The Pre-Dawn Descent of Thrushes at the Glen Dhu Wind Farm Site
An Acoustic Study

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Abstract

An acoustic study was undertaken of the nocturnal migration of *Catharus* thrushes at the Glen Dhu Wind Farm site on the Pictou-Antigonish Highlands of Nova Scotia. Research methods included aural listening and digital recording of the flight calls of these thrushes as well as observations along survey routes in the one hour period before dawn from 9 September and 20 October 2009. Each morning the survey rotated among four different acoustic monitoring sites.

Four species of *Catharus* thrushes were detected; Hermit Thrush, Swainson's Thrush, Veery, and Bicknell's Thrush. Peak migration of *Catharus* thrush species occurred in the week of 16 to 22 September 2009. Nocturnal migration occurred over a broad front, and there were no significant differences in the number of flight calls heard among the four sites or according to their elevation. The number of thrushes heard was highest when the skies were clear to partly cloudy, wind speeds were less than 11 kilometers per hour, and when overnight wind speeds were less than 19 kilometers per hour. All thrushes were heard in a 30-minute period, 60 to 30 minutes before sunrise. There was a tendency for more thrushes to be seen on the ground at the acoustic monitoring sites and on the survey routes on mornings when nocturnal migration was light or non-existent. The vast of majority of thrushes seen on the ground were Hermit Thrushes.

The digital recording of flight calls captured from 11 to 43 per cent of the flight calls heard, depending on the type of recording technology used. These recordings were useful in identifying the number of each species of thrush flying overhead. The peak passage of Swainson's Thrush and Veery was from 17 to 25 September with the peak for Hermit Thrush occurring from 29 September to 7 October. One Bicknell's Thrush was recorded on 21 September and 7 October. Within the 30-minute monitoring period, the calls of each species were concentrated within different time intervals, 55 to 45 minutes before sunrise for the Veery, 55 to 40 minutes before sunrise for the Swainson's Thrush, and 40 to 30 minutes before sunrise for the Hermit Thrush. Significant differences in the loudness of the flight calls of Hermit Thrushes within the monitoring period indicated they were flying at a lower altitude in the interval 50 to 40 minutes before sunrise compared to 40 to 30 minutes before sunrise.

The findings of this study are consistent with the literature on the nocturnal migration of *Catharus* thrushes and contribute to a greater understanding of this phenomenon, especially as it applies to Nova Scotia. It is clear that the thrushes heard in the twilight of the pre-dawn period were in a descent phase, and it is proposed that only Hermit Thrushes landed in the Pictou-Antigonish Highlands while Swainson's Thrushes and Veeries continued on to land in the coastal plain. Although the research methods could detect relative changes in flight altitudes of thrushes, further study using a microphone array would be required to determine absolute altitudes.

The study concludes that acoustic monitoring of nocturnal passage can be an important dimension in the assessment of the impact of wind farms on birds since other studies have shown that 80% of avian mortality at wind energy facilities is composed of songbirds which migrate primarily at night.

Introduction

The baseline avian study for the Glen Dhu Wind Farm site noted the regular occurrence of a pre-dawn descent of thrushes in the period lasting from one hour to one-half hour before sunrise during the autumn migration (Kearney 2008). A recommendation was made for a follow-up study of this phenomenon, and in the autumn of 2009, an acoustic study was undertaken.

The Glen Dhu Wind Farm site is located on the Pictou-Antigonish Highlands of Nova Scotia. Several kinds of thrushes regularly occur in Nova Scotia. These are the Eastern Bluebird (Sialia sialis), American Robin (Turdus migratorius), Veery (Catharus fuscescens), Gray-cheeked Thrush (Catharus minimus), Bicknell's Thrush (Catharus bicknelli), Swainson's Thrush (Catharus ustulatus), and Hermit Thrush (Catharus guttatus). It is the last five species, the *Catharus* thrushes, that are the subjects of this study.

All of the *Catharus* thrushes breed in Nova Scotia except for the Gray-cheeked Thrush which nests in the taiga of the Canadian north, including Newfoundland and Labrador. Until recently, the Gray-cheeked and Bicknell's Thrushes were considered the same species and are difficult to distinguish from each other in the field. Indeed, for the untrained observer, all of the *Catharus* thrushes look similar. Figure 1 shows a photograph of each species.

The *Catharus* thrushes are best known for the beauty and vocal complexity of their breeding songs. This study focuses on one of the least known dimensions of these birds, their nocturnal migration and the unique flight calls that they use only at this time.

Methods

This study is primarily based on acoustic methods for documenting the occurrence of thrushes on the Glen Dhu Wind Farm.

