programmable, all-weather instruments that record a series of sound parameters generated by intruding noise sources. We deployed ANMs at 33–39 nests each year and recorded a 3-year total of 2,212 jet aircraft overflights during ~135,000 h of monitoring. Annual exposure levels during nesting and brood-rearing at individual nests ranged from 0 to 392 overflights.

Behavioral Responses—Adult Peregrine Falcons exhibited little or no overt behavioral reactions to the majority (78%) of close (£1000 m slant distance from the aerie) military overflights (n = 191). Only 5.5% of the reactions to jets were classified as intense (i.e., stand, crouch/cower, flight intention movement, or flight). When compared with other potential disturbances, reactions to military jets and other mechanized stimuli were substantially less intense than were reactions to other raptors and mammals, including humans. Parental Care—Nest attendance and time-activity budgets of Peregrine Falcons differed significantly between eference nests (i.e., nests that received less than 7 noise events/ season) and overflown nests during periods with overflights. Differences depended on stage of the nesting cycle and gender. During the incubation/brooding stages of the nesting cycle, males attended the nest ledge less when overflights occurred than did males from

reference nests. Females apparently compensated for low male ledge attendance by attending the ledge more during overflown periods compared to females from reference nests. While females were still brooding nestlings, they were less likely to be absent from the nest area during periods with overflights than were females at reference nests. During late-nestling stage, however, females perched in the nest area less during periods when overflights occurred than did females at reference nests. Although nest attendance and time-activity budgets differed between overflown and reference nests, periods with and without overflights at the same nests did not differ. For all nests combined, we did not detect relationships between nest attendance and 1) the number of overflights within a given time period, 2) the cumulative number of above-threshold noise events at each nest, or 3) the average sound exposure level of overflights. Furthermore, nestling provisioning rates were not affected by overflights.

Productivity—We used number of overflights, event duration, and several A-weighted acoustical metrics to test whether noise exposure affected nesting success or productivity. We also used the ANM data to classify different regions of our study area as low, moderate, or high exposure. Failed nests generally were exposed to greater aircraft disturbance than were successful nests, although few of the statistical comparisons of exposure levels between failed and successful nests were significant. When the fate of all nests in the study area was evaluated by disturbance categories, there again was a nonsignificant trend for areas with high disturbance to have higher rates of nest failure; this trend was most pronounced in the off-river sites (i.e., sites away from major drainages). Models evaluating the effects of noise on productivity were not significant, although the off-river nests produced slightly fewer young than did nests on the Tanana River (a major drainage). Because the off-river population is expanding, whereas the population on the Tanana River is established and stable, these results suggest that pairs that are prospecting for new nesting territories are most vulnerable to disturbance. Off-river sites also may be less optimal for nesting (e.g., more storms and less food), and disturbance effects may be more pronounced for pairs that are subjected to harsher environmental conditions. Still, productivity of the off-river population equaled or exceeded other monitoring areas in Alaska that do not have jet aircraft activity.



Summary of Osprey Research Relating to the Low-Level Flying Program in Labrador and Quebec

Perry G. Trimper
Jacques Whitford Environment Limited
Box 274, Station C
Happy Valley-Goose Bay, Labrador, A0P 1C0

Peter Thomas
Environment Canada
6 Bruce Street, Donovans Industrial Park
Mount Pearl, Newfoundland, A1N 4T3

For the last ten years (1991-1998), the Department of National Defence (DND) has conducted a large scale monitoring program for raptor populations within the Military Training Area (MTA) of Labrador and northeastern Québec. These surveys have examined the nesting activity of gyrfalcon, peregrine falcon, golden eagle, bald eagle and osprey in support of DND's environmental mitigation program (DND, 1994). Active nest sites of these species were avoided by low-level flying (LLF) activities through the assignment of exclusion zones. Osprey is the most common of these raptors, although the area represents the northeastern range for this circumpolar species (Godfrey, 1986). With the reconfiguration of the MTA away from the productive cliff-nesting raptor habitat near the Labrador Coast in 1996, the MTA comprised a greater percentage of forested habitat. The relative abundance of known osprey nests program increased to the point where the number of exclusion zones began to seriously interfere with the effectiveness of the training. For example, the 1996 program identified 208 active and occupied territories of Osprey in the 150,000 km2 study area (JWEL, 1998).

DND's environmental mitigation program is designed to reduce potential effects military low-level flying (LLF) conducted from 5 Wing Goose Bay. Researchers have reported severe effects from sporadic human activity during critical periods after the initiation of nesting by osprey (Swenson, 1979; Vana-Miller, 1987). This species typically nests at the top of dominant conifers in the study area and exhibits aggressive behaviour towards intruders (Trimper et al., 1998a). In the early 1990's, DND's mitigation strategy to avoid nesting osprey involved placing a 2.5 nm radius exclusion zone to LLF activities around active nests. The selection of the 2.5 nm distance was arbitrarily proposed by DND and exceeded the maximum buffer (1,500 m) recommended for this species (Richardson and Miller, 1997). As the monitoring program evolved, a variety of techniques were utilized to determine the effect (if any) of LLF activity on the behaviour or reproductive success of osprey within the MTA. It should be noted that throughout this decade of research, a guiding principle was to limit potential hazards to Osprey. With the completion of each investigation, researchers progressively reduced protection to the species. This paper describes the results of these initiatives and the status of the ongoing, long-term monitoring program.

Nest Exclusion Zone Establishment and Reproductive Success Monitoring, 1991-1996

On behalf of the Goose Bay Office (GBO) of DND, Jacques Whitford Environment Limited (JWEL) completed aerial surveys annually during late May to early July to identify active and occupied (Van Daele and Van Daele, 1982) Osprey nests in the MTA. As indicated above, these sites were excluded from LLF by 2.5 nm zones. With increasing survey effort, knowledge of the study area and habitat associations; the number of known and available (i.e. not collapsed) nest sites increased dramatically each year.

Starting in 1994, several nests were revisited in mid- to late-August to determine reproductive success and output. Control areas were also examined during this period (1994-1996) with no significant difference detected.

Preliminary Removal of Nest Exclusion Zones, 1994

Due to increased restrictions to LLF in 1994, exclusion zones around five nests were removed but monitored carefully (i.e. bi-weekly) against five nests with protection. This first trial removal of exclusion zones indicated no significant difference in nest success or reproductive output and therefore led to further investigations in 1995.

Behavioural Investigation of Individual Reactions, 1995-1996

In 1995, we examined the 2.5 nm exclusion requirement for nesting Osprey, by subjecting five active nests to controlled low-level CF-18 overflights at distances ranging from 2.5 nm to directly overhead at speeds of 400-440 knots. Maximum noise levels varied from 52-101 dB during these events due to differences in terrain profile, wind and other background influences at each nest. Over 240 hours of direct observations from blinds investigated responses to overflights by examining nest attendance, exposure of young or eggs, and feeding (Chubbs and Trimper, 1998) and defence of the young. Similar observations were completed at two control nests. Nesting behaviour at exposed sites was similar to the control nests and no significant difference was observed as a result of overflight distance, noise level or nesting period as a result of 139 individual overflights. With the exception of nestlings crouching low in the nest no reactions of agitation or startle effect were observed despite rapid onset rates of aircraft noise (26 decibels/second) and all attempts to minimize possible habituation. Agitation, temporary nest abandonment and other extreme reactions by Osprey possibly influencing nest success were observed only in association with slower fixed-wing aircraft, other Osprey or raptors entering territories, and observers entering /exiting blinds (Trimper et al., 1998).

As controlled overflight distance and associated noise level were not correlated with the behavior of nesting Osprey, we attempted to determine if repeated uncontrolled overflights would elicit a significant response. In 1996, the same study area and experimental nests from 1995 were reused with increased noise stimulus. Maximum noise levels (L1) were recorded automatically using palm top data loggers connected to a Bruel & Kjaer Model 2231 or 2236 sound level meter. Sound level meters were calibrated for the expected noise levels prior to each field measurement. The objective was to determine if disturbance (described by the noise metric L1) caused by repeated jet aircraft overflights interfere with reproductive activities of Osprey through behavioural changes associated with nest attendance. If valid, this behavioural change could eventually result in a decrease in productivity and reduced abundance.

Flight track recording data indicated up to 170 low-level aircraft noise events (occasionally consisting of 2 or more aircraft) on the Naskaupi River during June and July 1996. Background noise level and maximum noise level associated with individual overflights remained similar to 1995 values (around 88 dBA) at each nest. Single Event Levels, representing the total acoustic energy of the aircraft event, were 90-121 dBA (usually 97 dBA, n=61). However, Equivalent Sound Level (Leq) values increased (<5 dBA) as flight track recording and field observations confirmed the increase of up to 17 overflights daily, versus a maximum of 16 per month in 1995.

We found no difference in behaviour between 1995 and 1996 experimental and control periods of observation throughout the study. As in 1995 (Trimper et al., 1998), we observed no overt reaction as a result of a LLF jet overflight. Reactions of adult Osprey during low-level overflights varied from alertness, to adjustments in incubation posture. Adult Osprey reacted strongly whenever other Osprey or raptors approached the nest, fixed-wing aircraft approached within 3 km of the nest, or an observer appeared outside the observation blinds. Adult birds continued to be agitated and display aggressive behaviour to these non-experimental stimuli throughout the two years of study. The high percentage of nest attendance by at least one adult indicated that the nest was rarely left undefended. As observed in other studies (Toner and Bancroft, 1986), we recorded several instances when the adults were away from the nest immediately prior to fledging. Situations in which nests were left undefended during incidental slower fixed-wing aircraft overflights were noted again in 1996.

Reproductive Success and Manipulating Exclusion Zone Size, 1995-1996

The objective of this study was to determine whether LLF military aircraft affected reproductive success, and if so, to determine the optimal avoidance distance to minimize these effects. As part of a Masters thesis, 49 nests were studied in 1995, and 68 nests in 1996 within the MTA. Nest occupancy, clutch size, number of hatchlings, and number of young at 41 days of age were assessed at each nest. GIS flight track records provided frequency of aircraft at given distances and altitudes from the nest. Logistic regression analysis assessed the impact of flight frequency in four distance categories and four altitude categories on Osprey reproduction. The frequency of flights within each category were not accurate predictors of Osprey reproductive output. Nests were then randomly assigned to a buffer-zone radius of either 0, 1.85, 3.7, or to a control of 7.4 km, and reproductive output was compared among treatments, and between years. No significant differences were discovered among the reproductive parameters within either 1995 or 1996, but reproductive output was significantly higher in 1995, likely due to adverse weather conditions experienced in 1996.

Reproductive Success and Manipulating Block Treatments, 1997-1998

The 1997 and 1998 program examined the effectiveness of exclusion zones by examining productivity in relation to different LLF treatments within the MTA and control areas. Following initial surveys to determine nest activity, a power analysis was conducted to determine the sampling effort required for the subsequent reproductive success surveys to detect a significant change, if one existed. Of the 168 active and occupied nests in 1997 and 276 nests in 1998, no relationship of nesting success or reproductive output was detected in relation to LLF. The cases examined in this large study included nests exposed to LLF for the first time, nests protected by 2.5 nm radius or larger exclusion zones, and nests in isolated control areas compared to the MTA. It was interesting to note that nests on transmission poles exhibited a significantly greater nesting success (p=0.03 in 1997, p=0.48 in 1998) and a greater number of young fledged per occupied and active nest (p=0.01 in 1997, p=0.08 in 1998) compared to natural tree nests. In recent years effort has shifted towards understanding the influence of habitat features such as ecoregions on reproductive success. We did detect a relationship of the active and occupied nest density, and productivity values by ecoregion in 1997

(R2=0.82) but this was not evident in the excellent weather conditions observed during 1998.

Long-term Monitoring Program, 1999-Present

As no measurable effect of LLF on the reproductive success of Osprey had been detected in previous studies, the maintenance of the exclusion zones was no longer recommended and the research switched to a long-term monitoring program, initiated in 1999. In December 1998, JWEL, in consultation with DND, provincial regulatory agencies and scientists from the Institute for Environmental Monitoring and Research, determined that such a program would be an effective means of evaluating trends. Several points were identified such as sufficient sample size, similar habitat as defined by Ecoregions, random selection of nests, and complete removal of exclusion zones. Three parameters, nest activity, nesting success, and productivity; were tested with the null hypothesis (i.e. no difference between the MTA and Control). Using a reduced study area, 60 active nest sites (30 inside the MTA and 30 in adjacent Eastern Control Area) of an initial 221 active from the spring were revisited to compare reproductive output. In 1999, 1.77 young were fledged per active nest within the MTA, and 1.57 in the Eastern Control Area. At the time of writing, the 2000 results have just become available indicating a similar trend (i.e. higher productivity inside the MTA) although productivity overall had declined by approximately 40%.

Summary

Other studies of Osprey nesting behaviour (Toner and Bancroft, 1986; Swenson, 1979; Vana-Miller, 1987) have reported instances of alarmed adults being repeatedly flushed from their nests (by a variety of stimuli) exposing eggs or nestlings to extreme heat or cold, predators, or premature fledging - all of which could lead to decreased nestling survival and production. Factors affecting noise perception in Osprey could be similar to that of humans and include the spectral content (the range of acoustic frequencies) and amplitude (loudness) modulation in the noise time history. Osprey reactions may be dependent on interactions between the physical perception of the sound energy in the ear and the mental interpretation of that sound. In addition to noise associated with each overflight, we were also able to address the visual stimulus of the aircraft, a shortcoming often identified with simulated noise effects research (Weisenberger et al., 1996).

These studies have been designed to determine if a threshold of LLF existed with measurable effects on Osprey that would lead to decreased reproductive success. Behavioural investigations have been completed in association with ongoing Osprey population (100-250 nests annually) monitoring inside and adjacent to the MTA. Since 1993 when analyses began, no relationship of nesting success or reproductive output has been detected in relation to LLF. Osprey on the Naskaupi River and elsewhere in the MTA have undoubtedly been exposed to overflights in previous years and may have previously habituated. Nevertheless, reactions to controlled and uncontrolled overflights on the Naskaupi River, indicate that Osprey are able to conduct nesting activity without being significantly disturbed by the ongoing LLF program. The extreme reactions noted during infrequent overflights of fixed-wing aircraft suggested that visual aspects (i.e. speed and not noise or the duration of the noise) may act as a stronger stimulus. Other factors such as weather (Spitzer, 1977; Van Daele and Van Daele, 1982; Wetmore and Gillespie, 1976) and food supply (Chubbs and Trimper, 1999; Van Daele and Van Daele, 1982; Hagan, 1986) appear to have greater influence on Osprey productivity and may mask subtle effects of jet aircraft disturbance if they exist.

Annual Osprey monitoring by DND has contributed greatly to the knowledge of raptors and other wildlife on the Ungava Peninsula. In 1999, Osprey productivity in both the MTA and eastern Control Areas were at the highest level observed since the research began one decade ago. The higher productivity in the MTA in 1999 and observed again in 2000 versus the Control Area, is interesting to note given that Osprey now receive the lowest level of protection to LLF.

