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Emerging directions in acoustic ecology – trends within Canada's national protected areas system

Jeannette Theberge
Parks Canada
jen.theberge@pc.gc.ca

Benjamin Dorsey
Independent Researcher
bpdorsey@gmail.com

ABSTRACT

A survey of ecologists in Parks Canada's protected area units (PAU) was conducted to understand the breadth of acoustic ecology applications, particularly current emphases, trends over the past two decades, and future trajectories. Eighty-seven acoustic projects, in 36 PAU, involve detection of species, monitoring of ecosystems, and to a smaller extent documentation of soundscape, anthropogenic noise and cultural sound. On average these PAU have ≥3 acoustic projects each; the longest project conducted for 18 years. Focus of projects has evolved across years (through birds, bats, marine, soundscape).

Described are emerging directions in acoustic ecology evident in Canadian national PAU, including: enhancing research on most taxa (i.e., aquatic species); improving species detection to identify changing spatial-temporal patterns (e.g., climate, noise); documenting anthropogenic noise impact; comparative analysis of biodiversity changes in soundscapes; and increasing technique efficiencies (e.g., automated detection, broad scales). Acoustics could contribute to PAU research priorities (e.g., arthropod inventory, geophysical rate changes, fragmentation restoration, population dynamics), and objectives (e.g., societal wellbeing, cultural landscape). Needed is commitment to document metadata, secure long-term data storage, and contribute to Open Data to ensure future utility of acoustic information. We hope the identification of these emerging directions help formulate momentum and synergies between agencies.

1. INTRODUCTION

Protected areas around the globe contribute to nature conservation but are increasingly impacted by regional and global environmental change. Over the past two decades, Canadian protected areas have turned to acoustic ecology to help document ecosystem and population changes, and to search for restoration opportunities [1]. As the field of acoustic ecology has evolved, so has its application in protected areas.

This paper provides a novel review of the state, breadth, challenges, and future potential of acoustic ecology research and monitoring for conservation and management in protected areas administered by Parks Canada. These areas include national parks and marine conservation areas, whose mandates of ecological integrity and sustainability encompass the perpetuation of acoustics which have evolved in place over millennia.

Most notably in this paper, we summarize emerging directions in acoustic ecology in these protected areas hoping to encourage momentum and synergies with other agencies on these topics to enhance progress towards effective conservation outcomes.

2. METHODS

During October 2022, a survey was distributed to 92 Parks Canada practitioners (i.e., ecologists and resource conservation specialists) within Protected Area Units (PAU). The survey targeted PAU with objectives to conserve ecological integrity or ecological sustainability (i.e., national parks [NP], reserves [NPR], national marine conservation areas [NMCA], national urban parks [NUP], and national historic sites [NHS]).

Survey respondents answered 15 questions and described several (≤ 3) examples regarding acoustic ecology projects in their PAU. Acoustic ecology projects were defined as any collection of environmental sound, regardless of purpose, method, or periodicity of collection.

Survey responses were organized in a database and were summarized using R statistical software [R Core Team 2022]. Several survey questions were re-classified into quantitative or categorical data.

3. RESULTS

3.1 Characteristics of acoustic projects

Thirty-nine ecologists reported on acoustic projects in 36 different PAU administered by Parks Canada. Eighty-one percent of responses represented NP and NPR. The remainder were NMCA, NUP, waterways, and one national-scale fire management program.

Details were provided for 87 acoustic ecology projects either currently underway (82) or recently completed in the past decade (5). Purpose of acoustic ecology projects was primarily related to environmental elements and conservation (Table 1). A smaller proportion addressed social aspects.

Acoustic Project Rationale	**%**
Species at risk	18
Monitoring of environmental change	17
Detection of species (e.g., uncommon, invasive)	16
Climate change (e.g., effects, adaptation)	8
Research of ecological relationships	7
Anthropogenic sound (e.g., detection, change)	6
Library of sound (e.g., variability in species)	5
Restoration documentation	5
Ecological corridors or connectivity	4
Soundscape or cultural landscape	4
Establishment of protected areas	3
Visitor experience, Societal wellness	3
Environmental impact assessment, surveillance	2
Virtual experience (e.g., internet)	1
Oral history	1

Table 1. Rationale for acoustic ecology projects in protected areas administered by Parks Canada, 2002-2022, by proportion of total projects. Projects often subscribed to more than one rationale.

On average there were 3.2 active projects per PAU, with maximum being 11 projects in Gwaii Haanas NPR. Engagement in acoustic ecology projects is anticipated to increase. Over half of PAU respondents plan to develop 1 or 2 additional projects (maximum = 5 at La Mauricie NP), adding approximately 36 acoustic projects to the 82 currently underway.

Projects underway or completed by Parks Canada have accumulated more than 442 project-years of acoustic data. Individual projects ranged in duration from 1 to 18 years, the longest being in Riding Mountain NP. While half of the projects had $\leq$ 4 years of data, 30% had been conducted for 4-10 years.

3.2 Scope of current acoustic ecology projects

Ecosystems are diverse and varied in Parks Canada's protected areas system. Most (60%) acoustic projects were conducted in terrestrial environments. Thirty-five percent investigated aquatic environments. A small portion addressed cultural sound or anthropogenic noise.

Terrestrial projects primarily targeted birds (35 projects) and bats (22 projects), situated in various ecosystem types, and focusing on environmental monitoring or rare species detection. Few projects involved large mammals (e.g., moose calls in Nahanni NPR).