Acoustic Monitoring – Aural Counts of Nocturnal Migration

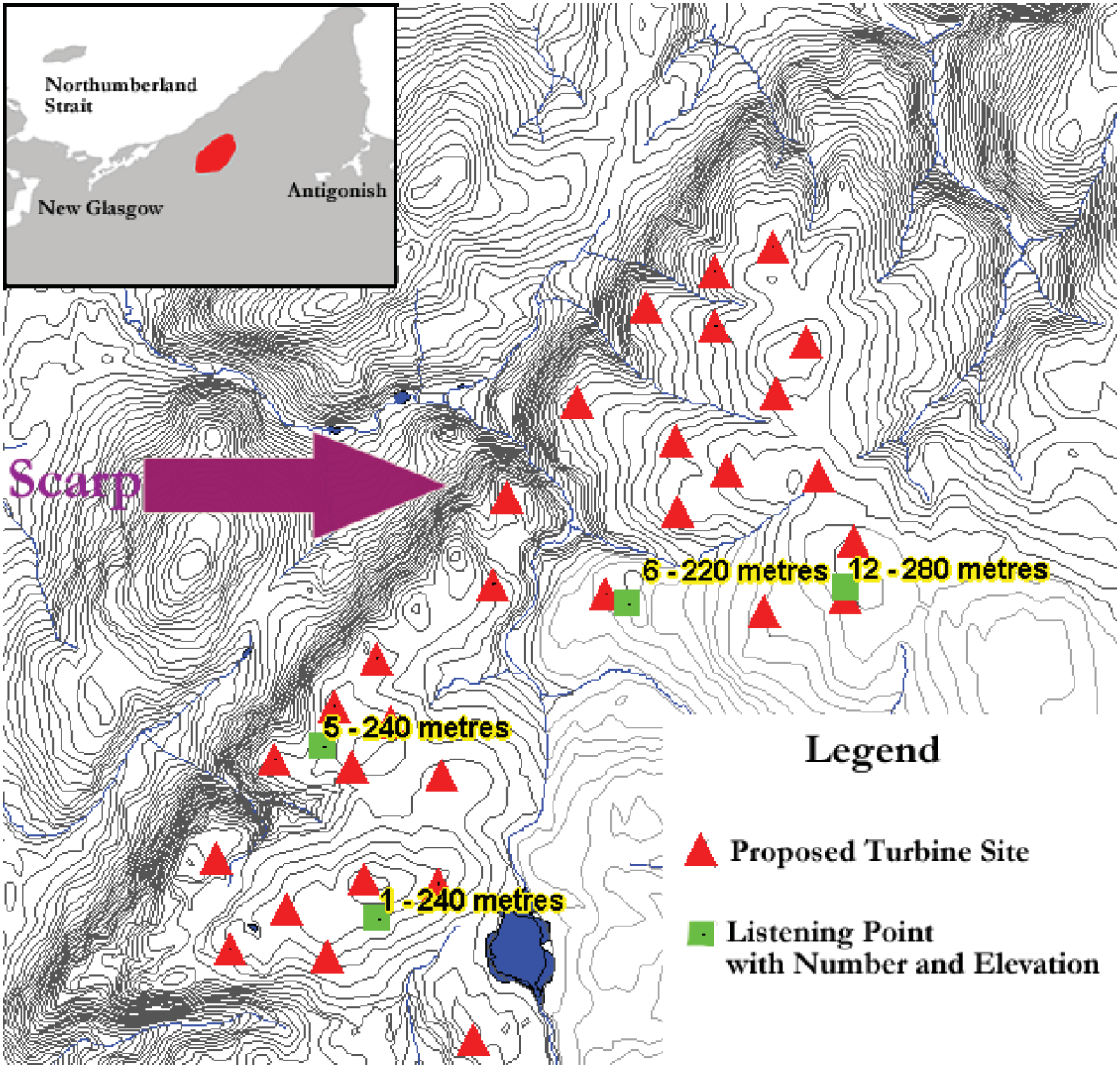
During the autumn migration of thrushes, from 9 September to 20 October 2009, aural counts of thrushes passing over acoustic monitoring points were conducted on twenty-eight occasions from one hour to one-half hour before sunrise. On most of the fourteen remaining nights during this period, weather conditions were not conducive to aural counts due to high winds or heavy rain. Counts were rotated between four acoustic monitoring sites shown in Figure 2.

Higher elevation sites were chosen on the wind farm site with a progression of distances from the steep incline of the scarp face of the highland area.

Each flight call of a thrush was noted and classified according to species. The accuracy of these identifications is discussed in the Results section. One thrush might be heard calling from 1 to 4 times during its passage overhead but each call was recorded separately.

Figure 1: Photos of *Catharus* Thrushes

Figure 2: Location of Acoustic Monitoring Points



Acoustic Monitoring – Aural Counts of Thrush Ground Vocalizations

At the end of the one-half hour period, the number thrushes giving call notes in the surrounding bushes and trees was noted and separated by species. About 5 minutes was given to these counts each morning.

Acoustic Monitoring – Digital Recording of Thrush Flight Calls during Nocturnal Migration

During the aural counts, digital recording of birds flying overhead was conducted. The recording methodology was an experimental procedure to develop acoustic technology for use in assessing the risk to nocturnal migrating birds from a wind farm.

Three recording configurations were tested: 1) a Panasonic IC recorder with zoom microphone, used from 9 to 16 September 2009; 2) a Panasonic IC recorder with zoom microphone within pressure-zone created by placing it on a 16.5 cm ceramic dinner plate, from 17 September to 20 October 2009, and 3) a modification of the "flowerpot" design described on the website of Old Bird Inc. (http://www.oldbird.org/), used from 13 to 20 October 2009. In this last configuration, a lapel microphone was mounted on a 16.5 cm dinner plate and lowered into a large flower pot with a diameter of 36 cm at its top opening. The label microphone was connected to a microphone pre-amplifier and then into a lap-top computer using the free-software, *Audacity*, to record the flight calls.

The free software *Thrush*, provided by Old Bird Inc., was used to separate out sounds in the frequency range of the flight calls of migrating thrushes. The free software *Glassofire*, also provided by Old Bird Inc., was used to view, play, and classify the spectrograms of these sounds.

The multi-media CD-ROM by Evans and O'Brien (2002) served as a reference for the identification of thrushes by their sound and spectrograms.

Analysis of the thrush flight calls was done for all three recording configurations.

Visual Monitoring – Access Road Survey

In the remaining time before sunrise, from about 25 minutes before to 5 minutes after sunrise, a survey was conducted along the access road leading away from the acoustic monitoring point for a distance of exactly 1.5 kilometers. Thrushes could be seen and often identified as to species in the beam of the headlights of a vehicle. Each thrush was noted as well as any other kinds of birds seen.

Weather Monitoring

Current weather conditions were recorded at the beginning of the acoustic monitoring period. Weather conditions for the night preceding the monitoring period were obtained from the online database of the nearest Environment Canada weather station, at Caribou Point, located 35 kilometres from the study area.

Results

The results will be presented in two sections. The first reporting on the more traditional methods of aural and visual counts and the second summarizing the analysis of the digital recordings.

The Seasonal Timing and Extent of the Autumn Nocturnal Migration of Catharus Thrushes Based on Aural and Visual Counts

During the aural counts of pre-dawn thrush calls, an attempt was made to separate the number of calls for each species. Only two species of *Catharus* thrushes could be distinguished, Swainson's Thrush and Hermit Thrush, and due to the rapidity with which thrushes were often heard, it was often difficult to separate these species with precision During the analysis of the digital recordings, it was found that more than two species of thrush were overhead and a more precise species ratio could be determined. Thus, these results will be presented in a subsequent section of this paper. In this section, the analysis will be for *Catharus* thrushes as a group.

Figure 3 shows the number of flight calls heard per morning during September and October 2009. The highest number of flight calls occurred on 21 September when 179 calls were heard.