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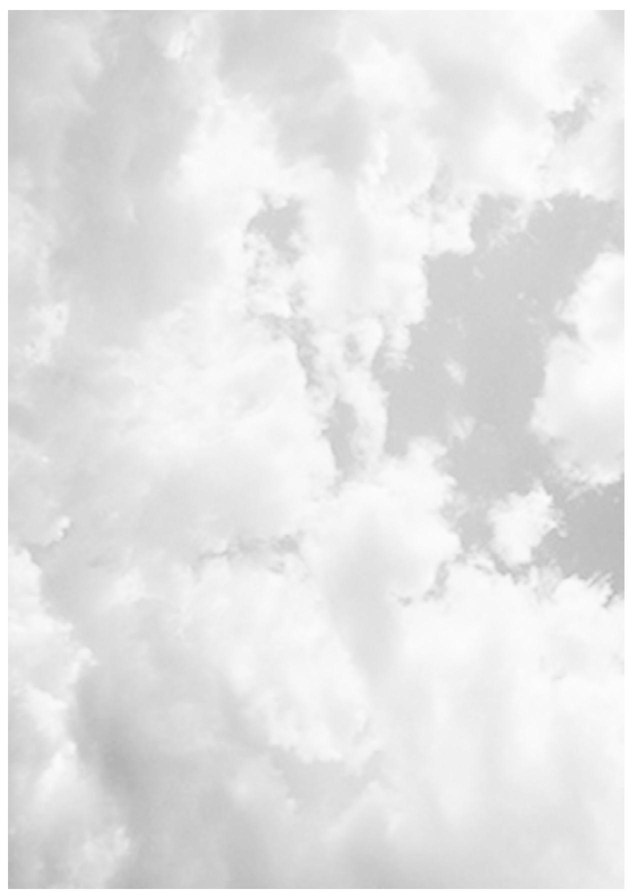


The Effects of Aircraft Operations on Passerine Reproduction

Don Hunsaker II, Ph.D.
Senior Research Fellow
Hubbs Sea World Research Institute
2595 Ingraham Street
San Diego, CA 92109, USA

This paper compiles results from several studies assessing the effects of aircraft noise on the reproductive success of passerine birds. Current projects involve the long term monitoring of reproductive success, habitat quality and noise levels in two populations of federally listed species, the coastal California gnatcatcher (gnatcatcher, CAGN), Polioptila californica californica, and the least Bells's vireo (vireo, LBVI), Vireo pusillus belli. The study areas are located in southern California on two military facilities. The gnatcatcher is studied on Marine Corps Air Station Miramar and the vireo on Marine Corps Base and Air Station Camp Pendleton. Other studies have produced data of relevance from other locations in San Diego County, including the flight path of Lindbergh Field, the primary commercial airport for San Diego.

Our work has been done at the population level with the assumption that effects at the individual level, such as habituation, responses to instantaneous loud noises and other adaptations, have been in place in the study populations. We considered that the most basic response to environmental stimuli, the ability to effectively reproduce and maintain the population level, was the best criteria to judge the adverse effects of noise. Secondary effects of stress and related behaviors are intrusive and hard to measure in nature. We are studying reproductive success of nesting birds exposed to all noise levels, from high noise to those in quiet areas. Quiet areas that support nesting birds could then be used as baseline data for quantifying impacts.

In order to isolate and identify any effects on reproduction from noise exposure levels, we measured several other variables, including habitat quality, climate, topography, predation, other human disturbances and related biotic and physical characteristics. In addition, extensive recordings and analyses of bird calls, fixed wing and helicopter sounds were done to determine the potential of masking bird acoustic communication signals.

Aircraft types utilized at the Stations include the fixed wing F-18 Hornet, the SA 3B Viking and a variety of helicopters including the UH-1 Huey, CH-46E Sea Knight, CH-53E Super Stallion, AH-1 Cobra and the AH-64 Apache. At various times, other types of aircraft were active contributing to the noise exposure levels of the study areas.

The LBVI study area is located along the Santa Margarita river which is a linear riparian willow woodland that serves as prime vireo habitat. The study area extends 13 kilometers along the lower reaches of the flood plain and includes riparian habitat immediately adjacent to the runway as well as habitat in quieter areas. These vireos have been studied extensively over past years and the study area averages approximately 500 pairs per year. Vireos are migratory, and the breeding season usually begins in April and extends until September when the birds have left for the southern parts of their geographic range.

The CAGN study area is located in the drier coastal sage scrub habitat located 6 miles inland from the coast of the Pacific Ocean and 20 miles north of the border with Mexico. The species is a year round inhabitant of the area, and nests in the coastal sage scrub and to a much more limited extent in chamise chaparral intermixed with the sage scrub habitat. These and other CAGN populations have been monitored for the past six years for this and other studies (Awbrey and Hunsaker, 2000; Hunsaker and Awbrey, 1996; Hunsaker, Awbrey and O'Leary, 1999). On average, there are approximately 55 pairs of CAGN per year. As one would expect in a small r-selected species, there is considerable range in the population numbers depending on climate.

Previous studies on the effects of aircraft noise on passerines have shown weak trends towards reduced reproductive success, but none were statistically significant. One criticism with field studies of the type has been a lack of statistical power to detect subtle effects of noise. In current studies, through rigorous statistical design we have been able to detect and quantify effects in preliminary analyses.

Methods

Reproductive Success

During the current projects, a minimum 1200 LBVI nests and 300-400 CAGN nests will be studied over the five year period. Least Bell's vireo nest monitoring includes following 216 pairs annually from 15 April through 31 July. Annual nest monitoring of California gnatcatchers includes following all pairs across the study area from 15 February through 31 July or until nesting has ceased. The number of pairs monitored varies from 40 to 80 per year, depending on climate and other factors.

Field data collected includes breeding and nesting chronology, reproductive success, reproductive behavior, and the number and location of failed and successful nests. For the statistical analysis the reproductive endpoints include the number of nesting attempts per pair, success or failure of the nests, the reason for failures and the number of chicks fledged.

Noise Monitoring

Noise data is collected by an array of noise analyzers that are in a grid system for the LBVI study and adjacent to nests in the CAGN study. The grid system was developed to study a high number of pairs in a small study area while the nest-based system was developed to study fewer pairs in a larger study area. These differences will enable us to compare the two methods in developing sound maps and in the subsequent analysis of the covariates. Our sound level and exposure models are also being compared to the standard airport noise monitoring program NOISEMAP (Mohlman, 1983; U.S. Airforce, 1992).

For these projects we use the Larson Davis Model 720 community noise analyzers which is a battery-operated sound measuring instrument consisting of an integrating sound level meter, a digitizer, a microprocessor for analysis, and memory to store the resulting data. These noise analyzers meet the American National Standards Institute (ANSI) S1.4-1983 type 2 specifications for general noise measurement (Acoustical Society of America, 1983, 1994). To reduce the sensitivity of the system to low frequencies, standard A-weighting was applied to all sound pressure level measurements except for unweighted peak sound pressure levels.

The noise analyzers summarize all sound data collected during each seven day period. A wide range of metrics have been selected for testing. They include average equivalent sound pressure level (LeqA), averaged hourly, daily, and over the entire monitoring period, sound exposure level (ASEL), the maximum and minimum fast sound pressure levels (LmaxA, LminA) and the A-weighted and unweighted maximum instantaneous peak sound pressure levels. In addition, the number of overflight events per week, the percentage of time that sound levels exceeded 60, 80, and 100 dB (LeqA), the number of overflight events in excess of 80 and 90 dB (LmaxA), and the A-weighted values for L5, L10, L50, L90, and L95 are collected at every location.

In order to collect data on individual overflights (events), threshold levels of the LD 720 systems are set at the start of each monitoring period. Two types of thresholds are set; an RMS level for each successive sample collected by the instrument and an LmaxA level that triggers the start of each exceedence event (referred to as the exceedence threshold).

Call Masking

Aircraft or other anthropogenic noise have the potential to mask bird calls. If noise were to mask vital communication signals, the normal reproductive bonding and predator avoidance activities of the bird would be disrupted. When noise is essentially constant, birds could be excluded from an area because their signals may be masked, inhibiting communication thus affecting reproduction.

Our previous studies focused on determining how call masking affects a bird's ability to communicate or detect calls in areas with aircraft overflights (Awbrey, Hunsaker and Church, 1995; Awbrey, 1993). In the field, digital recordings were made of a variety of aircraft under controlled conditions and recorded bird calls were played back at different distances to study attenuation. Three repetitions of the call were recorded through a microphone 2 m above the ground at 5 m intervals out to a distance of 60 m. These recording were used in the analysis of the spectrum characteristics and sound pressure levels. The sound spectrum characteristics in 1/3 octaves of these calls and aircraft were graphically plotted and overlaid with the sound spectrums of the birds. In this fashion, we could determine the potential for masking at any sound pressure level produced by aircraft under various flight conditions.

Current studies are attempting to collect additional information on how call masking potentially effects reproduction. Real-time monitoring data is used to ground-truth data collected by the noise analyzers. This information is compared to bird productivity data through the use of statistical models.

Habitat Quality

To determine the habitat quality throughout the study area, indices were developed for the habitat structure and composition at actual nesting sites and at a sample of sites throughout available habitat. These indices are used to quantify effects of habitat variation on observed nesting success and resource selection for nest sites. The available nesting habitat is sampled at random stratified locations throughout the study area, centered on the noise analyzer. The characteristics of the vegetation selected for successful and failed nests enables us to determine habitat quality and calculate the probability of nesting success in different vegetation types. Resource selection models and spatial use of habitat have been developed and discussed by Manly, McDonald and Thomas (1993) and for other species of passerines (Rotenberry and Wiens, 1998), golden eagles (Marzluff et al., 1997) and elk (Johnson et al., 2000). Erickson, McDonald and Skinner (1998) reviewed Geographic Information Systems (GIS) as a tool to determine habitat selection, a technique effectively utilized by this study. These and other studies served as the conceptual basis for the models developed for this study.

Statistics

The statistical analysis will include two basic components. The first component is development of a noise map based on noise data collected. The map is used to estimate the extent and magnitude of noise effects across the study area and to allow estimation of the noise covariate. The second component involves characterizing the magnitude of effects of noise on passerine reproductive success.

Exposure to aircraft noise is not uniform at all nest site locations and due to variations in habitat quality, all locations are not expected to be equally productive. Because the processes of nest site selection and sound exposure may be spatially biased, simple averages of noise impacts over all nests is not appropriate to estimate cumulative effects. Estimates of aircraft noise effects on productivity must take into account spatial variation in sound exposure and habitat quality. For example, at the population level, the reproductive impact due to a particular dose of noise in unproductive habitat is lower than that of a similar dose in areas of high quality habitat. A quantitative method is needed to determine impacts in a particular nesting area to enable evaluation of potential impacts due to changes in operations at airports and military facilities. We propose a spatially explicit method to quantify the cumulative reproductive effects of aircraft noise on nesting passerines that incorporates spatial variation in aircraft noise, nest site selection, habitat quality and other potential factors.

The method includes, 1) estimation of the noise field throughout the site, 2) estimation of a dose response (or discrete effects) relationship between reproductive endpoints and noise exposure metrics, 3) adjustment of dose response relationships for habitat quality, and other measurable covariates (i.e. predation, disturbance factors, other noise sources) 4) evaluation of noise effects throughout the site, and 5) integration of the noise effects over the study site. The average change in reproductive production or integral of spatially explicit noise effects represents the cumulative or net effect at the population level in the entire study area.

$$FP(x,y) = P(x,y) \times D(x,y) \times N(x,y),$$

To quantify the effect of noise on reproduction, we define Fledge Potential (FP) to be the number of fledges that would be expected to be produced per unit of area in any location in the study site. Fledge potential may be expressed as the product of the probability of nest success, nest density per unit area, and the average number of fledges per successful nest where x and y represent spatial location, P represents probability of nest success, D represents nest density and N represents number of fledges per successful nest. Probability of success, nest density and average number of fledges per successful nest are each modeled as functions of noise exposure, habitat quality, predation rate, topography and other disturbance factors allowing FP to vary spatially as a function of these factors. FP is not modeled directly as a function of habitat quality and noise exposure because it is a function of observation and modeling of larger areas. It is not directly observable at the smaller, single point spatial scales at which habitat and noise exposure vary.

To estimate the cumulative population level effects of noise, FP is integrated over the combinations of habitat quality, noise exposures and other significant factors present at the site. Actual fledge production in any area can be validated by direct observation of reproductive success to test and compare to the model. Preliminary evaluations indicate that probability of success may be weakly associated with noise exposure and habitat quality, and nest density may be associated with habitat quality, while the average number of fledges produced per successful nest appears to be unrelated to sound exposure and habitat quality (Hunsaker, 1999a, 1999b). Therefore we anticipate that FP will be modeled primarily as a function of noise exposure, habitat quality and seasonal climate with other human disturbances a factor in some specific areas.

Statistical Models

To estimate FP, individual models are developed for each component of the FP model, probability of success (P), nest density (D), and average number of fledges per successful nest (N). Each of these components are tested for association with aircraft noise exposure, habitat quality, disturbance factors, climate, predation and other noise sources. For example, P is tested for association with sound exposure, habitat quality, predation and disturbance factors using logistic regression (Hosmer and Lemeshow, 1989).

Factors that prove to be important predictors are included in logistic regression models for probability of success. In general, the potential predictors vary spatially, so P is also expected to vary spatially.

Preliminary analysis suggests that P may be associated with some noise exposure metrics. The logistic model relating probability of nest success to noise exposure is of the form:

$$P(x,y) = \frac{e^{\beta_0 + \beta_1 \times noise(x.y)}}{1 + e^{\beta_0 + \beta_1 \times noise(x.y)}}$$

The following shows a hypothetical example of the logistic model for probability on success. The probability of nest success decreases with increasing noise.

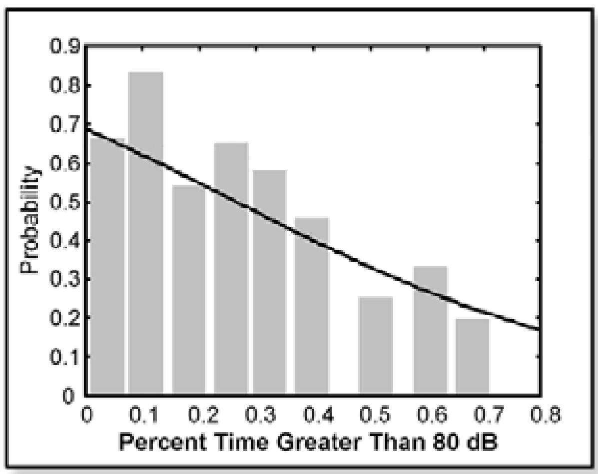


Figure 1: *Hypothetical nest success model*

Modeled predictions of FP can be mapped throughout the site by developing GIS layers of the important predictors. GIS layers of noise metrics have been developed using the geostatistical method, kriging (Krige, 1951). In addition to the estimated noise levels, uncertainty in mapped noise levels is quantified by estimated confidence limits on predicted noise levels at each location in the study site.

Sound level and exposure models are compared to the standard airport noise modeling program NOISEMAP, with NOISEFILE database and BASEOPS software which are commonly used by the industry. We also propose a hybrid between the deterministic NOISEMAP sound propagation models and the empirical models developed through kriging. This type of model is similar to the universal kriging model in the geostatistical literature (Cressie, 1991). In this case, the universal kriging model represents a hybrid between empirical and deterministic modeling, where the theoretical noise propagation model is locally fine tuned using kriging. This approach allows spatial variation in sound levels to be partitioned into that which can be explained by theoretical sound propagation models and that which is due to local scale spatial variation in noise levels. Kern (1995) discussed the application of large scale models for simulation of various functions, a study that was also used for our modeling concepts.

Reproductive Impact

The Reproductive Impact (RI) due to noise is the difference in fledging potential in the absence of aircraft noise (FP0) and fledging potential in the presence of aircraft noise (FP1). The subscripts 0 and 1 are used here in an analogy to null and alternative hypotheses. We think of FP0 as the rate of fledge production per unit area that would be possible at the site in the absence of aircraft noise, or at some particular noise level, while FP1 represents fledging potential at a location with some other noise level of interest. Reproductive impact can be predicted with the model and is expressed in reduction in fledges per unit area: (RI01 = FP0 - FP1). The effect of changes in aircraft operations can be evaluated by calculating the RI based on comparison of FP before and after changes in operations. Since RI is based on a model, it can also be predicted for various scenarios, including changes in number of operations, location of flight tracks and timing of operations.

Effective Impacted Area (EIA)

Reproductive impact as defined above is measured in fledges per unit area. It may also be of interest to quantify the impact in terms of area rather than number of fledges. We define the Effective Impacted Area (EIA) as the area of similar habitat required to produce the same number of fledges per year that would have been expected from the impacted area had the noise impact not been present.