Aquatic acoustic projects were established in freshwater, marine, and wetland ecosystems. Generally, marine projects focused on anthropogenic noise disrupting species at risk (e.g., Orca). The efficacy of protection measures (i.e., sanctuary zones, reduced vessel speed) is being explored in Gulf Islands NPR. Several wetland projects evaluated the effectiveness of long-term (7-year) acoustic data to monitor amphibian presence and population trends (i.e., Thousand Islands NP and Banff NP).

Some acoustic projects involved both terrestrial and aquatic monitoring under a mutual goal but reported these as separate projects (i.e., research prior to bridge construction at the Rideau Canal NHS).

Projects of longest duration related to long-term ecosystem monitoring programs, particularly those regarding terrestrial songbirds - many of which have been conducted >8 years. Other long running projects focused on documenting rare populations listed under the Species at Risk Act. Conversely, short-term projects related to the local resolution of management issues and to environmental assessments of proposed developments, targeting multiple species in terrestrial or underwater environments.

3.3 Soundscape and human experience

Only 10 acoustic projects involved rationales to typify broad-scale environmental soundscape [2] or cultural landscape. The purpose for these soundscape and cultural landscape studies was not fully investigated in this survey, but presumably includes extended uninterrupted recordings to document species presence and anthropogenic sound. Future inquiry will explore the characterisation of ecosystem-specific acoustic signatures in protected areas, particularly areas designated as wilderness or marine sanctuary zones.

From a human-experiential perspective, 5% of acoustic projects were related to visitor experience, societal wellness, virtual experience, communications, and oral history (Table 1).

4. EMERGING DIRECTIONS AND CONCLUSIONS

4.1 Data management and accessibility

One value of acoustic information is to document change over time. As technology and analysis capability improve it may be possible to glean more information from previous collections of acoustic data such as better species identification of insect or aquatic biota. Important then is stable, long-term, data storage of acoustic files.

Half of PAU ecologists reported that they feel uncertainty regarding sufficient data storage capacity, either currently or in the future. Based on detailed descriptions of active and completed projects, data storage requirements vary by project and year. Currently, nearly one quarter of projects need more than 1 Tb of data storage per year (i.e., 62% require $\leq$1Tb, 15% require 1-5 Tb, 8% require $\geq$5 Tb). Conservative projections suggest an annual storage requirement of 63 Tb, scaled by duration of project to 335 Tb. Accordingly, it will be increasingly important for individual PAU to plan for the generation and storage of large amounts of data.

The level of readiness to make data publicly accessible in an Open Data forum is currently developing. Most projects had well-documented metadata, including information on location and methods. A proportion of projects (15%), primarily those newly established, described incomplete metadata records. As acoustic projects continue to be implemented, it will be important to ensure the

completion of critical accompanying documentation so that these interpreted datasets can have long-term utility for future analyses. Clearly, public accessibility to acoustic data is still evolving, as 60% of respondents indicated that data are not yet easily accessible in Open Data formats.

4.2 Evolving investigations

Development of future research and monitoring will likely follow advances in technology and areas of conservation concern. This survey revealed a cumulative trend in project establishment – starting with songbirds in forested ecosystems (beginning 10-20 years ago), adding bats (5-10 years ago), and most recently including marine mammals (1-5 years ago) and soundscapes (2 years ago). Areas of future consideration may relate to emerging conservation needs, research priorities, and cultural interactions.

4.2.1 Conservation Needs

Surveyed ecologists indicated several areas in which future acoustic emphasis could assist conservation efforts in protected areas:
1) expand work on most taxa (particularly aquatic species);
2) improve species detection to identify changing spatial-temporal patterns related to climate change or other impacts;
3) emphasize documentation on the impacts of anthropogenic acoustics (i.e., urban sound, avalanche control, marine noise) upon vocalization attributes and species fitness;
4) support documentation of soundscapes, particularly to analyse biodiversity change within large datasets;
5) increase focus on techniques related to efficiency (i.e., automated detection of target species), interpretation capacity (i.e., species identification, comparative quantification, handling variable background noise), and ecosystem-based approaches (i.e., broad scale, soundscape).

4.2.2 Research Priorities

Several research priorities reported by Parks Canada sites to address key knowledge gaps could benefit from innovative acoustic ecology investigations, particularly arthropod inventory, changes in geophysical event rates (e.g., wind), landscape fragmentation impact and restoration, and wildlife population dynamics. Acoustic ecology may likely be important to future environmental assessment of proposed development, and demonstration of restoration results. For example, Parks Canada is using acoustics to determine the influence of fire on bird species (both species that are fire dependent or sensitive), with fire that is prescribed at varying intensities to restore ecosystems or protect townsites.

4.2.3 Cultural and Societal Interactions

From a social perspective, we anticipate that acoustic documentation will continue to expand, such as in the description of cultural landscape [3], a component of Parks Canada's cultural resource management policy. Archiving these landscape acoustics are particularly relevant ahead of significant proposed changes to soundscapes (i.e., before expansion of highways or linear infrastructure). Furthermore, there may be a role for soundscape in optimizing societal wellness, such as 1) providing citizens with outlets to manage eco-anxiety through the contribution of acoustic files in citizen science programs, 2) allowing citizens to access undisturbed quiet zones to enhance personal well-being [4] as prescribed by some medical doctors in British Columbia (www.parkprescriptions.ca), or 3) by providing natural sound on internet sites representing various protected areas.

Finally, the documentation of acoustic impoverishment and systematic loss of nature's sounds may provide a compelling argument for citizen concern and conservation action in a world that, in 2022, committed to halt and reverse global biodiversity loss [5]. In Canada, as new protected areas and ecological corridors are established to contribute to the global "30x30 Initiative" [5], to protect 30% of the Earth by 2030, acoustic monitoring may prove extremely useful in illustrating the progress and potential for local restoration and broader ecosystem resilience.

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