Figure 3: Total Number of Flights Calls of *Catharus* Thrushes Heard during Pre-Dawn Acoustic Monitoring Period by Date

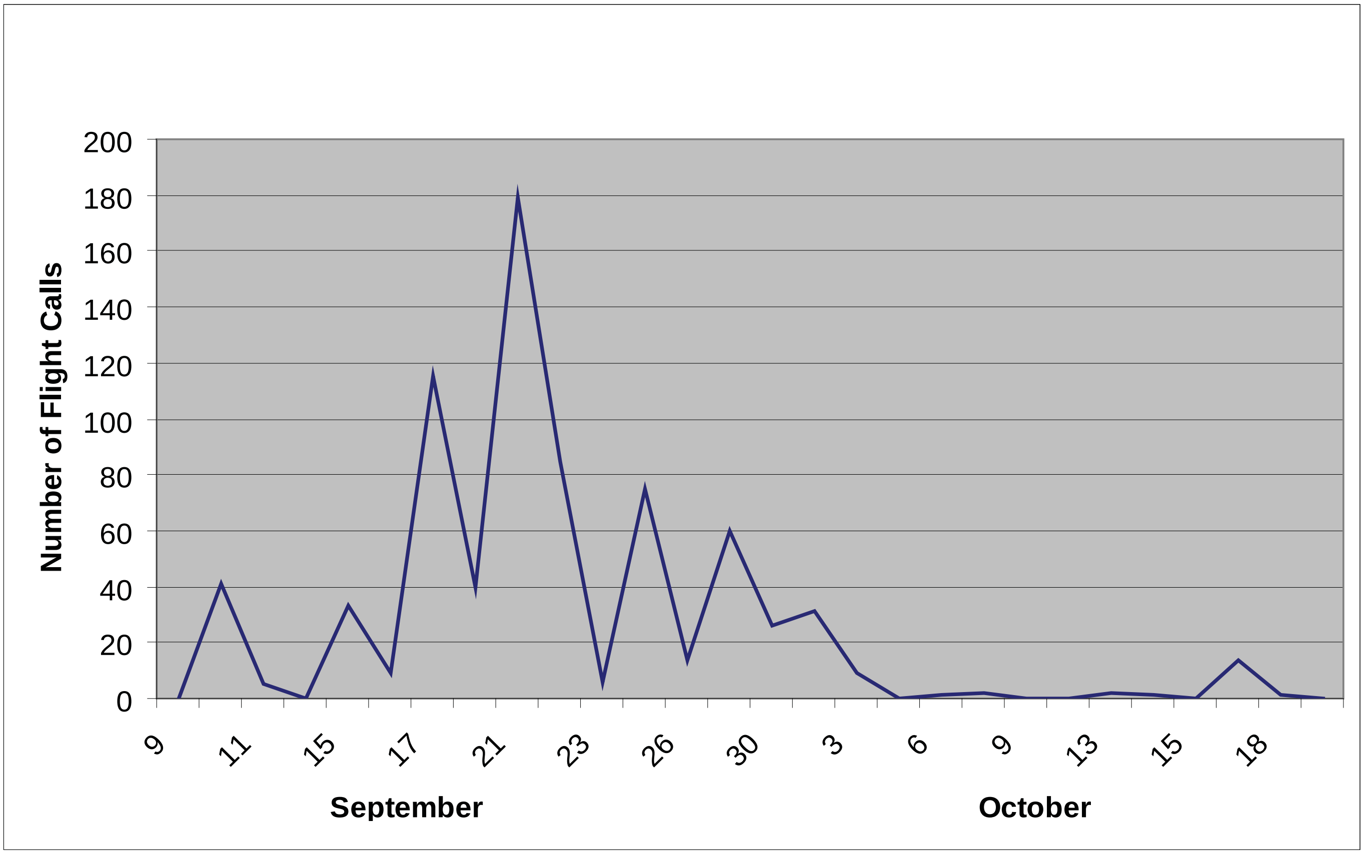


Figure 4 demonstrates the mean number of flight calls heard per acoustic monitoring period for seven day intervals in September and October 2009. Peak numbers of migrating thrushes occurred for the interval, September 16-22. Using an analysis of variance (ANOVA), the weekly mean number of thrush calls heard during the migration varied significantly at the 95% confidence level, although the statistical results lacked a certain robustness[2].

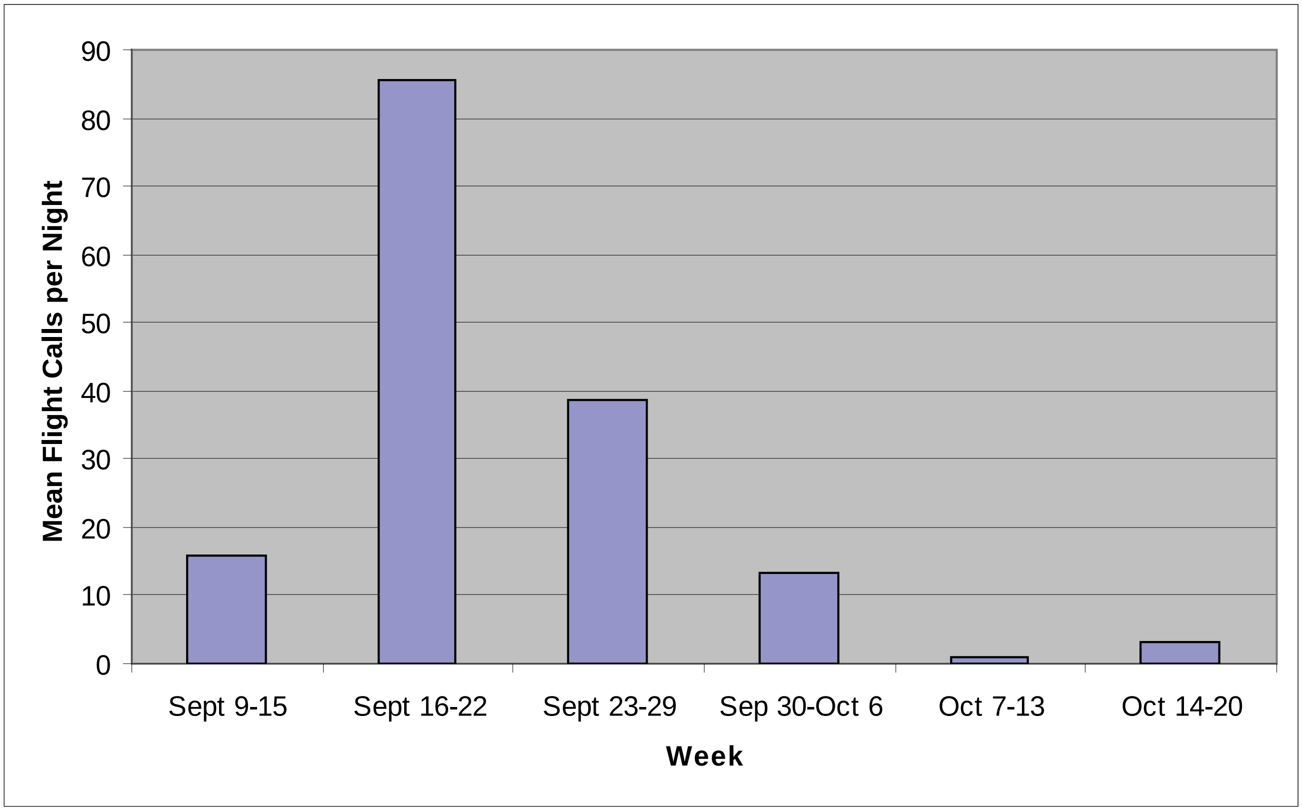
There was no significant difference in the number of flight calls heard between the four acoustic monitoring sites shown in Figure 2 and no significant difference by the elevation of the sites. This helps to support the impression gained during the baseline study that the pre-dawn descent of migrating thrushes occurred over a wide front.