The EIA is given by the product of the relative reduction in fledge potential (RI/FP0) and the total habitat area. It should be noted that in this context FP0 represents the fledge potential associated with the area under consideration that has not been impacted by high noise levels. For example if an area of habitat were under consideration as a mitigation site, or to be used for future aircraft operations, FP0 would be the fledge potential for that specific area. This can be calculated be evaluating the FP model over the specified area provided that habitat and other factors are reasonably similar to the study area. Evaluation of the EIA can be used for operational and land use decisions as well as to determine the area required to mitigate for impacts.

Sampling Variability of Fledge Potential

In addition to estimation of fledge potential, reproductive impact and effective impacted area for the site, estimates of the sampling variability in these terms are also needed to enable development of confidence intervals and to test hypotheses. Because the models for FP, RI and EIA are composed of individual separate models, estimation of their sampling distributions is not mathematically tractable. In situations where the sampling distribution of a particular statistic is not available, computer intensive methods such as Monte Carlo simulation (Diggle and Gratton, 1984), may be used to develop confidence intervals and to test hypotheses.

Results

Past studies have shown a weak tendency for effects on reproductive success as a function of noise. Figures 2 and 3 shows a regression correlation coefficient analysis of the effects of noise exposure levels on gnatcatcher reproductive success, i.e. fledging and egg production. The figures show that there is not a statistically significant correlation between noise levels and reproductive effort or success. These data agree with Larkin, Pater and Tazik (1996) in a review of the literature that indicated the effects of military noise on wildlife are difficult to measure at the population level. Their conclusions that the effects are subtle agree with the data shown on the graphs from our studies. The trends in these graphs are the basis for our current studies.

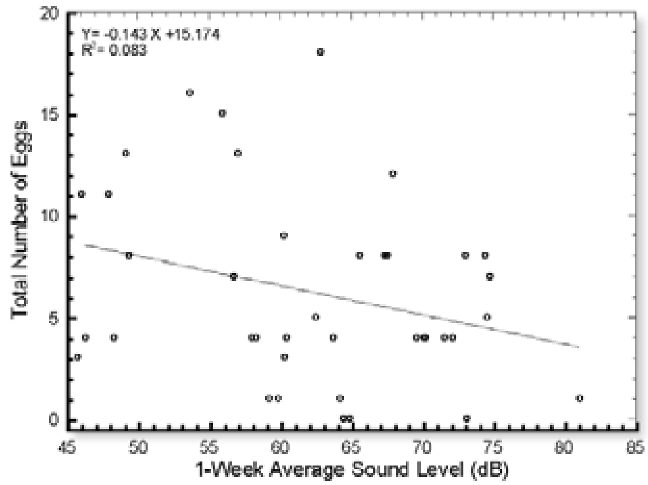


Figure 2: *Relationship between average sound level and number of eggs laid*

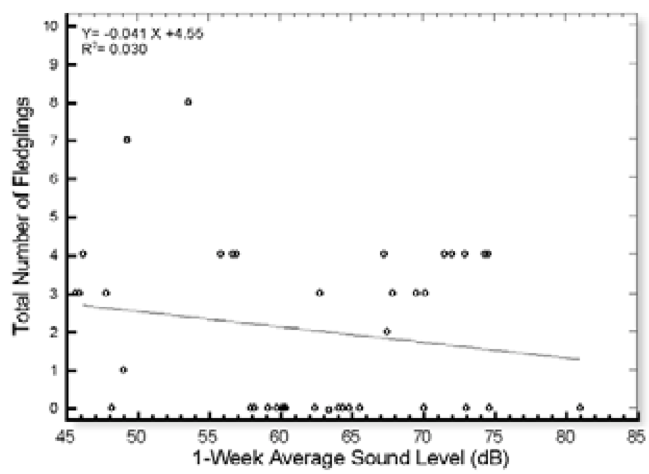
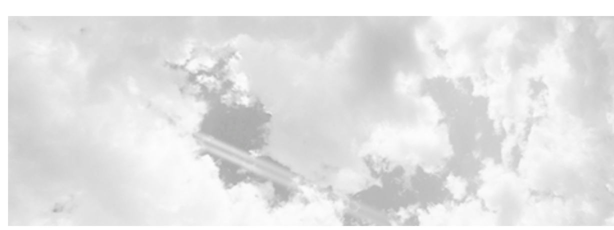


Figure 3: *Relationship between average sound level and number of fledglings*



The following data collected in the current studies shows the cyclical characteristics of the noise levels during a week (Figure 4). Night time flights are rare, and flights begin in early mid morning (7 to 8 a.m.) rather than daybreak. This provides valuable time in early morning and evening hours for feeding and pair bonding. Call masking is rare at these times. In this figure, recorded from 21 Sept - 2 Oct 1998, the Leq was 81.0 dB, SEL was140.8 dB with a peak of 136.3 dB. The meter was set for an event threshold of 70 dB.

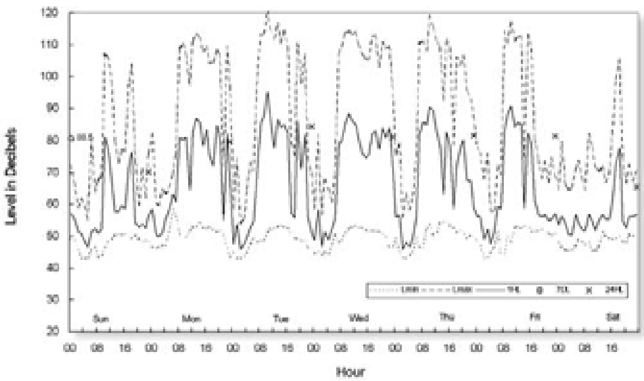


Figure 4: *Sound level variation during 1-week*

Figure 5 shows the amount or total time that the A-weighted sound pressure level was at or above each level. This is the data from the graph in Figure 4, and shows that percent of time above 70 dB was only 2.3% and above 80 dB was 1.1%.

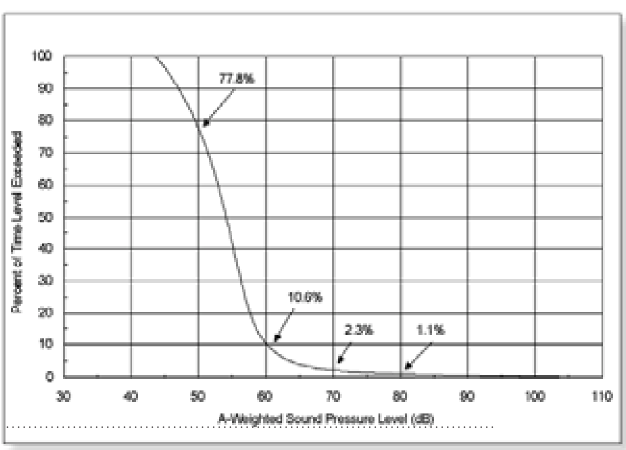


Figure 5: *Percent of time levels exceeded*

Figure 6 and 7 show examples of call masking during a helicopter overflight. Figure 6 shows the worst case scenario with the call completely masked and Figure 7 shows a call partially masked.

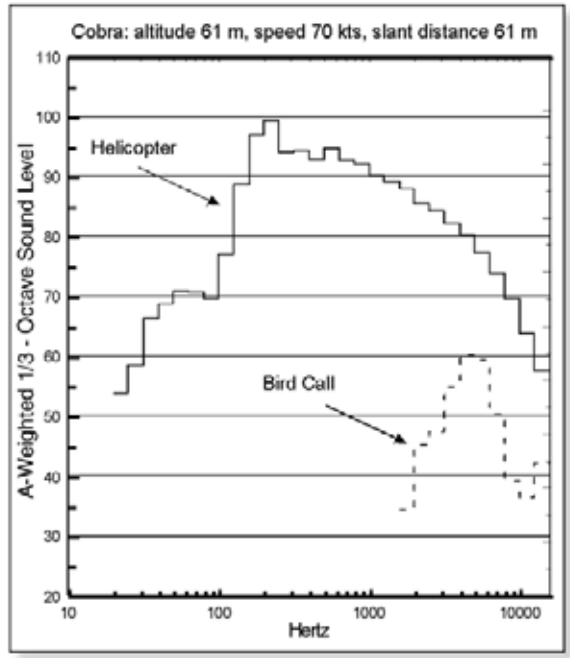


Figure 6: *Complete call masking*

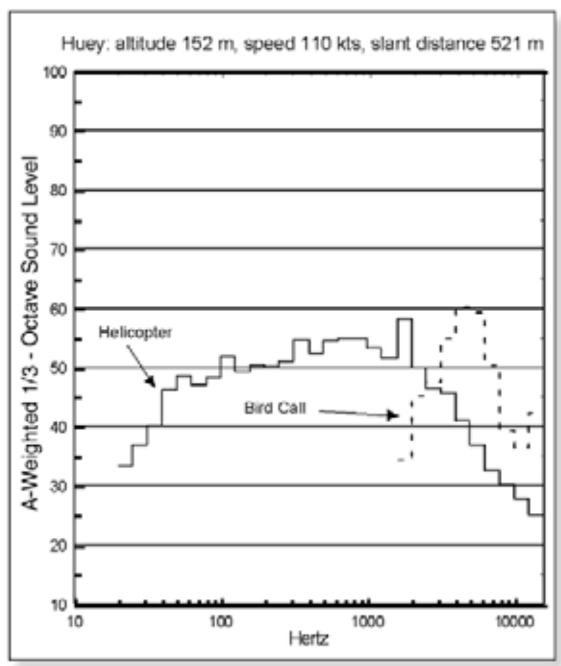


Figure 7: *Partial call masking*

The statistical analysis for the current studies is in progress and results are preliminary. A preliminary logistic regression model has been fit to the productivity data collected during one breeding season, and probability of nest success was found to be weakly associated with noise exposure for some noise metrics. Continued modeling will include evaluation of model consistency among years. The effects of habitat quality on nest productivity have not been evaluated to date, although it is anticipated that productivity may be associated with both noise and habitat. Current efforts include evaluation of habitat, other covariate effects and year to year variation into the productivity model.

Discussion

Research has shown that high sound and vibration levels can indeed be harmful to humans and animals. By far, most of the cases studied involve non-natural settings and testing for noise-induced hearing losses from chronic or instantaneous high noise levels achieved in industrial or other noisy environments (Kryter, 1994). Bowles, Tabachnick and Fidel (1993) reviewed the effects of aircraft overflights on wildlife and concluded the responses are variable, depending on several factors in the topography, levels of exposure and variability between species. A species' evolutionary adaptations to the environment it occupies results in different responses to noise. Natural environments include high noise level sources such as thunder, waterfalls and sea wave action, so one can assume that there is some evolutionary adaptation in the hearing systems of birds to tolerate and function at these noise levels. Seldom do natural settings produce high enough noise levels to induce physical or physiological hearing losses or related impacts to animals. Birds fledged in the flight paths of aircraft would be expected to respond differently to loud noises than naive birds that have never been exposed to those stimuli.

Noise generated by human activities such as aircraft, traffic and machinery, is generally assumed to harm animals, especially those that depend on sound for mating and social cohesion. Animals in general respond to environmental noise in numerous ways, ranging from little or no response to abandoning the area, calling louder or often or changing their activity patterns. If a call is completely masked from a potential receiving individual, for that amount of time, it is living in an environment that is devoid of any other bird or predators auditory input. The longer that time of masking continues, the greater the risk is for potential dangers to survival or reproduction of the individual.

The primary objective of the current studies is to quantify the cumulative impact, if any, of aircraft noise exposure on reproductive success of passerines. The results will assist the military and commercial aviation in the development of strategies to protect listed species as well as determine the losses or take associated with their operations. The law is very specific in that the United States Fish and Wildlife Service must provide the benefit of the doubt to the species when determining if impacts have occurred. This usually takes the worst case scenario into consideration when considering potential impacts of noise or other activities on a listed species. Quantifying the effects noise on a population allows operational designs and potential mitigation to be determined objectively rather than subjectively.

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An Overview of Studies to Assess the Effects of Military Aircraft Training Activities on Waterfowl at Piney Island, North Carolina

W. James Fleming
US Geological Survey, Reston, VA

James A. Dubovsky
US Fish and Wildlife Service, Laurel, MD

Jaime A. Collazo
USGS, North Carolina Cooperative Fish and Wildlife Research Unit,
North Carolina State University, Raleigh, NC

Edmund R. Temple, Jr.
Ducks Unlimited

John T. Conomy
North Carolina State University

We used field observations, controlled field studies, and experimental studies to examine the potential effects of aircraft activities on waterfowl in coastal North Carolina. Studies focused on the waters and marshes around Piney Island, NC. Piney Island is the location of the Mid-Atlantic Electronic Warfare Range operated by the Marine Air Station at Cherry Point, NC. The island was used throughout the year as a target area for aircraft training missions, resulting in frequent aircraft-produced noise events that exceeded 80 dBA. Noise levels at Piney Island, reported as 24-hr Leqs, averaged more than 60 dBAs during the during the1990-1992 time period of our studies. During the winters of 1990-91 and 1991-92, 22 species of waterfowl were observed in the study area at Piney Island, and nearby Cedar Island National Wildlife Refuge. We used mid-winter waterfowl survey data for the period 1961-1991, and accepted the null hypotheses that population trends and species diversity in the high noise environments were not significantly different from those of coastal North Carolina as a whole. Waterfowl time-activity budgets at Piney Island and Cedar Island demonstrated minimal responses of waterfowl to individual noise events and no noticeable disruptions of typical activity budgets relative to published data. These observations suggest that birds quickly accommodated to the noise events, something that we confirmed in black ducks held in pens near the center of aircraft activities at Piney Island, and in experimental studies designed to examine activity budgets and heart rates of waterfowl exposed to simulated aircraft noise. Time-activity data and heart rate data collectively suggest a minimal impact of the aircraft activities and associated noise on wintering waterfowl energetics at Piney Island. The potential impact of aircraft activities on energetics were further examined in the captive black ducks held in pens at Piney Island. These birds, provided ad libitum feed, had similar body mass throughout the fall-winter season as birds held in low-noise reference sites; we speculated that a relative reduction in body mass would be observed in the captive black ducks if aircraft activities induced higher energetic costs. A small population of black ducks and gadwall nested on Piney and Cedar Islands. Natural nests were extremely hard to find so we examined reproduction of waterfowl placed in pens at Piney Island and at a low-noise reference site. Black ducks held in these two types of coastal environments had similar pairing and nesting chronologies, egg numbers, and hatching success of eggs incubated to term. We did note a slight tendency for black duck hens to either lay, or remove eggs from the nest at a higher rate at Piney Island than the reference site. Significantly, nestling growth and survival was dramatically depressed at Piney Island, while ducklings in the low-noise environments grew at expected rates and survival was good. An experiment to examine a cause-effect relationship between simulated aircraft noise and duckling growth, demonstrated again that the growth of ducklings in high noise environments may be reduced, but the amount of reduction in these studies, while statistically significant, was minimal relative to that observed in birds raised at Piney Island.

Response of Geese to Aircraft Disturbances

David H. Ward
Alaska Biological Science Center
U.S. Geological Survey
1011 E. Tudor Rd.
Anchorage, Alaska 99503, USA

Robert A. Stehn
U.S. Fish and Wildlife Service
Migratory Birds
1011 E. Tudor Rd.
Anchorage, Alaska 99503, USA

Dirk V. Derksen
Alaska Biological Science Center
U.S. Geological Survey
1011 E. Tudor Rd.
Anchorage, Alaska 99503, USA

Low-flying aircraft can affect behavior, physiology, and distribution of wildlife (Manci et al., 1988), and over time, may impact a population by reducing survival and reproductive performance. Thus, it is important to identify the particular aspects of overflights that affect animals so that management strategies can be developed to minimize adverse effects.

