Common Nighthawk (*Chordeiles minor*) Recognizer: The effects of quality and score on accuracy using Song Scope; Active listening compared to automated recognition.

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Introduction

When trying to understand environmental change and industrial impacts on the surrounding habitats, it is important to collect information on where species occur and how many of each species occupy the area. As of 2007 the Common Nighthawk (*Chordeiles minor;* hereafter: CONI) has been listed as threatened in Canada. The most recent assessment of the species has indicated an annual decline of 6.6%, which indicates a decrease of 49.5% over the last ten years (COSEWIC 2007). It is suggested that this decline is due to the extensive use of pesticides, and the loss or modification of their habitats (COSEWIC 2007), it is also thought that the decline is mostly seen in the eastern North American population (Dunn & Alderfer 2006).

The Common Nighthawk is a crepuscular aerial insectivore; found in Alberta during its breeding season, which ranges from May to late August. The CONIs breeding range includes a large range of habitats: sand dunes, slash burned forests, woodland clearings, sagebrush, grasslands, open forest, and rock outcrop (Dunn & Alderfer 2006).

Males have a distinct, short nasal 'peent' call as well as a non-vocal courtship display that produces a 'Booming' sound. The CONI 'boom' occurs when the male pulls out of a dive and air rushes through its primaries. The 'peent' call is a contact call usually vocalized during foraging (Poulin *et al.* 1996, Roth & Jones 2000), its main use is to let conspecifics know that they have entered their territory (Roth & Jones 2000). CONI forage anywhere between 1 - 80 m above ground level (Todd *et al.* 1998, Fisher *et al.* 2004), and could be between 125m – 6 km from their day roost site (Fisher *et al.* 2004).

The CONI is deemed difficult to detect audibly due to the fact that they roost for almost 50% of the day with minimal vocalizations and visually trying to identify them is difficult due to their cryptic plumage (Fisher *et al.* 2004, Zwart *et al.* 2014). These factors, as well as the time of day point counts are conducted to determine species abundance will affect how many individuals can be counted using standard avian survey techniques. Researchers are often not out at their peak foraging times, CONIs are the most active one-hour before sunrise, and one-hour after sunset (Brigham *et al.* 2011).

New technology has opened up a wide range of opportunities in collecting bioacoustics data. It is now possible to set out automated recording units that are programmed to record on specific schedules for prolonged amounts of time. This has increased the amount of information available tremendously, but more data leads to increased processing time from trained listeners to record species abundance, diversity, occupancy and peak call times during the recordings. Active listening would take a substantial amount of time to go over every single recording, therefore, only a proportion of the data gets processed. Fortunately, Wildlife Acoustics, Inc., has developed software called Song Scope, which enables you to develop an automated recognizer that quickly scans audio recordings and automatically locates species specific vocalizations based on a specific algorithm. Song Scope proposes that you can use batch processing to analyze large datasets, greatly reducing processing time and increasing efficiency (Song Scope 4.0 User's Manual 2011, Duan *et al.* 2013).

The amount of variability in vocalizations within a species makes it difficult to correctly identify every call present in a data set. Bird vocalizations can range from being very robust and "noisy" to being very tonal and harmonic, ranging from one syllable to multiple syllables, and a single species can have regional dialects. All of these will affect how accurately a recognizer can perform. The CONIs 'peent' call is one syllable, but it is a mixture of plosive noise with harmonic emphasis, which may affect the recognizer's capability to detect the call. With that, active listening may be a better approach when searching for CONIs. A comparison between active listening and automated recognition, in detecting CONI 'peent' calls will help determine which approach is more efficient.

Methods

Building the Automated Recognizer

The Bioacoustics Unit at the University of Alberta, used Automated Recording Units (SM2+, Wildlife Acoustics Inc., hereafter known as ARUs), to collect bioacoustics data, trained listeners then processed the data. The processed data is where all initial CONI calls were found to build the automated recognizer. Forty-two recordings with CONI detections, accounting for a total of 5 hours and 45 minutes worth of data, were used to build the recognizer. These recordings were loaded in to the Song Scope Software (Wildlife Acoustics 2011), and 21 annotations were made around clear and distinct "peent" calls. Small amounts of background noise were left in the annotations as instructed by Wildlife Acoustics. Using the guidelines in the Song Scope manual parameters were set for the CONI automated recognizer.