Weather factors that were significantly related to the number of thrushes heard during a monitoring period were the current cloud cover and wind speed. The mean number of calls heard when the sky was clear to partly cloudy was 36.55 compared to 2.25 for mostly overcast or overcast skies. The mean number of thrush calls was 49.36 when the wind speed was 11 km/hr or less and 4.14 when winds were over 11 km/hr. A similar trend was seen for the wind speed during the nighttime hours preceding the listening period. The mean number of thrushes heard

2 The variances of the means were unequal and proved to be significant at the 95% level for the Brown-Forsythe test and at the 90% with the Welch test.

was 39.31 when the wind speed during the night averaged 19 km/hr or less compared to 10.00 when wind speed during the night was greater than 19 km/hr. However, in the last case, the statistical significance was weaker, at the 90% confidence level, compared to the 95% level for the other two factors, cloud cover and wind speed during the monitoring period.

Figure 4: Mean Number of Flight Calls of Catharus Thrushes during the Pre-Dawn Acoustic Monitoring Period by Week

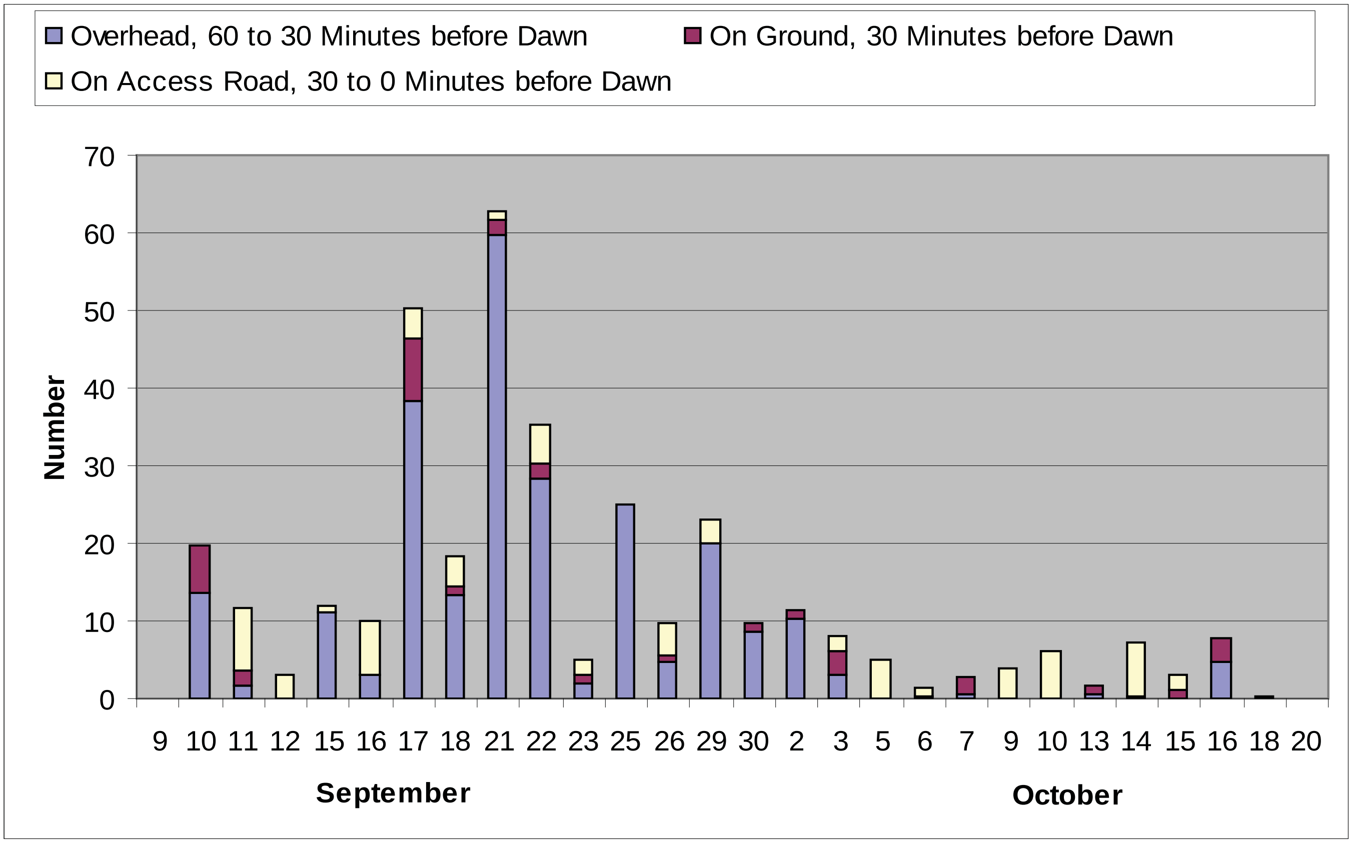


The number of thrushes on the ground (or in trees) at the monitoring site at the end of the monitoring period and the number on the access road were relatively small compared to the number of thrushes heard passing overhead. Figure 5 shows the estimated number of thrushes that passed overhead during the monitoring period, the number on the ground at the end of the monitoring period, and the number on the access roads in the one-hour after the monitoring period. The number of birds flying overhead was estimated by dividing the number of calls heard by three, with the assumption that a bird is heard calling three times while it is passing overhead.

The chart in Figure 5 indicates that there was a tendency for more thrushes to be on the ground at the acoustic monitoring sites and on the access roads on the mornings when few or relatively few thrushes had passed overhead. This suggests that 1) these birds were already present as migrants in stop-over and not primarily those which had descended in the previous hour, and 2) stop-over thrushes in the study area may depart the same night that large movements of thrushes are detected overhead.

The vast majority of thrushes on the ground or on the access roads were Hermit Thrushes. In total, 76% of thrushes on the ground at the monitoring sites were Hermit Thrushes while of those thrushes that could be identified by species during the access road counts, 98% were Hermit Thrushes. This corresponds with the data from the baseline study in the autumn of 2007. During the months of September and October in 2007, a single Swainson's Thrush was seen on two occasions on the survey transects compared with 41 Hermit Thrushes detected on 20 occasions.