Waterfowl are particularly sensitive to low-flying aircraft (Manci et al., 1988) and respond at all stages of their annual cycle, including breeding (Gollop et al., 1974a; Laing, 1991), molting (Derksen et al., 1979; Mosbech and Glahder, 1991), migration (Jones and Jones, 1966; Belanger and Bedard, 1989), and wintering (Owens, 1977; Kramer et al., 1979; Henry, 1980). Waterfowl response can be quite variable both within and among species (Fleming et al., 1996). For example, response can vary with age, sex, and body condition of individual, habitat type and quality, and previous exposure to aircraft (Dahlgren and Korshgen, 1992). However, the most important factors influencing a response are aircraft type (Davis and Wiseley, 1974; Jensen, 1990), noise (Mosbech and Glahder, 1991; Temple, 1993), and proximity to the birds, as measured in altitude and lateral distance (Derksen et al., 1979; Belanger and Bedard, 1989; Ward et al., 1994). Wildlife managers can reduce impacts on a population by controlling or modifying these factors.

In an experimental study conducted at Izembek Lagoon in southwestern Alaska in 1985-1988 (Ward and Stehn, 1989), we conducted planned aircraft overflights with control of aircraft type, noise, altitude, and lateral distance to flocks (hereafter called lateral distance) to measure behavioral response of fall-staging Pacific brant (Branta bernicla nigricans) and Canada geese (B. canadensis taverneri) to fixed- and rotary-wing aircraft. These data were then used to develop predictive models of the relationship between aircraft type, noise, altitude, and lateral distance and the response of geese (Ward et al., 1989). We also developed a simulation model incorporating energy intake and daily energy costs to assess the long-term consequences of repeated overflights on the ability of brant to obtain sufficient energy reserves necessary for fall migration and over winter survival (Ward and Stehn, 1989).

Izembek Lagoon is a shallow water embayment located at the end of the Alaska Peninsula (55o15'N and 163o00'W) (Ward et al., 1997). It is an internationally recognized wetland because of its importance to waterbirds (Smart, 1987). Each fall, this lagoon supports >400,000 waterbirds, including nearly the entire population of Pacific black brant and a majority of the Pacific flyway population of Taverner's Canada geese (Bellrose, 1980; Ward and Stehn, 1989). Geese migrate to the lagoon to take advantage of extensive beds of eelgrass (Zostera marina) and gain fat reserves, which fuel their long distance transoceanic migration to wintering areas in Washington, Oregon, California, and Mexico (Ward and Stehn, 1989).

We obtained a large sample size of overflights and concurrent behavioral observations of geese across a wide variety of aircraft flown at different altitudes and lateral distances, including observations on >1,500 flocks of brant during 356 overflights and >500 flocks of Canada geese during 209 overflights. Overall, 75% of brant flocks and 9% of Canada goose flocks flew in response to overflights. Mean flight responses of flocks were greater for rotary-wing than for fixed-wing aircraft. Only at low (<152 m) altitudes or distant (>2 km) lateral distances did geese respond similarly to these 2 types of aircraft.

Mean response of geese was greater for high noise (sound exposure level >76 dBA for fixed-wing aircraft and >80 dBA for rotary-wing aircraft at 152 m altitude) than for low noise aircraft. The most disturbing aircraft to all geese was the Bell 205 helicopter. This aircraft produced the greatest amount of noise of any aircraft. In general, rotary-wing aircraft produced more sound energy over the low- to mid-range frequencies (80 to 1.6 kHz) than fixed-wing aircraft. There was a strong positive correlation between the intensity of the aircraft noise and duration of the behavioral response, but noise data were highly correlated with aircraft altitude and lateral distance to suggest that noise alone caused the disturbance.

Lateral distance between aircraft and flock was the most important parameter in predicting response of brant and Canada geese to overflights. Response of geese decreased consistently at increasing lateral distances independent of aircraft type or noise. Altitude was the least reliable predictor because of interaction effects with aircraft type and noise. Although there was generally an inverse relationship between altitude and response, greatest response occurred at aircraft altitudes between 300 and 800 m. This pattern of response was most apparent for overflights of rotary-wing and high noise aircraft.

The increased response of geese to aircraft at intermediate altitudes may be a result of the windy conditions that are typical of Izembek Lagoon. Wind can cause upward-refraction of aircraft noise which results in shadow zones that reduce noise transmission of aircraft flying at low altitudes (Harrison et al., 1980). If the flock is upwind of the aircraft, sound can be deflected upward and the flock is essentially in a shadow zone and subjected to less noise. The opposite is true if the flock is downwind from the aircraft, i.e. the noise is deflected downward. When aircraft altitude increases, the shadow zone effect is diminished and the perceived noise may become louder even though the distance between the aircraft and flock increases.

Noise measurements of the Bell 205 helicopter at various combinations of altitude and lateral distances confirmed that noise levels were higher at greater distances from the microphone. Sound energy of the Bell 205 declined with increasing altitudes (as did flock responses), but starting at approximating 1 km away, sound energy began rising with increasing altitude (flock response also increased). This correlation between increased response and noise level at greater distance between the flock and aircraft provided the best evidence that noise was a key factor in response by geese.

To assess potential impacts of repeated aircraft disturbances on individuals we used a simulation model that incorporated our field observations of duration of responses and published literature measures of the energetics of disturbance responses, patterns of undisturbed behaviors over a 24 h period, and nutritional requirements (Ward et al., 1989). The model was based on body mass and body composition of brant collected at Izembek Lagoon and on the wintering grounds at San Quintin Bay, Mexico. The model simulated energy flow at the individual level from food resources ingested to expenditures. When the sum of the energy used exceeds energy gains, the bird's ability to gain weight for migration is reduced. The model contained 3 submodels: one addressing forage and energy intake, another summing daily energy costs, and a final converting energy gained or lost per day into grams of body mass.

The resulting energetic model for fall-staging brant at Izembek Lagoon predicted an undisturbed adult brant would gain about 310 g over a 54-day staging period from early September to early November. Ten daily helicopter overflights during the staging period would reduce body mass to 96% of the expected departure mass and if 45 overflights occurred daily, brant would experience high body mass loss. Body mass loss could be reduced 25% if overflights were conducted at night and decreased 15% if conducted over day and night. Predictions of body mass were most sensitive to changes in assimilation rate, total forage intake, and caloric value of eelgrass. A 10% increase in assimilation efficiency caused a 44% increase in total body mass gain and 2.5 fold increase in the number of daily disturbances that birds could handle, while a 10% increase in forage intake caused a 34% increase in body mass gain and 2-fold increase in number of disturbances tolerated. Such simulation models provide an important tool for understanding how aircraft overflights affect a species and to predict the magnitude of disturbance effects on parameters that influence individual fitness. Response data can be used to develop predictive models of the probability of response to different aircraft at varying altitudes and lateral distances. These models can then be combined with spatial data describing the distribution and abundance of birds to identify buffer zones or corridors that will minimize impacts (Miller, 1994; Miller et al., 1994).

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The Response of Sea Birds to Simulated Acoustic and Visual Aircraft Stimuli

Professor Lex Brown
School of Environmental Planning
Griffith University, Brisbane 4111
Australia

This paper describes an experiment conducted in the field to assess the response of seabirds to helicopter overflights. It also attempts to assess the importance of a visual cue to aircraft overflights as compared to the acoustic cue. The work reported here is for a species of sea bird nesting on the Great Barrier Reef in Australia – and it is not so much the results from this particular species that is important in the Canadian context – but more the approach to experimental technique, and the emphasis on good measurement of both disturbance stimulus and disturbance reaction. The finding in this study that visual stimulus appears to be much more important than the acoustic stimulus, if replicable in other species, allows the use of experiments where aircraft overflights are simulated – avoiding some of the ethical dilemmas associated with real life experiments on wild populations.

The author (Brown, 1990) has previously reported the response of Crested Tern (Sterna bergii), to acoustic stimuli simulating overflights of fixed-wing aircraft (a DHC-2 Beaver float plane). The experiments involved presentation of pre-recorded aircraft noise, with peak over-flight levels of 65 dB(A) to 95 dB(A), to sea bird colonies nesting on the Great Barrier Reef. Sea bird responses in the exposed colony were videotaped and these tapes were subsequently analysed by assessing the behavioural response of each bird in the colony. Results of the trial indicated that the maximal responses of preparing for flight, or escape, were restricted to exposures greater than 85 dB(A).

A scanning behaviour was observed in nearly all birds at all levels of exposure. An intermediate level of response, an alert behaviour, demonstrated a strong positive relationship with increasing noise level. This earlier work has been extended by examining sea bird responses to helicopter and responses to visual stimuli simulating the approach of low-flying aircraft. The significance of the contribution of the visual component to bird disturbance needed to be resolved in this work that relies on simulated aircraft noise to assess the effect of aircraft flights on wildlife.

The Study

The study site was Eagle Cay in the Cairns-Cormorant Pass section of the Great Barrier Reef Marine Park. Colonies on this cay had had no prior chronic exposure to aircraft overflights or to other forms of human disturbance. The species of sea bird examined was again the Crested Tern. It is a colonial nester, found mainly in open habitat among low grasses and herbaceous vegetation, and breeds in large numbers, up to several thousands, in the summer months. The eggs are laid on the bare ground in hollow scrapes (Langham and Hulsman, 1985). Because it nests in open areas, this species could be videotaped relatively easily, allowing detailed measurement of the behaviour of individual birds in the colony.

The experiment was conducted on a colonies of which only portions on the periphery, about 20 to 35 individual birds present at any one time, were observed in the experiment. When the experiments started the birds were in the late stage of the incubation period. A hide was established at 15 – 20 m distance from the edge of the colony and was the location from which the stimuli were controlled and bird behaviour filmed.

The acoustic stimuli consisted of instrumentation quality, mono tape recordings of Kiowa helicopter operations recorded at various distances from an alighting point. The aircraft operation consisted of approach and descent to the alighting point, a brief pause on the ground with motor and rotor idling, then lift off and departure. This operation simulates a tourist activity ferrying passengers to locations on the Great Barrier Reef. The Kiowa is a military equivalent of a Bell Jetranger helicopter, commonly used for tourist activities on the Reef. The recordings were conditioned to represent six "alighting" treatments where the peak level in the helicopter alighting operation ranged from 70 dB(A) to 95 dB(A) in five 5 dB(A) increments. In the field these recordings were amplified and replayed through a column loud speaker. No birds were located between the speaker and the part of the colony under observation. A microphone located in the column monitored the level of every simulated alighting operation to confirm that the correct treatment level had been delivered. These aircraft signals were superimposed on an acoustic background of bird calls from within the colony and the sound of wave action on the shores of the cay. The simulated alighting recordings were of some 80 to 90 seconds duration. A colony was exposed to five replications of each of the six helicopter alighting treatments and a control (no acoustic stimulus) over a period of four days. Treatments were applied in random order within each of the replications. Replications were separated by a minimum of four hours, most by 24 hours. Individual treatments were separated by at least 10 minutes.

The simulation of the visual stimulus of an aircraft overflight was not as sophisticated as that of the acoustic stimuli. It was achieved by towing a target on a fixed wire towards and above the colony. The wire was fixed to a 12 m high mast that had been erected at the edge of the colony and to a point on the ground some 60 m distant from the colony, the latter hidden behind bushes. The target was towed rapidly to the top of the mast by winding the tow wire on a reel. The birds in the colony would have first observed the target when it emerged above bushes some 40 to 50 m from the colony and at an angle of approximately 5o above the horizon. Four target sizes were used and each had the wing and fuselage shape of a fixed wing aircraft. Wing spans were 280 mm (Target A), 409 mm (Target B), 602 mm (Target C) and 948 mm (Target D). At the point at which they could first be observed by the colony, these targets would have subtended angles of between 0.4o and 1.4o at a bird's eye.

A colony was exposed to nine replications of each the four visual targets and a control (winding the tow rope along the target wire, but with no target attached). Treatments were applied in random order within each of the replications. Replications were separated by a minimum of two hours; individual treatments by at least 10 minutes. The experimentation was completed over a period of seven days. All targets were towed at the same, uniform, velocity.

Observations

Bird behaviour during each noise and target treatment was filmed on videotape, and laboratory viewing of this videotape was used to score bird behaviour. Laboratory analysis was undertaken by repeated replay, with the behaviour of a single bird observed over each replay of the same segment. The maximum response behaviour of the observed bird was scored and the segment then replayed to observe the next bird. A summary of the categories of the hierarchy of responses is (Brown, 1990):

- Scanning behaviour: head turning, tilting, appearance of "looking" for disturbance.

- Alert behaviour: neck extension, carriage erect/tense; re-orientation or stepping on spot.
- Startle/avoidance behaviour: incomplete intention movement to fly up or escape. wing flapping, possibly leaving eggs or chicks exposed momentarily.
- Escape behaviour: flying up, nest exposed for a longer time.

It should be noted that these behaviours could also result, not just from the simulated stimuli, but from routine interactions with other birds in the colony and also from the presence of predators. Behaviours that could be attributed clearly to such interactions were discarded and only those behaviours that could not be attributed to such causes were used in this analysis. If responses that could be attributed to interaction were observed before another that could not be attributed to interaction or predators, a conservative approach was adopted by excluding the latter from the analysis.

The results of the five replications of the helicopter alighting experiment are shown in Figure 1. The figure shows the mean proportions of the birds that exhibited a particular (or greater) behavioural response. It is clear that bird response depends on the level of helicopter alighting noise. Over three-quarters of the colony exhibited a scanning (or greater) behaviour for all levels of the helicopter alighting stimulus. Escape, and startle (or greater), behaviours were also observed at all levels of the noise stimulus, with between 16% and 36% of the colony reacting in this way. These proportions increased slightly with increasing helicopter noise levels. The proportion of the colony exhibiting alert (or greater) behaviours increased more steeply with increasing maximum helicopter noise levels. There were some small, and unexplained, behavioural responses to the control stimulus, but response to the noise stimuli were always greater than for the control. These findings reinforce those of the previous fixed wing experiment, viz that there is an observable behavioural response to all levels of aircraft noise that can be heard above the background sound levels of the cay.

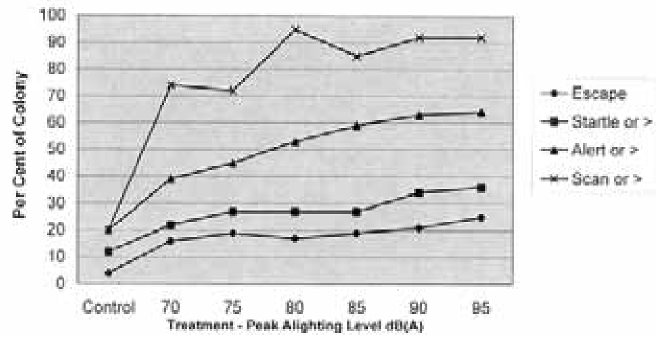

Figure 1. Mean Proportion of the Crested Tern colony exhibiting different behavioural responses to helicopter noise stimuli.

The results of the nine replications of the visual experiment are shown in Figure 2. The figure shows the mean proportion of the observed birds that exhibited particular behavioural responses to each size of visual targets (Target A was the smallest target, Target D was the largest). There was no measurable response to the control. The largest target (near 1m wingspan) was the only stimulus to result in any of the higher orders of behavioural response in the colony. The scanning (or greater) response was observed for much lower proportions of the colony than observed for the noise stimuli.

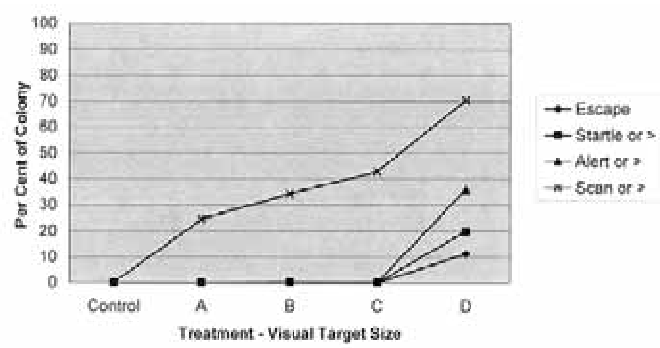

Figure 2. Mean Proportion of the Crested Tern Colony exhibiting different behavioural responses to visual stimuli. (Increasing target sizes A to D).

