Journal of Great Lakes Research 42 (2016) 248–255

Contents lists available at ScienceDirect

Journal of Great Lakes Research

journal homepage: www.elsevier.com/locate/jglr

The under-ice soundscape in Great Slave Lake near the city of Yellowknife, Northwest Territories, Canada

S. Bruce Martin [a,*], Peter A. Cott [b]

[a] JASCO Applied Sciences, 202-32 Troop Avenue, Dartmouth, NS B3B 1Z1, Canada
[b] Cumulative Impact Monitoring Program, Environment and Natural Resources, Government of the Northwest Territories, Box 1320, Yellowknife, NT X1A 2L9, Canada

ARTICLE INFO

Article history:
Received 25 November 2014
Accepted 20 August 2015
Available online 17 October 2015

Communicated by Bruce Hanna

Index words:
Soundscape
Under-ice
Fish vocalization
Great Slave Lake
Burbot
Lota lota

ABSTRACT

Most recent research and monitoring of under-water "soundscapes" has focused on marine systems in open water conditions. Here we present the first long-term assessment of the diel and seasonal patterns of a freshwater aquatic soundscape under-ice cover. Acoustic data recorded in Yellowknife Bay, Great Slave Lake in Canada's Northwest Territories, measured the under-ice soundscape near an ice road and airport. From December to late January, the soundscape consisted of geophony from ice cracking and anthrophony from snowmobiles, aircraft, and road vehicles. In late January, burbot spawning calls began and added a localized biophony source to the soundscape that increased the total sound pressure level due to an increase in sound levels in the 10–425 Hz frequency band. The median 1 min root-mean-square sound pressure level (rms SPL) in the period without burbot biophony was 90.3 dB re 1 μPa. The measured hourly rms SPL was negatively correlated with air temperature in the 200–800 Hz band but positively correlated with average hourly wind speed in the 800–8000 Hz band. The nightly mean rms SPL was 88 dB re 1 μPa and increased to 96 dB re 1 μPa in late afternoon. This diel cycle had a strong positive correlation with the number of minutes per hour where ice-road vehicles were detected. Further work is recommended to quantify the soundscape in deep-water areas of large lakes and to include particle motion. Such information will enable the assessment of cumulative impacts of anthrophony and geophony on aquatic biota.

Introduction

A soundscape results from the overlap of *biophony* (sounds from organisms), *anthrophony* (sounds created by human activities), and *geophony* (sounds not from biological or man-made sources) (Krause, 1987; Pijanowski et al., 2011; Farina, 2014). The framework proposed by Jennings and Cain (2013) divides the description of a soundscape into the measured properties of the sound with the mixture and evolution of the sources that created the sound. A fully described soundscape includes the number of sources, the evolution of the sounds in time, the proximity of the sources, whether they are identifiable or dominant, in the foreground or background, and, where possible, the direction of the sources.

Much is known about the generation and propagation of geophony sound sources in the ocean under sea ice (see Roth et al., 2012 for an excellent review). One of the most important sources of under-ice noise is broadband impulsive noise from ice fracturing or cracking (Ganton and Milne, 1965; Milne and Ganton, 1964; Zakarauskas et al., 1990). Less is known about the geophony of freshwater lakes, especially under ice. Mann et al. (2009) provide a short-term background spectrum for a sheltered bay in Kennady Lake more than 4 km from the Gahcho Kué diamond mine, in the Northwest Territories (NWT), Canada. They measured a nearly flat spectral density of ~45 dB re 1 μPa^2/Hz from 100 to 8000 Hz. Below 100 Hz, the spectral density decreased to 35 dB re 1 μPa^2/Hz at 10 Hz, with the exception of a small 50 dB re 1 μPa^2/Hz at ~50 Hz.

Whether a sound in the soundscape is a signal or noise depends on the context of the receiver (Farina, 2014). Mann et al. (2009) demonstrated that aircraft and snowmobiles generate under-ice noise at levels that may cause behavioural reactions in fish. Anthropogenic noise can also mask communications between fish (Popper et al., 2014). The behavioural effects and masking are of concern if they affect critical life functions such as spawning. Increased activity under ice in response to noise disturbance could be especially detrimental under hypoxic conditions which are known to occur in shallow ice-covered lakes (e.g., Stewart et al., 2015, this issue). Behavioural and masking effects on a freshwater gadoid fish burbot (*Lota lota*) are of concern since Cott et al. (2014), this issue recently demonstrated that this species vocalizes under ice-cover during their spawning period.

This study presents the under-ice soundscape recorded over 80 days at one location in Yellowknife Bay of Great Slave Lake next to the city of Yellowknife, NWT, Canada. The primary motivation for the recording was to determine if burbot, as in closely related marine gadoid species,

* Corresponding author.
E-mail address: bruce.martin@jasco.com (S. Bruce Martin).

http://dx.doi.org/10.1016/j.jglr.2015.09.012
0380-1330/

vocalize during mating (Cott et al., 2014, this issue), which occurs in winter under ice cover (Scott and Crossman, 1973; McPhail and Paragamian, 2000). To test the hypothesis that they vocalize pre-spawn, burbot were placed under the ice in a large net enclosure (hereafter the Lota-tron), and their vocalizations were monitored using an underwater sound recorder (Cott et al., 2014, this issue). The recorder was calibrated so that the data could also be used for soundscape analysis and to provide an understanding of the acoustic environment in which burbot call.