Figure 5: Comparison of the Number of *Catharus* Thrushes Passing Overhead, on Ground, and on Access Roads in the Pre-Dawn Period by Date

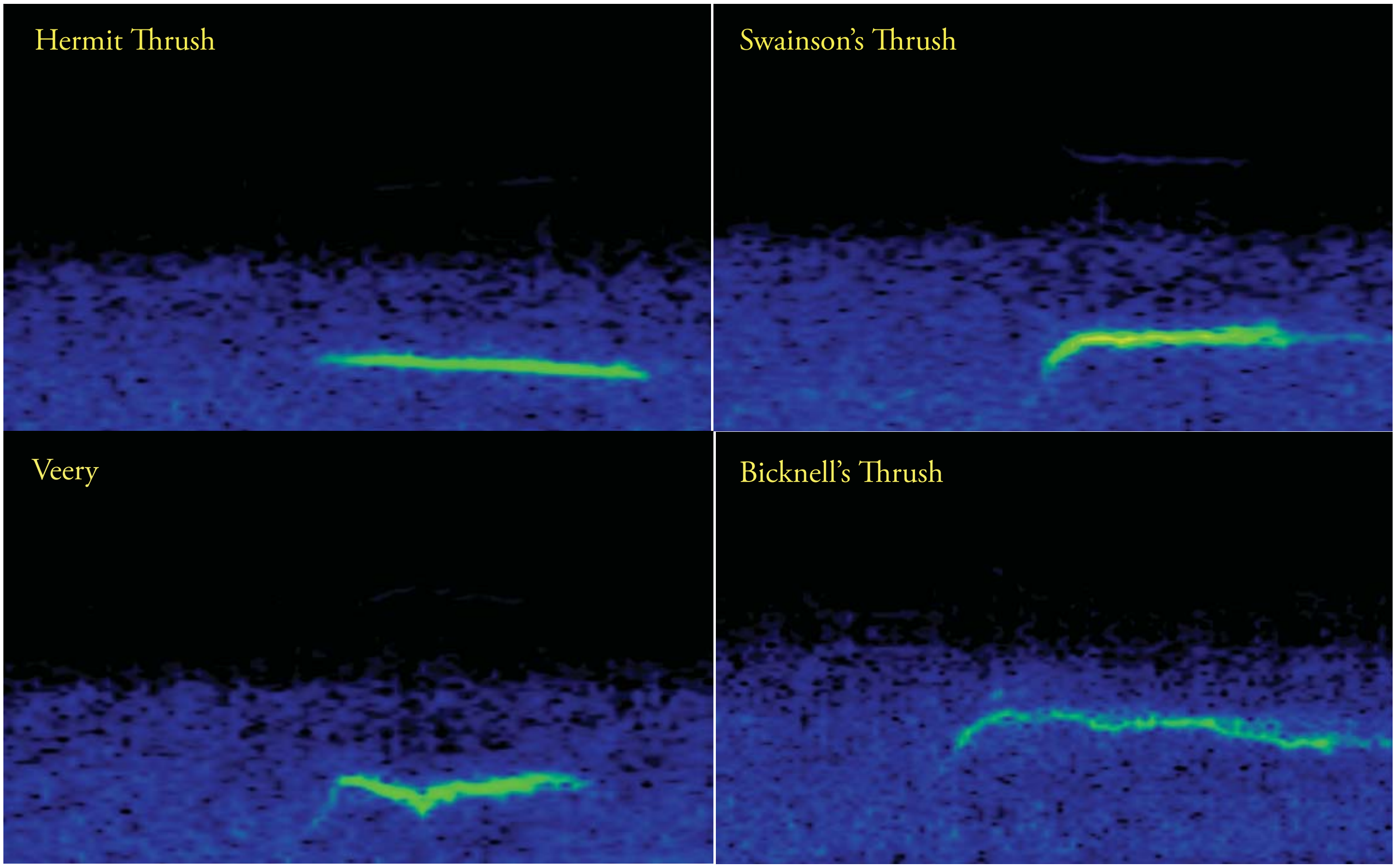


The Flight Calls, Species Composition, and the Seasonal and Matinal Timing of Nocturnal ***Catharus*** Thrush Migration Based on Digital Recordings

The nocturnal flight calls of *Catharus* thrushes can be difficult to distinguish from one another. However, this task becomes considerably easier by examining the spectrograms of their flight calls. A spectrogram is a visual representation of a sound changing through time with time on the x-axis, frequency on the y-axis, and amplitude coded in the colour of the display. The spectrograms of the *Catharus* thrushes recorded in this study are shown in Figure 6. The sound of the flight call associated with each spectrogram can be heard at the following web address: http://www.johnfkearney.com/page7.html.

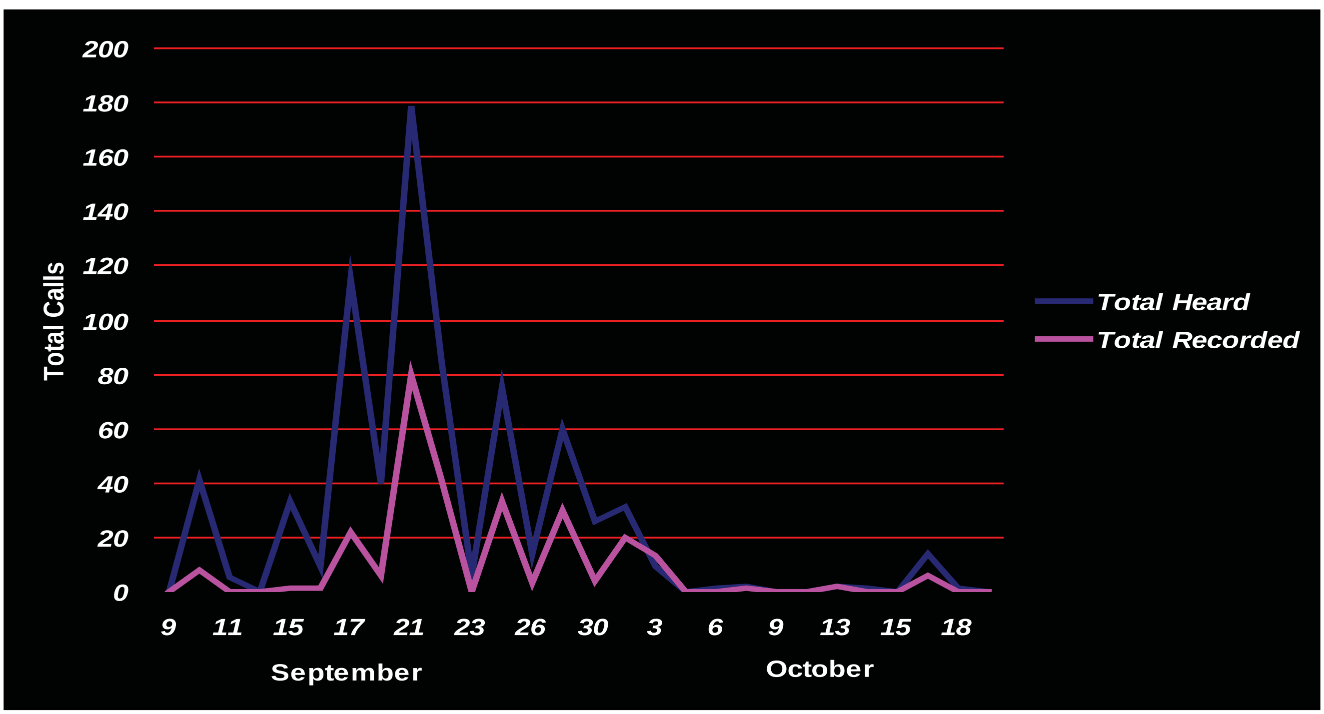
Of the three recording configurations described in the methods section above, only 11.36% of the birds heard by aural listening were recorded with configuration #1 (recording microphone alone), 38.88% with configuration #2 (recording microphone in pressure zone), and 42.86% with configuration #3 (flowerpot microphone with pre-amplifier). The use of what appears to be the most promising recording configuration (#3) was employed only during the last part of the season and thus was not as completely tested as would have been desired.