Discussion

The results of the helicopter alighting noise simulation experiments conform broadly to those found for the fixed wing DHC-2 Beaver float plane. For both helicopter and fixed wing sources, Crested Tern demonstrate an observable behavioural response to aircraft noise at all levels of noise exposure audible above the background sound levels. Escape or startle responses are exhibited by only a small proportion of the colony, whereas for the fixed wing noise source these behaviours were restricted to the higher noise level exposures of 90 and 95 dB(A). There was no similar threshold for the helicopter noise source. Overall, the noise of helicopter alighting generated greater levels of escape or startle behaviours than did the noise of fixed wing aircraft. For both noise sources, the most prominent relationship between level of noise and proportion exhibiting a particular response was for the alert (or greater) behaviour – though the gradient of the relationship was not as strong in the helicopter results as it was for the fixed wing results.

While the peak noise levels to which colonies were exposed were the same in the treatments for the fixed wing and the helicopter experiments, the difference in bird response to the same peak noise levels is notable. It may be possible to attribute the somewhat greater response to different frequency and temporal components in the noise sources. In particular, it may be the variability in the levels of sound produced by a helicopter as it hovers, alights, idles and takes off, relative to the somewhat more "predictable" signature of an overflying fixed wing aircraft, produces a greater response in the colony. These results suggest that a cautious approach should be taken in the control of helicopter movements when these are operating near wildlife.

The results of the visual stimulus experiments suggest, at least within any limitations of the current simulations, that the acoustic component of aircraft overflights near sea bird colonies may be far more important in generating behavioural responses than the visual components. There clearly is a response to visual stimuli, but of a much lower magnitude than to acoustic stimuli. This result means that simulating aircraft overflights by means of replay of recorded sound of aircraft movements is not overly confounded by the absence of a visual component of the stimulus. This finding is of considerable value. It means that it is possible to design experiments to determine operating limits for aircraft near wildlife which expose just small parts of a colony to disturbance using simulated noise operations, rather than exposing the whole of the colony, as would be the case if using real aircraft overflights. There is still a need, of course, to validate any findings obtained through simulation experimentation using actual aircraft.

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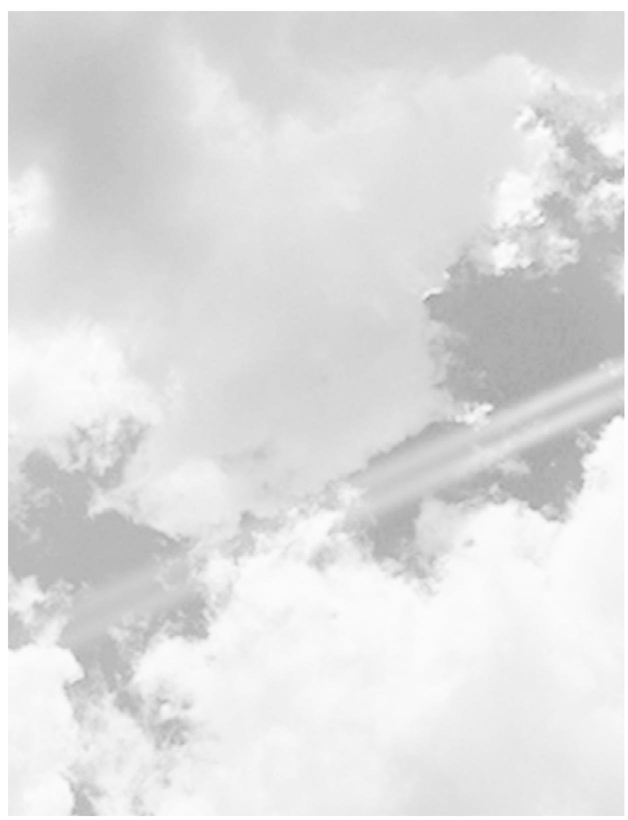


Effects of Overflights by Jet Aircraft on Activity, Movements, Habitat and Terrain use of Caribou

Julie A. K. Maier
Institute of Arctic Biology
University Alaska Fairbanks
Fairbanks, AK, U.S.A. 99775

Robert G. White
Institute of Arctic Biology
University Alaska Fairbanks
Fairbanks, AK, U.S.A. 99775

Stephen M. Murphy
ABR, Inc., P.O. Box 80410
Fairbanks, AK, U.S.A. 99708

Michael D. Smith
ABR, Inc., P.O. Box 80410
Fairbanks, AK, U.S.A. 99708

As human populations expand into traditional wildlife habitats, evaluating the effects of human activities on wildlife populations becomes critical. In Alaska, vast tracts of uninhabited land make this state an attractive location for increasing the range and intensity of military training exercises. In response to concerns of augmented military exercises, the United States Air Force (USAF) initiated a number of research projects to better understand the effects of their training exercises on wildlife.

Because of natural differences in activity and movements among seasons, we evaluated responses by caribou (Rangifer tarandus) to overflights by jet aircraft on a seasonal basis to identify potentially sensitive times of the year. We conducted research in late winter, post-calving, and the insect season because of the importance of each of these seasons in the annual cycle of the caribou. The goal of this research was to quantify long-term responses of caribou to overflights by subsonic jet aircraft flying at altitudes <33 m above ground level (agl). Our specific objectives were (1) measure the noise exposure experienced by caribou overflown by jet aircraft, (2) determine activity cycles ad movements of caribou exposed to overflights by low-altitude jet aircraft, (3) evaluate responses of caribou to overflights as a function of noise exposure, and (4) determine habitat and terrain use by caribou exposed to overflights.

We captured and instrumented caribou with radio collars and Animal Noise Monitors (ANMs) prior to the onset of each sampling period. One group of 5 caribou, the treatment group, was designated to be overflown by jet aircraft. We captured 5 other animals, the control group, > 16 km from the treatment group. Control animals were not exposed to overflights. All captured animals were instrumented with Wildlink radio collars equipped with VHF radio transmitters and activity counters. We also outfitted the 5 animals in the treatment group with ANMs. The prototype ANMs represents the first time that a measurement of noise exposure was made on free-ranging animals in their natural habitats.

We analyzed effects of overflights on bout number, bout length, daily time spent resting and active and daily distance traveled by control versus treatment caribou using one-way analysis of variance. We then used stepwise multiple regression to evaluate whether specific aspects of noise could be identified as influencing the aforementioned activity variables and daily movements of caribou. The independent variables considered were (1) number of overflights > 85 dBA and < 1km, (2) loudest overflight each day, and (3) time-averaged noise exposure level for the treatment day (LT). We later imported caribou locations into the Geographic Information System ARC/INFO to determine the effects of overflights on habitat and terrain use by caribou. Location coverages were overlain onto aspect, slope, elevation, and terrain ruggedness grids as well as a LANDSAT-TM image developed jointly by the Bureau of Land Management (BLM) and Ducks Unlimited, Inc. We used logistic regression to differentiate between control and treatment caribou.

Caribou subjected to overflights in late winter interrupted resting bouts and consequently engaged in a greater number of resting bouts than caribou not subjected to overflights (P=0.05). This change in activity was significantly related to the number of overflights per day. Caribou subjected to overflights during post-calving were more active (P =0.03), moved farther (P = 0.01), and avoided closed mixed forests compared to caribou not subjected to overflights. Caribou subjected to overflights during the insect season responded by becoming more active (P = 0.01) and utilized higher elevation, more rugged terrain, dominated by gravel and rock

Responses of caribou to overflights by jet aircraft were mild in late winter, intermediate in the insect season, and strongest during post-calving. We conclude that female caribou with young exhibit the most sensitive response to aircraft disturbance and that overflights by jet aircraft do constitute a disturbance to caribou with young calves. Military training exercises should avoid caribou during the calving and post-calving periods. Moreover, military exercises should be curtailed during the cool of the day in the insect season, as this is a critical feeding time in that period.

Movements and Site Fidelity of Woodland Caribou of the Red Wine Mountains Herd in Relation to Low-Level Aircraft Training in Labrador

Thomas S. Jung
Institute for Environmental Monitoring and Research
Goose Bay, Labrador, A0P 1E0

Colin C. Jones
Institute for Environmental Monitoring and Research
Goose Bay, Labrador, A0P 1E0

More than 5,000 low-level jet fighter training sorties occur annually in the Military Training Area (MTA) of Labrador, and the effect of these activities on sedentary woodland caribou (Rangifer tarandus) are largely unknown. In 1996, the MTA was reconfigured, with the result that the entire range of the Red Wine Mountains Herd (RWMH) was exposed to sub-sonic low-level overflights. Prior to 1996, about 45% of the RWMH range was exposed to low-level overflights. We investigated the effect of exposing the entire range of the RWMH to low-level overflights on the movements and site fidelity of woodland caribou of the RWMH.

During 1993-1998, location data were obtained for a total of 25 woodland caribou, via satellite telemetry. Home range size, movement rates, distance traveled, path tortuosity and site fidelity for each animal, during each of 4 biological seasons, were calculated. The analytical design followed a factorial approach, with 2 main treatment effects: season (4 levels: spring, early summer, late summer, fall) and reconfiguration [2 levels: before (1993-1995) and after reconfiguration of the MTA (1996-1998)]. Two-way ANOVAs and 2-sample T-tests were used to statistically test for an effect of season, reconfiguration, and their interaction, on the movements and site fidelity of all satellite-collared woodland caribou ($n = 25$), and for a sub-sample of individuals for which data was available in both the before and after reconfiguration periods ($n = 7$).

Time of year, season, had a significant effect on woodland caribou movements (i.e., home range size, movement rates, distance traveled; $P < 0.005$) and site fidelity ($P < 0.001$). Typical of woodland caribou, home range size, movement rates and distance traveled were greater in the spring and fall then in the early summer and late summer periods. Site fidelity was greater in the early summer, late summer and spring then other periods during the annual cycle. Reconfiguration of the MTA, and hence greater exposure to low-level jet overflights, had no effect on the home range size, movement rates, distance traveled, path tortuosity or site fidelity of woodland caribou ($P < 0.396$). Furthermore, no significant interactive effect of season and reconfiguration was observed for the movement parameters ($P < 0.332$), suggesting that increased exposure to low-level overflights did not differentially effect the movements of woodland caribou in relation to season. However, there was an interactive effect of season and the reconfiguration of the MTA on the site fidelity of woodland caribou ($P = 0.003$), suggesting that, during some seasons, site fidelity was differed between the before reconfiguration and after reconfiguration periods. Multiple pairwise comparisons revealed that site fidelity was greater before reconfiguration than after reconfiguration during the late summer, but not during the other 3 seasons.

These analyses suggest that increased exposure to low-level jet overflights as a result of reconfiguration of the MTA had no effect on the movements and site fidelity of woodland caribou of the RWMH, with the exception that site fidelity was less during the late-summer after reconfiguration then before reconfiguration. While this retrospective analysis represents an advancement in our knowledge of the effects of low-level overflights on woodland caribou, it is limited in that it compares only the broad exposure of woodland caribou to low-level overflights. To provide greater resolution to the questions posed herein, the actual dosage of disturbance should be investigated.

Managing Low Level Jet Aircraft Noise

Lieutenant Colonel (Ret'd) Maurice A. Pigeon
National Defence Headquarters
General Pearkes Building
Ottawa, ON, K1A 0K2

The presentations to date have offered interesting scientific insights on the effects of noise on various wildlife. My focus addresses some environmental management issues faced by the Department of National Defence (DND) in dealing with noise associated with a dynamic flight training activity over a large wilderness area.

I work within an organization called the Goose Bay Office - we are a component of the Chief of the Air Staff at National Defence Headquarters in Ottawa. We are dedicated solely to providing specific management support services to the foreign military training program here in Goose Bay. My responsibility entails Environment and External Relations; our team works closely with Canadian Forces and allied personnel at 5 Wing to implement a rather unique and comprehensive mitigation program designed to minimize the potential adverse effects from low-level jet aircraft noise.

Our mission statement is - To maintain and enhance the viability of the allied training activity in Goose Bay, and the resulting socio-economic benefits, in an environmentally sustainable manner.

Project Description

Low-level flight training involves activity below 1000 feet and as low as 100 feet above all obstacles within a designated military training area (MTA). This MTA measures 130,000 square kilometers (roughly the size of England) and it extends over two provinces in eastern Canada. Seventy "camera targets" are dispersed throughout the MTA; these are mock-up structures simulating enemy installations. Crews navigate between selected targets utilizing terrain masking to avoid radar detection and conduct simulated attacks using on-board cameras to verify their accuracy. No live weapons are used and no stores are dropped anywhere other than within a single 4-nautical mile radius Practice Target Area. An average of 6,000 sorties are flown every year during a 30-week training season between April and October by crews from four allied nations, with occasional participation by other air forces. Figure 1 illustrates the MTA in bold outline and the surrounding area.

Figure 1 Military Training Area(s)

There is only one community (Churchill Falls, population 800) within the training area and it is protected from disturbance by a 10-nautical mile radius exclusion zone. Roughly a dozen small aboriginal communities are situated some forty miles or more from the training area perimeter; members of these communities practice traditional hunter/gatherer harvesting activities within the training area during different periods of the year. The training area also contains various species of endangered, threatened, naturally rare and commercially or culturally important wildlife thought to be sensitive to noise. Among them is the world's largest caribou herd, several other woodland herds (threatened), Peregrine Falcons, Bald and Golden Eagles (naturally rare), Osprey, Harlequin Ducks (endangered), Moose (sensitive during late winter period) and Gyrfalcons (naturally rare).

Environmental Review

Public concerns regarding possible impacts on wildlife and people led to the project being referred for public review under the federal Environmental Assessment and Review Process (EARP) in 1985. After an extensive examination, an independent environmental assessment panel issued a report and recommendations to the Government of Canada in 1995. Based on a review of the DND Environmental Impact Statement (EIS) as well as many other submissions from experts, interested parties and the general public, the Panel concluded that there was little to confirm significant negative environmental, social or health impacts from the project. Accordingly, it recommended that the project proceed, subject to some key conditions. Among its 58 recommendations, it highlighted the need to establish and fund an Institute, with a Board of Directors representing federal, provincial and regional government interests, along with aboriginal groups and other stakeholders as equal partners. It would be assisted by a scientific review committee to advise on research initiatives. The Institute mandate includes monitoring and effects research to independently verify project impacts.

The Panel also agreed with the DND proposal in the EIS to reconfigure the training area in a manner that would permanently exclude certain areas deemed to be most sensitive due to the presence of valued wildlife or human activity. The elimination of those areas through reconfiguration has allowed us to systemically deconflict a sizeable portion of the MTA and thus simplify the remaining environmental management challenge. Figure1 depicts the previous MTA configuration in feint outline, as two separate areas extending beyond the current northerly and southerly boundaries and joined by corridors. The omitted portion to the north was extensively occupied by the George River caribou, and further east, by various sensitive raptor populations. To the south, the eliminated portion has removed flight activity from areas of higher interest to local
communities.

The Noise Issue

Clearly, the major concern arising from our activity is the noise component. For that reason, it is important at the outset to have an appreciation of the project noise context, including its occurrence rate, distribution, levels and duration. Figure 2 represents a typical low-level jet overflight event taken in the field. It shows a rapid increase in noise level at the twenty-second mark of the timer to a maximum of 107 dBA, followed by a slightly slower rate of decrease in noise level. A single noise event above the 70 dBA level has a typical duration of 13 seconds. The small precursor peak at the 10 second mark may be the result of the aircraft positioning in its circuit for the inbound leg.