Parameters

Sample Rate: 22050	Frequency Min: 8	Dynamic Range: 15 dB
Max Sample Delay: 64	Frequency Range: 100	Complexity: 32
FFT: 256	Max Syllable: 50	Resolution: 6
FFT Overlap: ½	Syllable Gap: 100	Song: 360
Background filter: 1 sec		

Effects of Quality and Score on Automated Recognition

The CONI recognizer was then tested against locations where active listeners have detected CONI to see how accurate it was at detecting foraging 'peent' calls. There are two parameters that needed to be set before running the recognizer, *quality* and *score*. Quality and score are values assigned by the Song Scope Software indicating if the signal characteristic matches the characteristics of the annotations in the training data, and how well it matches the model made in Song Scope. The recognizer was first set up with a quality value of 45 and a score value of 70. It was then set up again using a quality of 50 and score of 75, these are the values used with the Bioacoustics Unit's Yellow Rail (*Coturnicops noveboracensis*) recognizer. This was intended to give insight on which parameter values produce the highest amount of detections without causing a substantial amount of false positives. A data set consisting of 5 site locations for a total of 32 hours of recordings was used to test quality and score.

Comparison between Active Listening and Automated Recognition for Common Nighthawks (C. minor)

After the best quality and score values were determined the automated recognizer was ran through a portion of the Bioacoustics Unit's 2013 Yellow Rail (*C. noveboracensis*) data, clusters 4 – 10. Within each cluster there are two or more sites, each site has 5 ARUs, one per station (NE, NW, CT, SE, SW). This data set was chosen because it has the most recordings listened to by an active listener. The ARUs were programmed to turn on for 10 minutes at the beginning of every hour and were out for a minimum of 7 days for every station. ARUs were deployed between late may till late July in Alberta's Lower Athabasca region.

Active listeners processed 662 recordings, from 14 sites, 70 stations, for a total of 110.26 hours of bioacoustics data. The automated recognizer was run through 17 sites for a total of 85 stations, the recordings accounted for approximately 1024[1] hours of bioacoustics data.

Results

Effects of Quality and Score on the Automated Recognizer

The automated recognizer with the quality of 45, and score of 70, resulted in 299 flags where it perceived a 'peent' call to exist. Out of those 299, 107 were correct detections of the 'peent' call; rate of true positives was 53.77%. The recognizer with a quality of 50 and score of 75, resulted in 69 flags, 59 of them were true positives giving it an accuracy of 85.50%.

Active Listening Detections

Active listening detected 55 recordings with CONI; these detections encompassed 6 sites, 18 stations. Actively listening to these recordings had a processing time of 82.5[2] hours for the 110.26 hours of bioacoustics data. CONI were detected at five different times of day, 12 am, 1 am, 2 am, 7 pm, and 10 pm.

Automated Recognition Detections

The automated recognizer resulted in 2316 flags perceived to be CONI 'peent' calls, of those 2316, 1665 were true positives. This gives the recognizer an accuracy of 71.89%. To process all 1024[1] hours of bioacoustics data, it took the recognizer approximately 50[3] hours (this includes the time it took to validate the results to determine true positives). Detections were found at 15 of the 17 sites, and it included 56 stations. Detections had a broad range of call times, covering all hours of the day; peak call times were 3 am, 4 am, 10 pm, and 11 pm.

Discussion

Quality And Score

The recognizer gave the best results when the parameters of quality and score were set at 50, 75, respectively. The automated recognizer detected 'peent' calls at 85.5% accuracy when the recognizer parameters were set at these values, but the false negative rate was also affected. There is a drop in detections from 107 to 59, but the

31.2% increase in true positive detections shortens processing time and increase efficiency. When the parameters were set at a higher level, a decrease in the number of faint calls, as well as calls that are overlapping with other birds being detected was seen, increasing the false negative rate.

Faint calls will always be a problem with the automated recognizer for the CONI. Since the CONI forage for insects above ground (up to 80 meters) the placement of the ARU on the ground is not close enough to get a distinct call. Song Scope is sensitive to the purity of syllables in calls; when calls/syllables are masked with non-targeted species calls, or industrial/abiotic noise the accuracy of the automated recognizer decreases (Duan *et al.* 2013). At dawn there is an increased amount of species vocalizing simultaneously causing the accuracy of species detections to decrease for both humans and the automated recognizers. A lower quality (45) and score (70) may be better fitted for when population abundance and density are the focus of interest. The higher quality and score values are adept for occupancy research.

Comparison between Active Listening and Automated Recognition for Common Nighthawks (C. minor)

Active listening had 55 CONI detections, 25 were only the 'booming' from their wings, the other 30 were 'peent' or a combination of the 'peent' and 'boom'. The automated recognizer was not developed to recognize 'booms', since the 'boom' is a low frequency sound. Using this as an auditory cue for locations of CONI is not a precise as using the 'peent' call, because low frequency sound will travel further

(Marten & Marler 1977). For this segment, ’detection’ is classified as a CONI vocalization with a unique site, station, date, and time. Of the 30 ‘peent’ detections found by active listening, only 3 were also detected by the automated recognizer. Giving the recognizer a false negative rate of 27/30, 90%. However, the automated recognizer detected 461 detections not found by active listening, which increases our ‘peent’ detections by 1537% (461/30).