Figure 6: Spectrograms of the Flight Calls of *Catharus* Thrushes



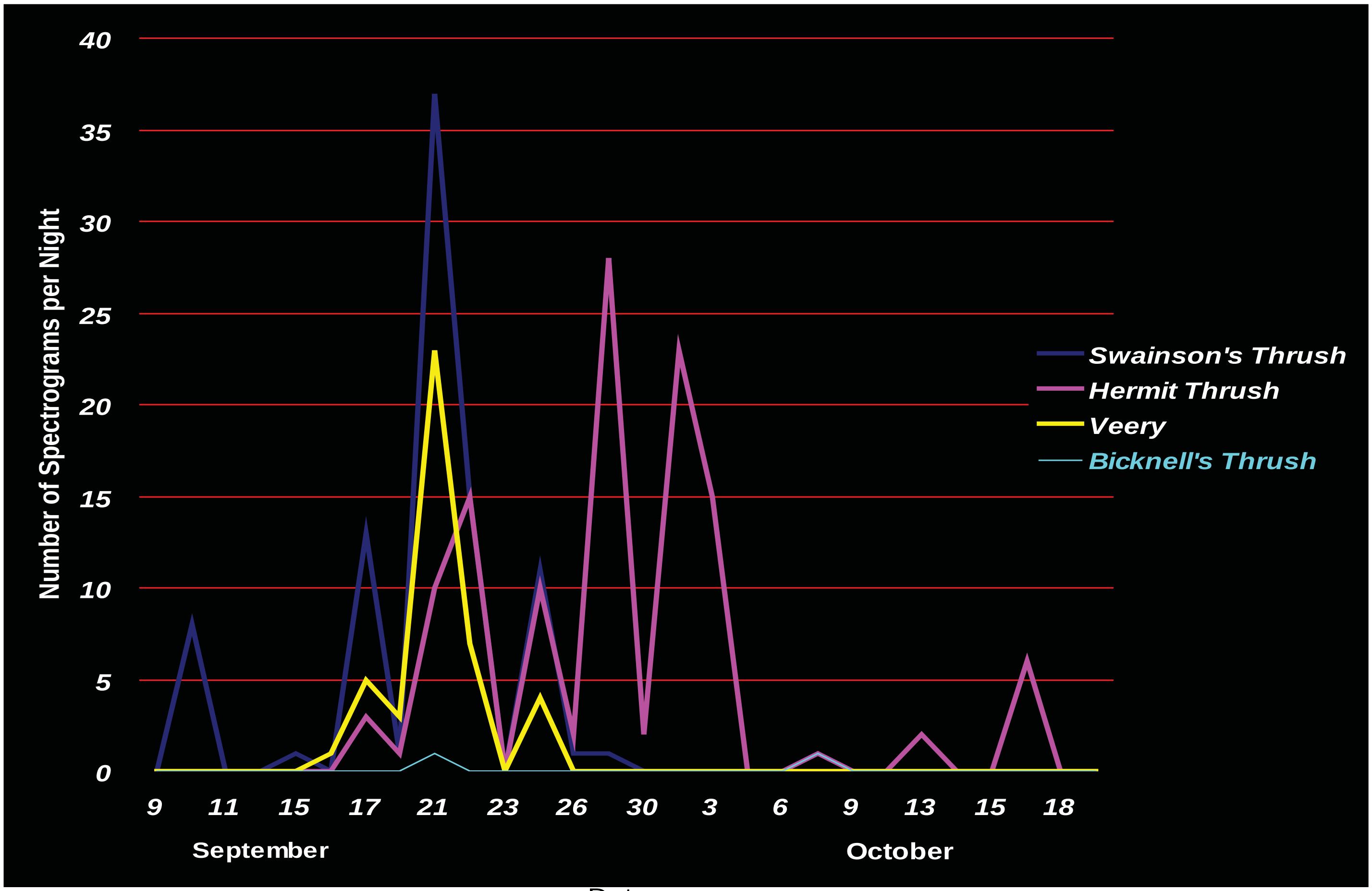
As can be seen in Figure 7, the number of flight calls recorded was similar in distribution over the autumn season compared to those detected by listening.

Figure 7: Comparison of Total Flight Calls Heard and Total Recorded



However, it is in revealing the species composition of thrushes flying overhead and the seasonal timing of *Catharus* thrushes by species that the digital recording of flight calls proved very useful. Figure 8 shows the seasonal occurrence of *Catharus* thrushes by species.