Figure 2 Sample Aircraft Noise Time History

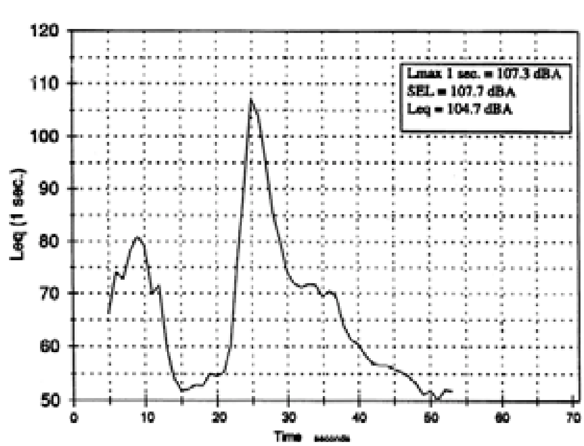
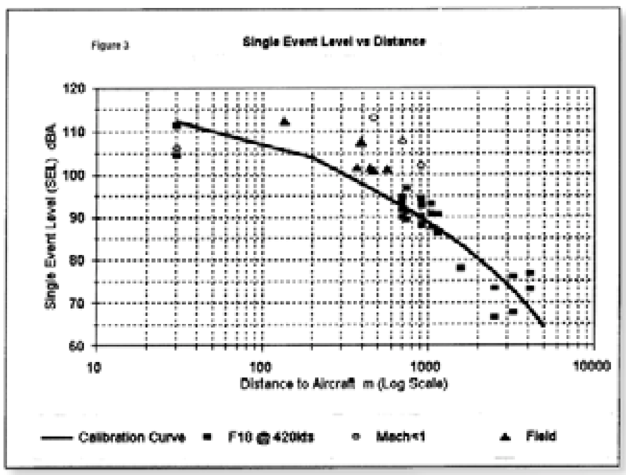


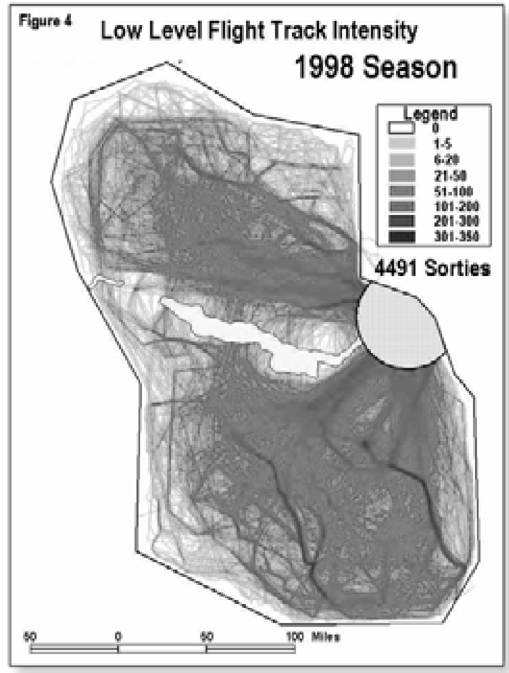
Figure 3 illustrates field truthing measurements showing noise levels at various distances from the aircraft noise source. Those measurements are overlaid on a simplified noise model with predicted values that do not consider such variables as wind, terrain or atmospheric conditions. This graphic supports statements made by earlier presenters that a lateral offset of 1000 meters provides sufficient buffer to ensure that the noise exposure does not exceed 90 dBA, below which impacts are not likely to occur. As you will see shortly, the protection criteria applied to our project far exceed this buffer range.



Finally, the noise dosage over the MTA can be visualized in Figure 4 - this data reflects the flight track intensity, and distribution, for the entire 1998 training season. Based on an average 200 days per season and on the indicated legend, more than 98% of the MTA experiences less than a single overflight per day. Only the areas indicated in brown and black (coinciding with river valley systems which are favored for terrain masking) receive more flights, but even these do not exceed 4 flights per day.

Follow-on Mitigation Program

Government decisions arising from the Panel's recommendations provide specific commitments and tasks to be undertaken by both DND and the Institute. All tasks assigned to DND have been fully implemented or



'operationalized' within published Mitigation Orders. These establish DND coordination and procedures associated with government-directed tasks and with those stemming from our annually revised Environmental Mitigation Program, which has been in place and under continuous development since 1990. The cost of operating that program is shared among the air forces training in Goose Bay. As the Responsible Authority under the environmental legislation, DND is solely responsible for establishing and managing a mitigation program appropriate to its activity. This program is also presented to the Institute, wildlife resource managers and aboriginal groups for comment as part of our consultation process. In that way, we can also consider how we might collaborate in various field studies or monitoring activities, thereby optimizing resources or providing mutual support to achieve complementary objectives.

The DND noise consultant, Mr. Neil Standen, earlier presented a concept that we are still developing as a future mitigation approach using noise modeling. To date, however, we have endeavored to refine an expanding program based on wildlife monitoring and avoidance. The credit for this development goes to Major Gary Humphries - the project has benefited from his continued participation over the last ten years.

Spatial and temporal separation of the flying activity from sensitive areas was adopted as the most practical method to mitigate, particularly until sufficient effects research could be conducted. It is based on a worst-case premise and reinforces Larry Pater's earlier statement that a lack of definitive knowledge of effects results in a conservative approach. The program is designed to afford population level protection to the various species and is based on an avoidance criteria matrix that caters to individual species' seasonal sensitivity. Priorities and standards are applied, based on the type of activity, safety, scientific or cultural importance, and on perceived sensitivity to aircraft noise disturbance. The Tables are reviewed annually, in consultation with wildlife and other Provincial officials and with the benefit of Institute recommendations.

Wildlife mitigation relies on a series of near real-time monitoring activities to gather population location and density information. This is based on a combination of satellite collar telemetry, aerial radio surveys, field studies or historical data, as depicted in Figure 5. When sensitive locations are identified, avoidance closures are designated and then issued as Operations Directives to each foreign operations center. From these, aircrews plot out the closures in preparation for their mission planning to remain clear of the identified locations. The avoidance protection standard (radius) may vary, but is often established as a 2.5 nautical mile radius (67 km2). A maximum total closure area of 40,000 km2 can be accommodated before measures are taken by DND to rescind closures such as to assure an absolute minimum of 90,000 km2 of unrestricted airspace available for training.

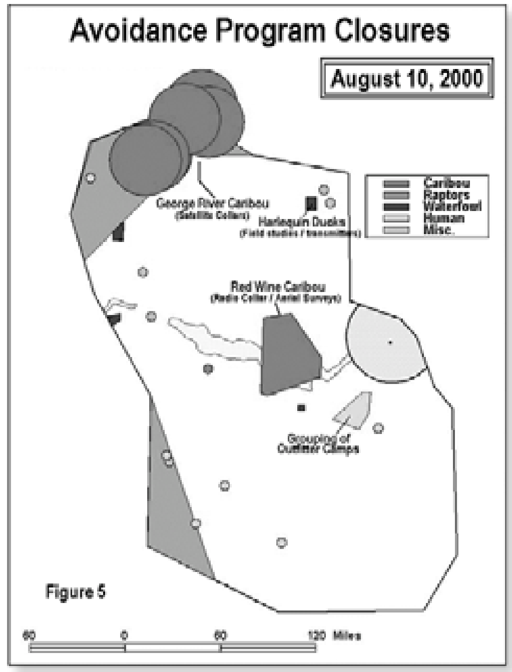


Figure 5

Compliance Monitoring

As a final step in the mitigation program, a Flight Track Compliance Monitoring function is designed to verify that the flying activity is conducted in accordance with applicable Flying Orders and that military aircraft are avoiding designated sensitive areas. This is particularly relevant to the Institute since it is expected to conduct an annual audit of that function. The Institute may also utilize the dataset in conducting its effects research activities.

The flight track information is reported by aircrews after every mission, entered into a digital file at the Base and downloaded daily by GBO staff in Ottawa. At that point, individual flight tracks are constructed

and overlaid on the constraint map in a centralized Geographic Information System (GIS) for analysis, in a somewhat more detailed manner than depicted at Figure 6. Results of this process indicate a high level of compliance on the part of aircrew.

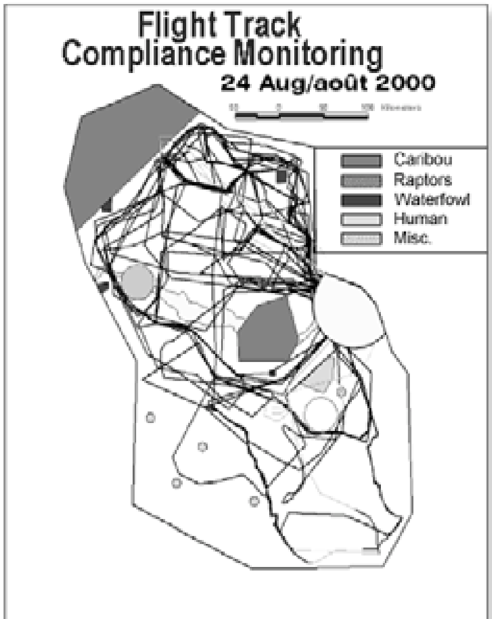


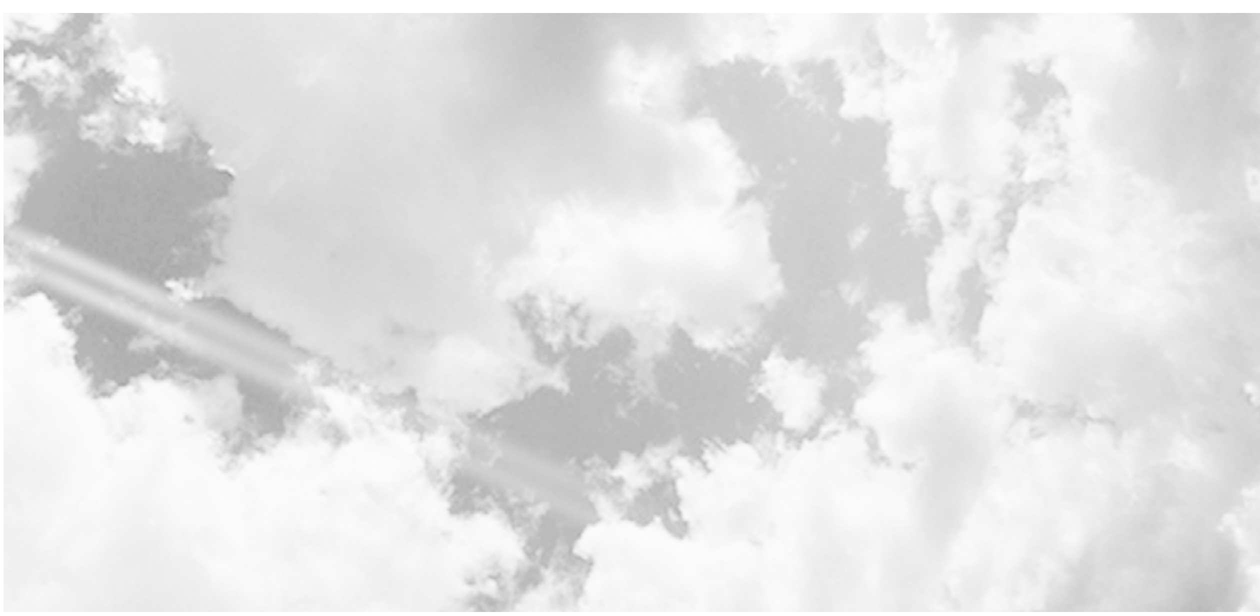
Figure 6

Concluding Remarks

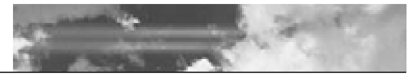
Environmental noise is a growing public policy and health issue, and one which DND continues to address. We are striving to improve the way in which we can best mitigate our activity and believe that the project setting which exists in the Goose Bay MTA lends itself to an environmentally sustainable program. Clearly, success rests largely on professionalism and cooperation of all parties and access to adequate resources and expertise.

Our office is in the process of revising our environmental management system with a view to registration to ISO 14001 standard within the next year. This is a commitment to continued improvement in every aspect of our environmental performance.

Should you be interested in obtaining more information on our training activity and mitigation program, I refer you to our website at www.goosebay.org.



Overflights and National Parks



Steven Opperman
National Parks Service
3015 S. Linley Court
Denver, Colorado 80236, USA

Overview

The National Park Service is required by law to preserve unimpaired the natural and cultural treasures of the United States, while providing for visitor enjoyment, and natural sounds are among those park resources and values to be protected. However, the sounds of nature are disappearing at an alarming rate, overwhelmed by mechanical noise from a wide variety of sources, one of which is aircraft. The opportunity to experience the sounds of nature and such values as serenity, tranquility and solitude can be a very important part of the visitor experience in many parks, a fact reinforced by recent nationwide surveys of park visitors. The growing disparity between visitor expectations and park sound environments is of increasing concern to the National Park Service. As Chip Dennerlein, Alaska Regional Director for the National Parks Conservation Association (NPCA), says, there are a number of parks that look much like they did 200 years ago, but very few that sound as they did even 20 years ago.

The Park Service is currently engaged in a major effort to characterize, document and preserve park "soundscapes", meaning all of the sounds that naturally occur there. A number of parks are starting to develop separate soundscape management plans, led by Biscayne, a national park in South Florida that covers more water than land. This plan will address all of the park's noise concerns, including the park's own operations, visitor activities, etc. Other parks, including Grand Canyon, Zion and Glacier, are now addressing overflights as part of overall noise management plans.

The depth of the Park Service's commitment to the preservation of park soundscapes is reflected in the agency's very recent decision to establish a Headquarters Office of Soundscape Management. This new office will be located in Fort Collins, Colorado, in recognition of the fact that the majority of soundscape issues have occurred to date in units of the inter-mountain and pacific west regions.

Commercial Air Tours

Commercial air tour flights over parks has been the highest profile overflights issue for more than a dozen years, starting with the enactment of Public Law 100-91, the National Parks Overflights Act, in 1987. That law, authored by Senator John McCain of Arizona following a mid-air collision between two sightseeing aircraft over Grand Canyon, required the Park Service and the Federal Aviation Administration (FAA) to work together toward the "substantial restoration of natural quiet" at the Canyon. It also required each agency to submit a report to Congress on the impacts of overflights throughout the National Park System. Since 1987, the number of air tour flights over Grand Canyon has increased from an estimated 40,000 to roughly 125,000 in 1996, and both the Park Service and the FAA have found that we've actually lost ground toward the statutory objective of substantially restoring natural quiet. In an effort to reverse this trend, and to make progress toward the legislative mandate, the FAA and the Park Service have recently published a final rule which includes new restrictions on air tour flights at the Grand Canyon, expanded "no-fly zones" over

American Indian cultural sites, and a cap on the number of flights. One of the key elements of the new rule is to provide incentives (e.g., more favorable routes) for operators who make use of quieter air technology.

While a number of park air tour management bills had been introduced in Congress since 1987, particularly in the period starting in 1994, no new system wide legislation had been enacted until this year. The 106th Congress, led by Senator John McCain of Arizona, Chairman of the Senate Commerce Committee, and Representative John Duncan of Tennessee, Chairman of the House Aviation Subcommittee, passed the National Parks Air Tour Management Act of 2000 as Title VIII of the FAA Reauthorization Act (Public Law 106-181) and the President signed it into law in April. The new law requires the development by FAA and the Park Service of an Air Tour Management Plan (ATMP) at any park where air tour operations exist or are proposed. Existing operations are "grand fathered" in at their current levels, but cannot be expanded or otherwise modified without the approval of both the Park Service and the FAA. New entrant operators cannot commence operations over a park until an ATMP has been developed and implemented, and one possible result of the ATMP would be that no air tour flights are allowed over that particular park.

On the administrative front, in December of 1993, Transportation Secretary Federico Pena and Interior Secretary Bruce Babbitt jointly established an interagency working group to address air tour overflight issues of mutual concern. The first priority of the group was to deal with major, high profile problem areas such as Grand Canyon and both of Hawaii's national parks–Haleakala and Hawaii volcanoes.

Then, on Earth Day 1996, President Clinton issued an executive memorandum directing all federal executive agencies to participate in the effort to preserve or restore natural quiet in the national park system. The executive memorandum provided a timetable for issuance of air tour rules for Grand Canyon and Rocky Mountain National Parks, and mandated the development of a national rule covering air tour operations over park areas throughout the system as well as a public education initiative.