Looking at the results on a broader scale, comparing site and stations pairs between active listening and automated recognition, there is a large difference. Active listening only had 1 site (Site 225) with 3 stations (CT, NE, SE) that the automated recognition process declared CONIs absent, when they were in fact present. The automated recognition process on the other hand, detected CONI at 8 sites encompassing 34 stations where active listening had not detected CONI. Active listening did not process three sites intentionally, but it missed CONI detections at five sites.

Further investigation into site 225 showed that the detections at the NE and SE stations were very faint non-vocal CONI ‘boom’ detections, so faint that even when looking at the spectrogram it was hard to see its presence. The centre point at site 225 was a singular ‘peent’; most recordings where CONI are detected are filled with ‘peent’ calls for the entire ten minutes. The single detection at this site could suggest that the CONI was flying past while moving between roost sites and foraging sites.

A comparison of the times that CONI were detected shows a clear difference. The 2013 data was listened to in hopes of finding specific species. Therefore, recordings were only listened to at specific times (12 am, 1am, 2am, 7pm, and 10 pm) and only some of the dates, whereas the automated recognition process goes through all recordings and all dates. The active listening process suggests that the peak call times for the CONI are 12 am and 10 pm (see Figure. 1). Peak call times suggested by the automated recognition process are 3 am, 4 am, 10 pm and 11 pm (see Figure. 1). These call times are a better fit with the crepuscular foraging of the CONI. The automated recognition process has given more insight into the best times to look for CONI if the active listening method were to be used to determine occupancy or population density of the species on recordings in the future.

Using the active listening method, only one tenth of the bioacoustics data collected was listened to, and still used 30 more hours to process. This report shows that it is more feasible to use the CONI automated recognizer when looking for occupancy of the species, processing 90% more data in less time. Active listening may become more useful when trying to determine population densities, but further inspection into lowering quality and score on the automated recognizer to lower our false negative rate may become helpful in looking at population densities, with a slight increase in our processing time.

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[1] Assuming that for every day the ARU was deployed it collected 24, 10-minute recordings.

[2] Processing time was not entered for 38 recordings; they were given the average of all processing times, 7.5 minutes.

[3] This is an approximation, due to the fact that I was not in the office 24 hours a day to see when it was finished.

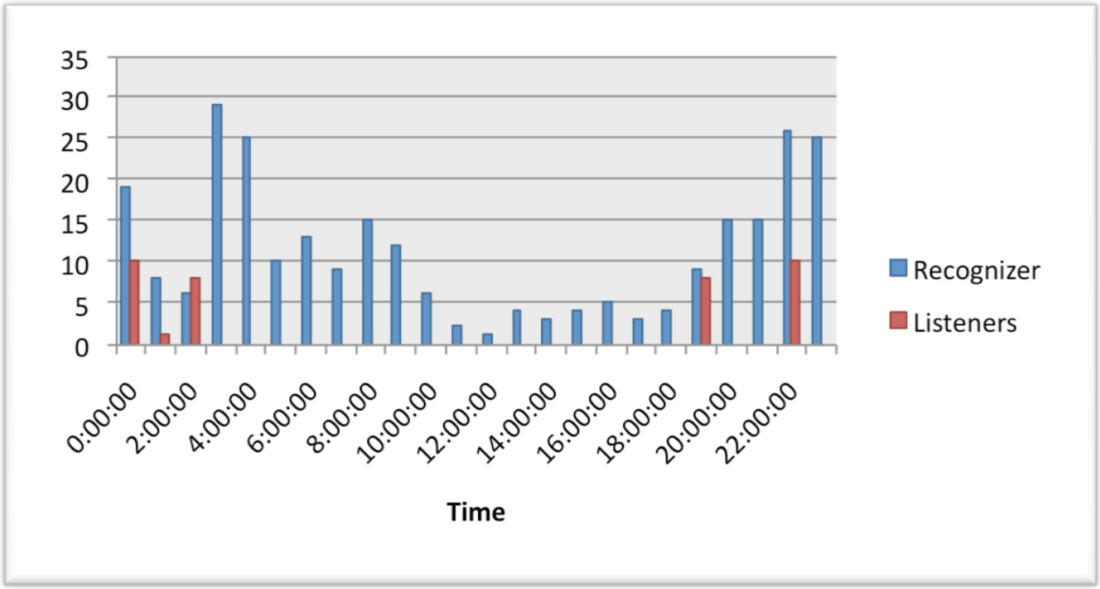

Figure. 1. A comparison between the active listening and automated recognition processes and their detected Common Nighthawk (*C. minor*) call times.