Figure 8: The Total Number of Flight Calls Recorded by Species and Date

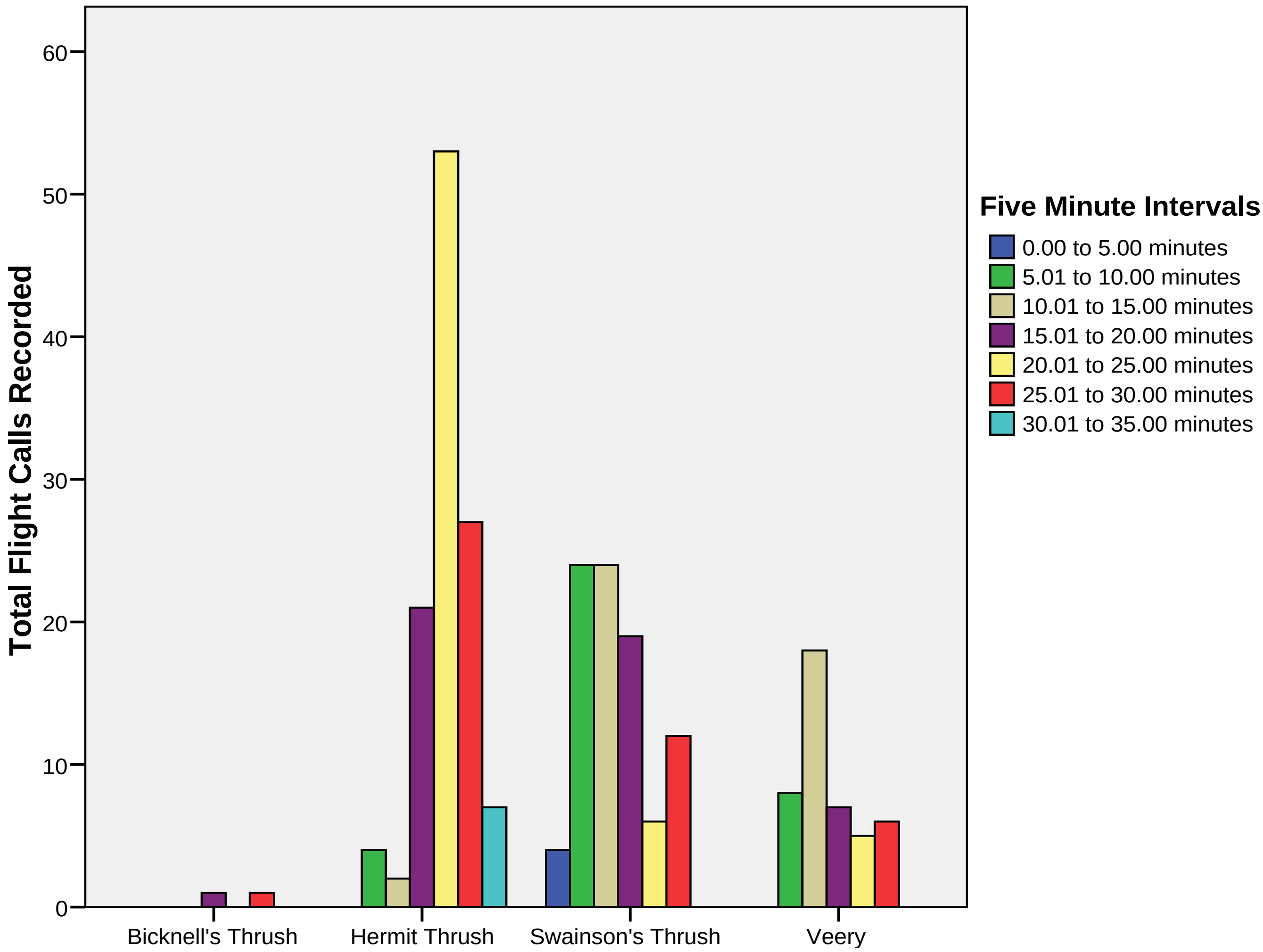


The peak passage of Swainson's Thrush and the Veery was in the period 17-25 September with only three Swainson's Thrushes and no Veeries recorded after that time. In contrast, the passage of Hermit Thrushes extended over a longer period, with the first recorded on 17 September, the last on 16 October and a peak passage later in the season, from 29 September to 3 October. Bicknell's Thrushes were recorded on two occasions, 21 September and 7 October.

The digital recording of flight calls also facilitated the quantification of the timing of thrush passage during the one-half hour recording period. Figure 9 shows the number of thrush calls recorded by species in five-minute intervals.

According to the Pearson Chi-Square Test, there was a significant difference (at the 95% level) in the timing of the *Catharus* thrush passage by species during the monitoring period. The passage of Veeries was higher than expected in the number of flight calls (counts higher than would be expected by chance) during the 5.01 to 15.00 minute interval of the recording period (that is 54.99 to 45.00 minutes before sunrise). The Swainson's Thrush had higher than expected counts in the 5.01 to 20.00 minute interval (54.99 to 40.00 minutes before sunrise). Finally the Hermit Thrush was the latest with higher than expected counts in the 20.01 to 30.00 minute interval (39.99 to 30.00 minutes before sunrise). Only the Hermit Thrush had the occasional spill-over of flight calls into the 30.01 to

Figure 9: Total Flight Calls Recorded per 5-Minute Interval during the Monitoring Period (one hour to one-half hour before sunrise) by Species



35.00 minute interval and only the Swainson's Thrush had recorded flight calls in the first five minutes of the recording period[2].

The digital recording of flight calls can also provide some evidence about the altitude of the thrushes. Assuming that the thrushes are constantly moving either toward or away from the microphone location, changes in the mean loudness of the flight calls over a specific time period should represent changes in the altitude of the birds. Loudness is measured in decibels, a logarithmic unit that measures the pressure or force of a sound relative to some reference point. If the reference point is explicitly stated, e.g., the lowest threshold of human hearing, then decibels are considered an "absolute" measurement. Otherwise, decibels are considered "relative" measurements. In this study, the decibels were measured relatively using the same recording configuration (#2, recording microphone in pressure

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2 Both the 0.00-5.00 and the 30.01-35.00 minute intervals were excluded from a statistical analysis due to the low number of flight calls recorded at these times.

zone), for each thrush species separately, as determined by the *Audacity* recording program. The decibel (dB) range of the flight calls in this context ranged between -50 and -15.

Table 1 presents the mean loudness of the flight calls of *Catharus* thrushes over 5-minute and 10 minute intervals during the acoustic monitoring period for the autumn season.

Table 1. Mean Loudness (in Relative Decibels) of *Catharus* Thrushes over 5-Minute and 10-Minute Intervals during the Recording Period for the Autumn Season

	Hermit Thrush		Swainson's Thrush		Veery	
	5 Min	10 Min	5 Min	10 Min	5 Min	10 Min
0.00 to 5.00 minutes		-44.00	-40.33	-35.33		-39.13
5.01 to 10.00 minutes	-44.00		-34.71		-39.13	
10.01 to 15.00 minutes	-25.50	-37.48	-35.41	-34.67	-35.61	-36.56
15.01 to 20.00 minutes	-38.62		-34.00		-39.00	
20.01 to 25.00 minutes	-40.64	-40.81	-34.80	-35.29	-38.00	-39.50
25.01 to 30.00 minutes	-41.15		-35.50		-40.50	
30.01 to 35.00 minutes	-39.29	-39.29				
35.01 to 40.00 minutes						

All three species appeared to have louder flight calls in the 10.01 to 20.00 minute period. Since decibels are on a logarithmic scale, small changes in decibels can represent relatively large increases in loudness. For example, a change in 18.5 decibels, as seen in the Hermit Thrush flight calls, translate into a 3.6 fold increase in loudness. Nonetheless, there were no statistically significant differences in loudness for the 5-minute and 10-minute intervals for the Swainson's Thrush and Veery. On the other hand, the flight calls of the Hermit Thrush were significantly louder at the 95% confidence level for both 5-minute and 10-minute intervals using an analysis of variance (ANOVA). A Post Hoc Test using the Tukey Honestly Significant Difference Test showed that Hermit Thrush flight calls were significantly louder in the 10.01 to 15.00 minute interval compared to every other 5-minute interval. At the same time, Hermit Thrush flight calls were significantly louder in the 10.01 to 20.00 minute period compared to the 20.01-30.00 minute period. These results suggest that the altitude of Hermit Thrushes was lowest during the 10-20 minute interval of the monitoring period, or 40 to 50 minutes before sunrise but higher during the 20-30 minute recording interval or 30-40 minutes before sunrise.