In the spring of 1997, the FAA and the Park Service, acting to implement the President's executive memorandum, jointly appointed an advisory body – The National Parks Overflights Working Group (NPOWG) – to develop a draft national commercial air tour rule. The nine members of the NPOWG, all coming from the private sector (four selected by FAA, four selected by the Park Service, and one representing Native American interests), surprised virtually everyone by reaching consensus on a process for regulating air tour flights over park areas. The NPOWG recommended that an air tour management plan (ATMP) be developed for each park where air tour flights are proposed; the FAA and the Park Service would jointly conduct a planning process that would ensure public participation in the development of the ATMP. Such ATMP "may prohibit, authorize, or authorize with conditions commercial air tours". The NPOWG also urged Congress to "clarify the authority of the FAA and the Park Service to implement" the group's recommendations.

The legislative and administrative approaches to regulating commercial air tours over national parks have now dovetailed because both the McCain and Duncan bills were, like the draft national rule, based on the recommendations of The National Parks Overflights Working Group. The FAA and the Park Service are very close to finalizing the Notice of Proposed Rule Making (NPRM) to implement the new law. The NPRM will be published in the federal register and will provide a 60-day comment period. After the comment period ends, the agencies will review and analyze all comments and will make any appropriate and necessary changes to the text before publishing the final rule. The two agencies are also jointly developing a process for developing individual Air Tour Management Plans and are working together to determine the highest priority parks for the purpose of ATMP development. Implementing the new law will be a complex and, in many parks, controversial process which requires public input.

The task is further complicated by the fact that, while the two agencies are working together cooperatively, the Park Service and the FAA have very different missions and organizational cultures.

Military Overflights

While the issue of military overflights of national park units has been much less publicized than that of commercial air tours, many more parks have the potential to be affected by military flights than by air tours. National Parks Conservation Association surveys of park managers have consistently revealed major concerns about military overflights. In fact, in the most recent survey, close to half of the 378 or so units scattered throughout the country reported actual or potential military overflight issues. The potential for so many national park units throughout the system to be affected by military overflights is one of the main reasons that the Park Service participates in Regional Air Force Airspace and Range Meetings around the U.S. on a regular basis.

Largely as a result of its ongoing participation in these meetings, the Park Service has established and maintained a very good working relationship with the Air Force, and is now in the process of doing the same thing with Navy. In the case of Joshua Tree National Park, in the desert lands of Southern California near Palm Springs, the Park Service worked with both Navy and Air Force to move an existing Navy training route. The park benefited because the route was moved to a less sensitive resource (e.g., desert tortoise) and visitor use area, and the Navy gained because it was able to do lower-altitude training over portions of the new route. The Air Force and the Navy have cooperated with the Park Service in reducing the impact of flights over Sequoia-Kings Canyon National Parks. In fact, the Commanding General at Edwards Air Force Base now requires any unit that plans to fly over the park to get his personal approval in advance. He recommended to Air Force Headquarters that flights over the park take place no lower than 18,000 feet above ground level. The Pentagon has now accepted that recommendation.

The special working relationship that has developed between the Park Service and the Air Force is illustrated by the fact that the Park Service is the only non-department of defense agency to have hosted one of these regional meetings, and has now done so twice, first in Palm Springs in July of 1997 and then again in March of 1998 in Santa Fe. In addition, the Chief of Ranges and Airspace for the regular Air Force appears in "wild minute" videotaped segments which are part of the Park Service's public education campaign on "natural quiet".

In an effort to expand the knowledge base in both agencies, and to encourage the identification and resolution of issues/problems at the lowest possible level, the Air Force and the Park Service are in the early stages of developing a communication guidebook. The plan is for one guidebook to be developed for each of the six Air Force regions. Each guidebook will provide contact points and phone numbers at each base/installation and each park unit within the region. It will also contain a wide variety of information about each agency, including organizational structure from top to bottom; park and base locations; overflight maps; missions; resources; types of military aircraft flown; park resources to be protected; visitor expectations; success stories; and a guide to agency-specific terms and symbols.

Aircraft Use by the Park Service and Other Agencies

The National Park Service owns or leases aircraft in a number of parks to accomplish certain missions, including resource management, maintenance, and search and rescue. Thus, the Park Service's own aviation use can adversely impact a park's soundscape. In addition, other land management agencies such as the U.S. Forest Service may fly over park units (e.g., to fight wildfires), and law enforcement agencies such as the Drug Enforcement Administration, the Federal Bureau of Investigation, and the U.S. Customs Service may transit the airspace over a park unit.

Park Service management recognizes that the agency must actively manage its own use of aircraft and that of other agencies and must budget money to purchase or lease aircraft, which utilize quieter air technology. One example of the Park Service's commitment in this area is the new "quiet air technology" helicopter that is being leased by Grand Canyon National Park at a far greater cost than the lease that it terminated.

General Aviation

General aviation flights take place over or near a number of park units. While such flights can have adverse impacts on parks, in most cases general aviation flights are occasional rather than routine, and they are only viewed as a significant problem by a relatively small number of park managers. The Park Service has established and maintained a working relationship with the Aircraft Owners and Pilots Association (AOPA), the largest general aviation organization in the United States. The Park Service also attempts to maintain communication with pilots' organizations in various states, and staffs a booth each year at the Oshkosh Air Show, the largest air show in the United States.

Airports In or Near Park Units

Commercial or general aviation airports in or around certain national park units can have significant impacts on park soundscapes. Accordingly, the National Park Service is attempting to become more involved in the FAA's planning process with regard to establishing new airports or modifying existing ones within or in the vicinity of park units.

There are a number of park units around the national park system where commercial or general airports either already exist or are in the planning stages. Perhaps the major current problem area is South Florida, where Homestead Air Force Base, which was devastated by hurricane Hugo, is in the process of being turned over to Dade County for use as an alternative to overcrowded Miami International Airport. Another ongoing, and extremely complex, issue is the FAA's proposal to extend the length of runways at the commercial airport operating in Grand Teton National Park. There is also a commercial airport that operates just outside Glen Canyon National Recreation Area in southern Utah. The town of Hulett, Wyoming, near Devils Tower National Monument, has proposed building a commercial airport; at one point, the plan was to have aircraft taking off directly toward the monument. The FAA is also proposing to extend the runways at busy Kahului Airport on Maui, Hawaii, thus allowing larger aircraft to arrive, and increasing the threat to Halaeaka National Park from invasive exotic species, including the Guam brown tree snake. The newest threat from commercial aviation airports is to Mojave National Park and preserve in Eastern California. Clark County, Nevada, aviation officials are looking to build a new airport near the park, which would serve as a reliever airport to McCarren International Airport in Las Vegas.

In many cases, the Park Service has not had the opportunity to participate meaningfully in the FAA's process for establishing or modifying commercial or general aviation airports in the vicinity of units of the national park system. There have been a few exceptions, such as Grand Teton, where the fact that the airport is actually located within the park and the park staff's continued efforts to articulate and protect the interests of Grand Teton have resulted in ongoing discussions among FAA, the Park Service, and the Airport Board, up to and including the national offices of the two agencies. There are a number of signs of increasing sensitivity on the part of the FAA to Park Service concerns, including contacts initiated by FAA with the Park Overflights Coordinators in the Park Service's inter-mountain and pacific west regions.

Sound Education Plan

The National Park Service recently developed a comprehensive, multimedia education package, dubbed "the nature of sound". This package is designed to educate park staff, the visiting and general public, school children, aviation interests, etc., as to the importance of preserving park soundscapes. Parks can use the interpretive program "off the shelf" or can adapt it to meet a park's specific needs.

Conclusion

Public Law 106-181, Title VIII, The National Parks Air Tour Management Act of 2000, only deals with one facet – commercial air tours – of park overflights, which, in turn, is only one aspect of soundscape management, but has heightened public awareness of Park Service efforts to preserve the sounds of nature in appropriate units of the national park system. It has also served as a catalyst for Park Service efforts to address other major mechanical noise concerns such as snowmobiles, personal watercraft, trains, buses, and maintenance vehicles operated by the Park Service itself or by park concessionaires, etc. The Park Service is in the process of developing management policies, directors' orders, and other internal guidelines that will complete the regulatory framework for these efforts to address park soundscape management issues. The "bottom line" is that visitors have a reasonable expectation of experiencing tranquility, serenity, peace and solitude in certain park areas, and the National Park Service is determined to continue providing that opportunity. And while much more research is required, existing research indicates that certain species of wildlife in national park units may be affected by mechanical noises.

Delegate List

Australia

Prof. Lex Brown
School of Environmental Planning
Griffith University
Room 0.21 E1 (Environment 1 Building) Nathan Campus
Brisbane, Queensland 4111
Australia
Email: Lex_Brown@hotmail.com
Telephone: 61 (07) 3875-7645
Fax: 61 (07) 3875-6684

Canada

David Alexander
Public Works and Government Services Canada
Municipal Grants and Land Information
PO Box 2247, 1713 Bedford Row
Halifax, NS
B3J 3C9
Email:
david.alexander@pwgsc.gc.ca
Telephone: 902-496-5252
Fax: 902-496-5276

Wally Anderson, M.H.A.
Torngat Mountains District
3rd Floor, East Block, Confederation Building
PO Box 8700
St. John's, NF
A1B 4J6
Email: wanderson@mail.gov.nf.ca
Telephone: 709-729-0990/0989
Fax: 709-729-5774

Daniel Ashini
Innu Nation
PO Box 409
Sheshatshiu, Labrador
A0P 1M0
dashini@innu.ca
Telephone: 709-497-8875
Fax: 709-497-8396

Jackie Ashini
General Delivery
Sheshatshiu, Labrador
A0P 1M0

Stanley Baikie
Town Office-Churchill Falls
PO Box 87
Churchill Falls, Labrador
A0R 1A0
Email: sbaikie@cancom.net
Telephone: 709-925-3402
Fax: 709-925-3384

Maureen Baker
Administrative Manager
Institute for Environmental Monitoring and Research
PO Box 1859, Stn. "B"
Happy Valley-Goose Bay, Labrador
A0P 1E0
Email: mbaker@cablelab.net
Telephone: 709-896-3266
Fax: 709-896-3076

Guy Bellefleur
Mamit Innuat
700, Boul Laure, Bureau 208
Sept-Îles, QC
G4R 1Y1
Email: innuqc@quebectel.com
Website: www.innu.ca

Gilles Champoux
National Defence Headquarters
Major General Pearkes Building
101 Colonel By Drive
Ottawa, ON
K1A 0K2
Email:
gj.champoux@debbs.ndhq.dnd.ca
Telephone: 613-995-7008
Fax: 613-995-1031

Tony Chubbs
Mitigation Officer
Goose Bay Office
(5 Wing Goose Bay)
PO Box 7002, Stn. "A"
Happy Valley-Goose Bay, Labrador
A0P 1S0
Email: techubbs@cablelab.net
Telephone: 709-896-6900 ext. 7811
Fax: 709-896-1909

Gus Dicker
PO Box 16
Nain, Labrador
A0P 1L0
Telephone: 709-922-2942
Fax: 709-922-2931

Rachel Dubois
Ministère Des Affaires Indiennes
10 Wellington, 8é étage
Hull, QC
K1A 0H4
Email: duboisr@inac.gc.ca
Telephone: 819-953-2771
Fax: 819-997-5517

Michael A. D. Ferguson, Ph.D.
Regional Wildlife Biologist
Sustainable Development
Government of Nunavut
Pond Inlet, NU X0A 0S0
Email: baffbio@nunanet.com
Telephone: (867) 899-8876
Fax: (867) 899-8711

Alain Fontaine
Wildlife Biologist
Institute for Environmental
Monitoring and Research
PO Box 1859, Stn. "B"
Happy Valley-Goose Bay, Labrador
A0P 1E0
Email: afontaine@cablelab.net
Telephone: 709-896-3266
Fax: 709-896-3076

Paul Fougère
Department of National Defence
340 Reynolds Drive
Orleans, ON
K1E 1T2
Email: p.fougere@dnd.ca
Telephone: 613-995-8714
Fax: 615-995-1031

Ian Goudie
17 Waterfowl Bridge Road
St. John's, NF
A1E 1C5
Email: igoudie@thezone.net
Telephone: 709-579-9238
Fax: 709-579-9244

Rex Goudie
Director, Labrador and Aboriginal
Affairs
PO Box 3014, Stn. "B"
Happy Valley-Goose Bay, Labrador
A0P 1E0
Email: rgoudie@mail.gov.nf.ca
Telephone: 709-896-1780
Fax: 709-896-0045
Website: www.nf.gov.ca

Fred Harrington, Ph.D.
Chair, Psychology Department
Mount Saint Vincent University
Halifax, NS
B4M 2J6
Email: fred.harrington@msvu.ca
Telephone: 902-457-6230
Fax: 902-457-6455
Website: www.msvu.ca

Kevin Head
Innu Nation
PO Box 13
Davis Inlet, Labrador
A0P 1A0
Email: khead@innu.ca
Telephone: 709-478-8943
Fax: 709-478-8833
Website: www.innu.ca

Rexanne Hopkins
Conference Coordinator
PO Box 6487
Manuels, NF
A1W 1L5
Email: hopkins@nfld.com
Telephone: 709-834-7110

Major Gary Humphries
Goose Bay Office
National Defence Headquarters
General Pearkes Building
Ottawa, ON
K1A 0K2
Email: ghumphries@goosebay.org
Telephone: 613-996-1787
Fax: 613-996-7162

Jean Huot, Ph.D.
Directeur
Départment de biologie
Pav. Alexandre -Vachon
Université Laval
Ste-Foy, QC G1K 7P4
Email: jean.huot@bio.ulaval.ca
Telephone: 418-656-7954
Fax: 418-656-2043

Bart Jack Sr.
Self-Government Negotiator
Innu Nation
PO Box 119
Sheshatshiu, Labrador
A0P 1M0
Telephone: 709-497-8398
Fax: 709-497-8396
Website: www.innu.ca

Colin Jones
Wildlife Biologist
Institute for Environmental
Monitoring and Research
PO Box 1859, Stn. "B"
Happy Valley-Goose Bay, Labrador
A0P 1E0
Email: cjones@cablelab.net
Telephone: 709-896-3266
Fax: 709-896-3076

Thomas Jung
Wildlife Biologist
Institute for Environmental
Monitoring and Research
PO Box 1859, Stn. "B"
Happy Valley-Goose Bay, Labrador
A0P 1E0
Email: tjung@cablelab.net
Telephone: 709-896-3266
Fax: 709-896-3076

Jean-Baptiste Lalo
Conseil des Innu de Unamen Shipu
La Romaine, Québec G0G 1M0
Email: 1mark@globetrotter.net
Telephone: 418-229-2917
Fax: 418-229-2921

Chef Marcel Lalo
Conceil Des Innu de Pakua Shipi
C.P. Pakua Shipi, QC G0G 2R0
Email: elalo@globetrotter.net

Louis LaPierre, Ph.D.
Chair
Institute for Environmental Monitoring and Research
PO Box 1722
Moncton, NB E1C 9X5
Email: lapierl@umoncton.ca
Telephone: 506-863-2056
Fax: 506-863-2000

Hilda Letemplier
Central Labrador Economic Development Board
PO Box 390, Stn."B"
Happy Valley-Goose Bay, Labrador
A0P 1E0
Email: northoxy@cancom.net
Telephone: 709-896-0529
Fax: 709-896-0530
Website: www.centrallabrador.nf.ca

Patricia Loder, P.Ag
Industrial Technology Advisor – Labrador
PO Box 1720, Stn. "B"
Happy Valley-Goose Bay, Labrador
A0P 1E0
Email: patricia.loder@nrc.ca
Telephone: 709-896-6347
Fax: 709-896-9533

Dan MacKenzie
Senior Analyst
Executive Council – Intergovernmental Affairs Secretariat
PO Box 8700
St. John's, NF
A1B 4J6
Email: danm@mail.gov.nf.ca
Telephone: 709-729-2980
Fax: 709-729-5038
Website: www.gov.nf.ca

András Mák
1111, ave de Bourlamaque
Québec, Québec
G1R 2P4
Email: amak@globetrotter.net
Telephone: 418-522-0828
Fax: 418-522-6316
Website: www.innu.ca