This is the first report of the under-ice soundscape for fresh water environments. The biophony, geophony, and anthrophony contributions to the soundscape are quantified using special purpose automated detectors. The major sound sources are identified, as well as diel and weekly trends in sound levels. This study provides insight into the levels of natural and anthropogenic sounds that enter under-ice aquatic ecosystems and how a sudden onset of biological sound production changes the local soundscape. These data may be used to establish ecological baselines and to better assess the cumulative impacts of the anthropogenic noise.

Methods

Site description

Acoustic data were recorded continuously from 15 December 2009 to 6 March 2010 in Great Slave Lake, near Yellowknife, NWT, Canada (Fig. 1). Yellowknife is NWT's largest urban centre with over 20,000 residents. A 6 km long ice road spans from Yellowknife to the community of Dettah located along the east side of Yellowknife Bay. The road is open approximately 110 days per year and supports 540–1100 vehicles per day (Northwest Territories Transportation, 2013). An Autonomous Multichannel Acoustic Recorder (AMAR G2, JASCO Applied Sciences) was placed in the 'the Lota-tron', a 10 m × 10 m × 10 m net frozen into the surface ice of the lake. The Lota-tron housed burbot close to the recorder. The water depth at the Lota-tron was 9.5 m with a nearly flat bottom. The ice was over 50 cm thick at the time of deployment and increased to over 1 m thick during the study. Details of the Lota-tron study can be found in Cott et al. (2014, this issue). The Lota-tron was almost directly in-line with a Yellowknife airport runway (Fig. 1).

Acoustic recordings

The AMAR sampled continuously at 16,000 samples per second. It was positioned within the Lota-tron, approximately 1 m off the lakebed from 15 December 2009 to 6 March 2010, spanning the burbot spawning period in Yellowknife Bay (Cott et al., 2014). The AMAR was fitted with an M15B hydrophone (GeoSpectrum Technologies Inc., −160 dB re 1 μPa/V sensitivity) and set with an input voltage gain of 6 dB. The complete recording system was calibrated before deployment and after retrieval with a 42 AA pistonphone calibrator (G.R.A.S. Sound & Vibration A/S) at 250 Hz. The AMAR had a broadband noise floor of 80.6 dB re 1 μPa and a spectral density noise floor of 46 dB re 1 μPa^2/Hz from 50 to 1000 Hz and 36 dB re 1 μPa^2/Hz above 3000 Hz. The recorder had a noise artefact at 4750 Hz, with a root-mean-square sound pressure level (rms SPL) of 94 dB re 1 μPa, which was removed with an equi-ripple notch finite impulse response filter during analysis (4650–4850 Hz, 1024 points). The recorder also created a short pulse of electrical noise lasting 0.01 s every 1.37 s while writing data from short-term memory to long-term storage. The memory writes increased the current consumed by the recorder, which modulated the battery pack voltage and injected noise into the hydrophone due to inadequate power supply rejection. This pulse created broadband energy to 50 Hz, with tone-like energy at 29, 37, and 210 Hz; the amplitude of the pulses increased as the battery pack was depleted. At the beginning of the deployment, the spectral density noise floor at 10 Hz was 50 dB re 1 μPa^2/Hz; at the end of the deployment the level at 10 Hz had increased to 70 dB re 1 μPa^2/Hz and decreased to the normal value of 46 dB re 1 μPa^2/Hz by 50 Hz. This increased the noise floor in the band of 10–40 Hz from 70 dB re 1 μPa to 79 dB re 1 μPa over the deployment period.

Data analysis

Acoustic analysis was performed in two stages using custom software (JASCO Applied Sciences). The first stage quantified the sound

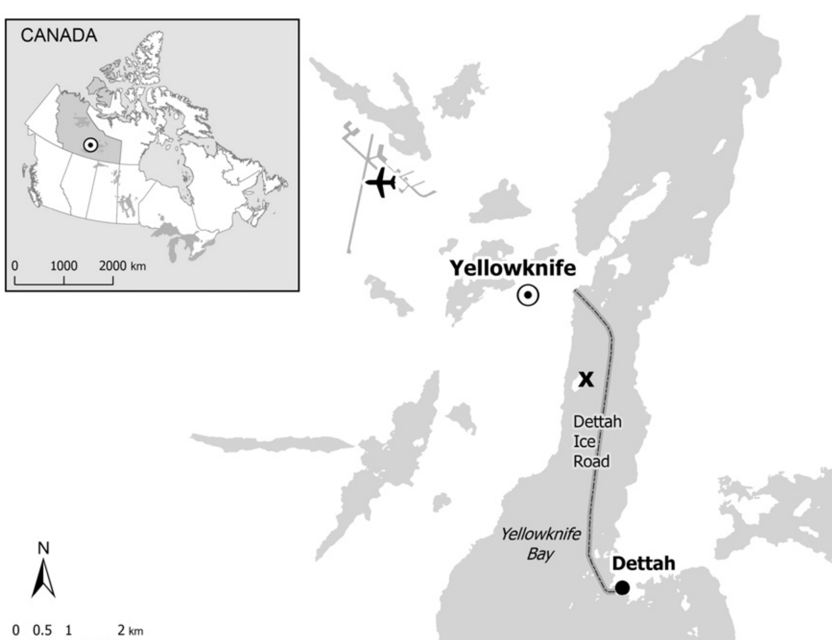

Fig. 1. The Lota-tron project site near the city of Yellowknife, NT, Canada. The Lota-tron was approximately 600 m from the 6 km long Dettah ice road and directly below the flight path for the secondary runway of Yellowknife Airport located 6 km northwest.