Discussion

It is necessary to relate the findings of this study to the scientific literature on the nocturnal migration of *Catharus* thrushes. Studies using radio telemetry have demonstrated that the nocturnal migratory flights of *Catharus* thrushes, follow three phases: 1) ascent, lasting 11 minutes on average; 2) cruise, averaging 307 minutes, and 3) descent at morning twilight, averaging 23 minutes (Cochran, Bowlin, and Wikelski 2008). Before take-off, there is evidence supporting the view that *Catharus* thrushes calibrate their magnetic compass in reference to the solar azimuth at sunset and continue using a geomagnetic compass after takeoff (Cochran, Mouritsen, and Wikelski 2004). Weather conditions at the time of takeoff are also critical: winds less than 10 km. per hour, falling barometric pressure, and clear to mostly clear skies. Wind direction is not a determining factor for takeoff, even when they are favourable (Bowlin, Cochran, and Wikelski 2005; Matthews and Rodewald 2010). Flying altitude ranges between 180 meters (generally in rainy conditions) and 1500 meters (Cochran, Bowlin, and Wikelski 2008) but can go over 2000 meters (Bowlin, Cochran, and Wikelski 2005). *Catharus* thrushes travel up to 4800 km. twice a year between Canadian and northern United States breeding areas and winter destinations in the southern United States, Mexico, Central and South America, at ground speeds of 54 km./hr., and at a rate of 265 km./night (Cochran and Wikelski 2005; Clement 2000). This represents 18 nights of flying in both the spring and autumn.

During the descent phase of a nocturnal flight it has been shown by radio telemetry that the heart rate increases more than would have been expected, and there is an increase in the pauses between wing flapping. These facts have led researchers to speculate that the thrushes are searching for suitable stopover habitat in this descent phase during the early morning twilight (Cochran, Bowlin, and Wikelski 2008; Bowlin, Cochran, and Wikelski 2005). Once this habitat is found, they exhibit considerable fidelity to the stopover area until conditions are once again favourable for nocturnal passage (Matthews and Rodewald 2010; Bowlin, Cochran, and Wikelski 2005).

The findings of this study are consistent with this overview of nocturnal migration in *Catharus* thrushes and helps add to it. Peak counts in this study occurred when winds were calm to light, skies were clear to partly cloudy, and light winds had occurred throughout the preceding night; all conditions favourable to *Catharus* thrush migration. The literature supports the observation in this study that the number of thrushes seen in stopover was highest when weather conditions were not favourable for flight and lowest on the same mornings that nocturnal passage was occurring, thus suggesting that thrushes were leaving the study area on the same nights that nocturnal passage was detected in the morning.

Given the mostly clear skies and low winds on the mornings when the flight of thrushes was most intense and its occurrence in the twilight, it is apparent that the thrushes heard and digitally recorded were in the descent phase. This phase lasted 25 to 30 minutes (consistent with the literature) but was concentrated within a fifteen minute period. However, the peak of the descent, even within this narrow time frame, was different for each of the three most common species.

The loudness of the flight calls indicated that the altitude of the thrushes, and significantly, that of the Hermit Thrush, was not lowest at the end of the descent period but near its beginning. Extrapolating from the literature, it can be proposed that Hermit Thrushes choosing the Pictou-Antigonish Highlands as a stopover area did so immediately upon descent while other Hermit Thrush as well as Swainson's Thrushes and Veeries were overhead in a search pattern looking for suitable stopover habitat. As seen in this study and in the baseline study, the Pictou-Antigonish Highlands were not an important stopover area for the latter two species. It has been noted elsewhere (Kearney 2010) that the coastal plain along the Northumberland Strait below the Pictou-Antigonish Highlands is a favoured stopover area for another, non-*Catharus*, thrush species, the American Robin (*Turdus migratorius*) due to the great abundance of wild fruit in this area in the autumn. Both the Swainson's Thrush and the Veery are known to be primarily frugivorus during the autumn migration whereas fruit is only a supplement to the diet of the Hermit Thrush (Jones and Donovan 1996; Mack and Yong 2000; Bevier, Poole, and Moskoff 2005). Thus it appears that in their descent, the Swainson's Thrush and Veery pass over the highlands to land on the coastal plain.

This study does not determine the exact altitude of thrushes during their descent and therefore the potential risk of collision with wind turbines. This could be determined by attaching a microphone array to the top of a meteorological or turbine tower and determining the altitude of the thrushes by the arrival time delays in their flight calls (William R. Evans, personal communication).

There are several reasons why acoustic studies can enhance the environmental impact assessment process for wind farms. As pointed out by William R. Evans (Unpublished) acoustic monitoring can be used in the pre-construction phase to assess the relative densities of birds and bird species during the migration season and their responses to weather, lighting, and landscape features such as ridges and water bodies. In the post-construction phase it can be used to predict mortality in conjunction with on-the ground carcass searches or be an indicator for identifying the days when carcass searches should take place. Acoustic monitoring can also identify the presence of species of conservation concern that would be missed in diurnal studies. For example, in this study, it was seen that the threatened species, Bicknell's Thrush, was likely an occasional nocturnal migrant over the study area.

Finally, a review of a number of recent avian assessments on proposed wind farms in Eastern Canada reveals that many if not most do not include any monitoring of nocturnal passage. And while it is acknowledged that wind turbines pose the most threat to birds when they are migrating, there is not the same recognition that 80% of avian fatalities by wind turbines are of passerine birds (songbirds), the majority of which migrate at night (Manomet Center for Conservation Sciences 2009). With the rapid advancement of technology in this field, acoustic monitoring could be conducted by remote sensing, thus reducing personnel costs, while at the same time, providing a more robust assessment of the risk to birds from a wind energy facility.

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