Jean-Baptiste Malleck
Conseil des Innu de Pakua Shipi
C.P. 178
Pakua Shipi, QC G0G 2R0

Chef Léo Mark
Conseil des Innu de Unamen Shipu
La Romaine, QC G0G 1M0
E-mail: 1mark@globetrotter.net
Telephone: 418-229-2917
Fax: 418-229-2921

William Pierre Mark
Conseil des Innu de Unamen Shipu
La Romaine, Québec G0G 1M0
Email: 1mark@globetrotter
Telephone: 418-229-2917
Fax: 418-229-2921

Brigitte Masella
Paul F. Wilkinson and Associates
5800, ave. Monkland, 2e étage
Montréal, QC
H4A 1G1
Email: masella@wilkinson.ca
Telephone: 514-482-6887
Fax: 514-482-0036

Col. Paul McCabe
Wing Commander, 5 Wing Goose Bay
PO Box 7002, Stn. "A"
Happy Valley-Goose Bay, Labrador
A0P 1S0
Email: hq@hvgb.net
Telephone: 709-896-6900 ext. 7200
Fax: 709-896-6997

Armand McKenzie
Mamit Innuat
700 Boul. Laure, Bureau 208
Sept-Îles, Québec
G4R 1Y1
Email: amck@quebectel.com
Telephone: 418-968-4890
Fax: 418-968-2370

Ben Michel
Lands Rights Negotiator
Innu Nation
PO Box 119
Sheshatshiu, Labrador
A0P 1M0
Email: bmichel@innu.ca
Telephone: 709-497-838-98
Fax: 709-497-8396
Website: www.innu.ca

Jérôme Mollen
Conseil des Innu d'Ekuanitshit
28 rue Manitou
C.P. 319
Mingan, QC G0G 1V0

Vincent Napish
Conseil des Innu d'Ekuanitshit
28 rue Manitou
C.P. 319
Mingan, QC G0G 1V0

Lieutenant Colonel Koen Nobbe
Wing Commander – Royal Netherlands Air Force
PO Box 355, Stn. "A"
Goose Bay, Labrador
A0P 1S0
Email: rnlaf@hvgb.net
Telephone: 709-896-6900 ext. 6400
Fax: 709-896-6403

Judy O'Dell
Deputy Mayor, Town of Happy Valley-Goose Bay
PO Box 40, Stn. "B"
Happy Valley-Goose Bay, Labrador
A0P 1E0
Email: jaodell@yahoo.com
Telephone: 709-896-3321
Fax: 709-896-9454
Website: www.happyvalley-goose-bay.com

Stanley Oliver
Executive Assistant to the Minister Ernest McLean
PO Box 719, Stn. "B"
Happy Valley-Goose Bay, Labrador
A0P 1E0
Email: soliver@cablelab.net
Telephone: 709-896-3099
Fax: 709-896-8461

Keith Oram
Jacques Whitford Environment Ltd.
PO Box 274, Stn. "C"
Happy Valley-Goose Bay, Labrador
A0P 1C0
Email: koram@jacqueswhitford.com
Telephone: 709-896-5860
Fax: 709-896-5863

Robert Otto
Senior Wildlife Biologist (Labrador)
Inland Fish and Wildlife Division
Department of Forest Resources and Agrifoods
PO Box 3014, Stn. "B"
Happy Valley-Goose Bay, Labrador
A0P 1E0
Email: robotto@cablelab.net
Telephone: 709-896-5107
Fax: 709-896-0188

Donna Paddon
Assistant to the President
Innu Nation
PO Box 119
Sheshatshiu, Labrador
A0P 1M0
Email: dpaddon@innu.ca
Telephone: 709-497-8398
Fax: 709-497-8396
Website: www.innu.ca

Gerry Parker
Canadian Wildlife Service
PO Box 6227, 17 Waterfowl Lane
Sackville, NB
E4L 1G6
Email: gerry.parker@ec.gc.ca
Telephone: 506-364-5045
Fax: 506-364-5062

Tony Parr
GIS Specialist
Institute for Environmental Monitoring and Research
PO Box 1859, Stn. "B"
Happy Valley-Goose Bay, Labrador
A0P 1E0
Email: tparr@cablelab.net
Telephone: 709-896-3266
Fax: 709-896-3076

Dennis Peck
Economic Development Officer
Town of Happy Valley-Goose Bay
PO Box 40, Stn. "B"
Happy Valley-Goose Bay, Labrador
A0P 1E0
Email: development@happyvalley-goosebay.com
Telephone: 709-896-5427
Fax: 709-896-9454
Website: www.happyvalley-goose-bay.com

Chef Jean-Charles Piétacho
Conseil des Innu d'Ekuanitshit
28 rue Manitou
C.P. 319
Mingan, QC G0G 1V0
Email: jpetahu@ekuanitshit.qc.ca

Philippe Piétacho
Conseil des Innu d'Ekuanitshit
28 rue Manitou
C.P. 319
Mingan, QC G0G 1V0

Peter Penashue
President
Innu Nation
PO Box 119
Sheshatshiu, Labrador
A0P 1M0
Email: utshimau@innu.ca
Telephone: 709-497-8398
Fax: 709-497-8396
Website: www.innu.ca

Lieutenant Colonel (Ret'd) Maurice Pigeon
Goose Bay Office
National Defence Headquarters
General Pearkes Building
Ottawa, ON
K1A 0K2
Email: mpigeon@goosebay.org
Telephone: 613-992-8463
Fax: 613-996-7162

Daniel Poker
Mushuau Band Council
PO Box 107
Davis Inlet, Labrador
A0P 1A0
Telephone: 709-478-8827
Fax: 709-478-8936

Sarah Proceviat
Large Mammal Research Center (Dr. F.F. Mallory)
Dept. of Biology
Laurentian University
935 Ramsey Lake Road
Sudbury, ON
P3E 2C6
Email: sarah.p@sympatico.ca
Telephone: 705-675-1151 ext. 2290
Fax: 705-675-4859

Cynthia Pye
Program Coordinator
Labrador Métis Nation
PO Box 2164, Stn."B"
Happy Valley-Goose Bay, Labrador
A0P 1E0
Email: labmetis@hvgb.net
Telephone: 709-896-0592
Fax: 709-896-0594

Chief Paul Rich
Sheshatshiu Band Council
PO Box 160
Sheshatshiu, Labrador
A0P 1M0
Email: chiefprich@nf.aibn.com
Telephone: 709-497-8522
Fax: 709-497-8757

Judy Rowell
PO Box 70
Nain, Labrador
A0P 1L0
Email: jrowell@nunatsiavut.com
Telephone: 709-922-2942
Fax: 709-922- 2931

Carter Russell
Manager
Labrador Métis Nation
PO Box 2164, Stn."B"
Happy Valley-Goose Bay, Labrador
A0P 1E0
Email: labmetis@hvgb.net
Telephone: 709-896-0592
Fax: 709-896-0594

Jim Schaefer, Ph.D.
Trent University
Peterborough, ON
K9J 7B8
Email: jschaefer@trentu.ca
Telephone: 705-748-1378
Fax: 705-748-1378

Brent Sellars
Newfoundland and Labrador Hydro
PO Box 12400
St. John's, NF
A1B 4K7
Email: bsellars@nlh.nf.ca
Telephone: 709-737-1764
Fax: 709-737-7777

Jack Selma
General Delivery
Sheshatshiu, Labrador
A0P 1M0
Telephone: 709-497-8398
Fax: 709-497-8396

Neil Standen
3266 Kodiak Street
Ottawa, ON
K1V 7S8
Email: standen.ual@sympatico.ca
Telephone: 613-521-4251
Fax: 613-523-8408

Jason Stevenson
Large Mammal Research Center (Dr. F.F. Mallory)
Dept. of Biology
Laurentian University
935 Ramsey Lake Road
Sudbury, ON
P3E 2C6
Telephone: 705-675-1151 ext. 2290
Fax: 705-675-4859

Robyn Stevenson
Large Mammal Research Center (Dr. F.F. Mallory)
Dept. of Biology
Laurentian University
935 Ramsey Lake Road
Sudbury, ON
P3E 2C6
Telephone: 705-675-1151 ext. 2290
Fax: 705-675-4859

Anne Storey, Ph.D.
Department of Psychology
Memorial University of Newfoundland
St. John's, NF
A1B 3X9
Email: astorey@play.psych.mun.ca
Telephone: 709-737-7665
Fax: 709-737-2430
Website: www.mun.ca

Peter Thomas
Environment Canada
6 Bruce Street
Donovans Industrial Park
Mount Pearl, NF A1N 4T3
Email: peter.thomas@ec.gc.ca
Telephone: (709) 772-4297
Fax: (709) 772-5097

Perry Trimper
Jacques Whitford Environment Ltd.
P.O. Box 274, Station "C"
Happy Valley-Goose Bay
Labrador, NF
A0P 1C0
Email:
ptrimper@jacqueswhitford.com
Telephone: 709-896-5860
Fax: 709-896-5863

Lieutenant Colonel Tubi
Wing Commander – Italian Air Force
PO Box 7002, Stn. "A"
Goose Bay, Labrador, NF
A0P 1S0
Telephone: 709-896-6900 ext.
7719/7080
Fax: 709-896-1948

Bruce Turner
Head, NF-LAB Wildlife Conservation
Section
Environment Canada, Environment
Conservation Branch
Canadian Wildlife Service
6 Bruce Street
Mount Pearl, NF
A1N 4T3
Email: bruce.turner@ec.gc.ca
Telephone: 709-772-3278
Fax: 709-772-5097

Natasha Voisey
Administrative Assistant
Institute for Environmental
Monitoring and Research
PO Box 1859, Stn. "B"
Happy Valley-Goose Bay,
Labrador, NF
A0P 1E0
Email: iemr@hvgb.net
Telephone: 709-896-3266
Fax: 709-896-3076

Ron Webb
PO Box 99
Nain, Labrador
A0P 1L0
Telephone: 709-922-2942
Fax: 709-922-2931

Jonathan Wiersma
Large Mammal Research Center (Dr.
F.F. Mallory)
Dept. of Biology
Laurentian University
935 Ramsey Lake Road
Sudbury, ON
P3E 2C6
Email: jh_wiersma@hotmail.com
Telephone: 705-675-1151 ext. 2290
Fax: 705-675-4859

Wing Commander R.D. Wright
Royal Air Force Unit
PO Box 907, Stn. "A"
Goose Bay, Labrador
A0P 1S0
Email:
admin.rafu_goosebay@cablelab.net
Telephone: 709-896-6900 ext.
6800
Fax: 709-896-6806

United States of America

Ann E. Bowles, Ph.D.
Senior Research Biologist
Hubbs-Sea World Research Institute
2595 Ingraham Street
San Diego, CA 92019
Email: annb1@san.rr.com
Telephone: 619-226-3870
Fax: 619-226-3944

W. James Fleming, Ph.D.
U.S. Geological Survey
Biological Resources Division
12201 Sunrise Valley, Mailstop 300
Reston, Virginia 21092
Email: jim_fleming@usgs.gov
Telephone: 703-648-4261
Fax: 703-648-4269

Garth Hengen, Ph.D.
Chief Executive Officer
Industrial Hearing Health
Associates, Inc.
19 Midstate Drive, Suite 220
Auburn, MA 01501
Email: garthhengen@industrialhearing.com
Telephone: 508-832-8484
Fax: 508-832-3199

Martha Hengen, B.A.
Controller
Industrial Hearing Health
Associates, Inc.
19 Midstate Drive, Suite 220
Auburn, MA 01501
Email: mardyhengen@industrialhearing.com
Telephone: 508-832-8484
Fax: 508-832-3199

Robert J. Henke
Science Applications International Corporation (SAIC)
8100 Shaffer parkway; Suite 100
Littleton, Colorado 80127
Email: henker@saic.com
Telephone: 720-981-2414
Fax: 720-981-7488

Barbara Hunsaker
11458 Meadow Creek Road
El Cajon, CA 92020
USA
Email: bhunsaker2@juno.com
Telephone: 619 444-4211

Don Hunsaker, Ph.D.
Hubbs Sea World Research Institute
2595 Ingraham St.
San Diego, CA 92109
USA
Email: dhunsak@hswri.org
Telephone: 619 444-4211
Fax: (619)-588-7408

Julie Maier, Ph.D.
Institute of Arctic Biology
University of Alaska Fairbanks
Fairbanks, AK 99775
Email: ftjak@uaf.edu
Telephone: 907-474-7172
Fax: 907-474-6967

Mark Miller
336 S. Garfield Ave.
Schuylkill Haven, PA 17972
Email: mark_w_miller@hotmail.com
Telephone: 570-385-3387

Stephen Murphy
ABR Inc. -- Environmental Research and Services
PO Box 80410
Fairbanks, AK 99708, USA
Email: smurphy@abrinc.com
Telephone: (907) 455-6778
Fax: (907) 455-6781

Stephen M. Oppermann
3015 S. Linley Court
Denver, Colorado 80236
Telephone: (303) 922-7409
Fax: (303) 922-5290
Email: opie89@hotmail.com
Email: steve_oppermann@nps.gov

Larry Pater, Ph.D.
Project Leader for Military Noise Management
US Army Corps of Engineers
Engineer Research and Development Center (ERDC)
Construction Engineering Research Lab (CERL)
2902 Farber Drive
Champaign, Illinois 61821
Email: l-pater@cecer.army.mil
Telephone: (217) 373-7253 or 1-800-USACERL ext. 7253
Fax: 217-373-7251
Website: www.cecer.army.mil

Jackie Smith
Natural Resources Branch
Naval Air Station
22541 Johnson Road
Patuxent River, MD 20670-1700
Email: smithjc@navair.navy.mil
Telephone: 301-757-0007
Fax: 301-757-1889

David Ward
US Geological Survey
Alaska Biological Sciences Center
1011 E. Tudor Rd.
Anchorage, Alaska 99053
United States of America
Email: david_ward@usgs.gov
Telephone: 907-786-3525
Fax: 907-786-3636

Thomas Wright
1314 Harwood St. SE
Code 20
Washington Navy Yard
Washington, DC 20374
Email: wrightta@efaches.navfac.navy.mil
Telephone: 202-685-3447
Fax: 202-685-3350

Note

The following presentations were made at the Conference but no abstract or paper was submitted for publication in the proceedings:

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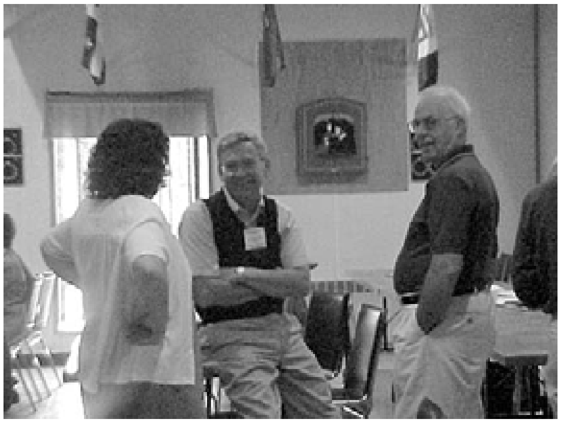
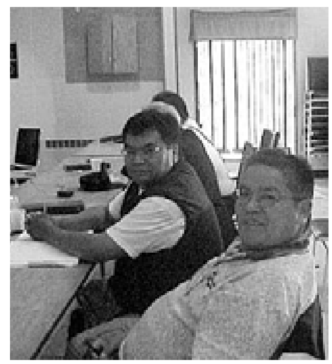
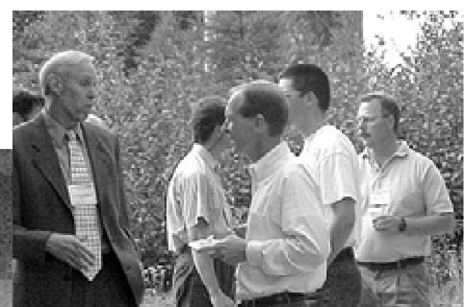
Photographs







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Ann Bowles, Hubbs Sea World Research Institute, USA

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