Determining the Effectiveness of Forestry Beneficial Management Practices for Olive-sided Flycatcher, a Species at Risk Bird in Nova Scotia

by

Hannah Freeman

Submitted in partial fulfillment of the requirements for the degree of Bachelor of Science in Environmental Science

at

Dalhousie University
Halifax, Nova Scotia
April 2024

Supervisor: Dr. Cindy Staicer

Table of Contents

List of Figures

Abstract

The Olive-sided Flycatcher (OSFL) is a bird species at risk that breeds across Canada, including in Nova Scotia's forests. It is considered threatened in the province, experiencing recent population declines. While OSFL occupies protected areas in Nova Scotia (NS), research indicates that these areas alone are insufficient for conservation, emphasizing the need for conservation efforts in working forests. Species-specific beneficial management practices (BMPs) were developed for OSFL in the context of forest harvesting and applied in a stand in Cape Breton in 2022. However, their effectiveness in conserving OSFL is undetermined.

This study assesses BMP effectiveness by evaluating OSFL reproductive success inferred from vocalization activity as a measure for successful conservation. Bioacoustic data from the harvested site in Cape Breton a non-BMP control site in Southwest NS were collected using autonomous recording units and analyzed in Raven Pro/Lite. Songs and calls were counted independently using visual and auditory clues, as well as aid by BirdNET identification highlights. These counts were averaged over varied time periods, and vocal activities were compared to expected patterns observed for pairing, successful nesting, and failed nesting.

In the harvested site, results on song rate activity were consistent with patterns expected for male OSFL that pair and reproduce successfully. On the other hand, those at the control site displayed song rate activity consistent with patterns expected for male OSFL that pair but experience a failed nest. This indicates that harvesting with BMPs allowed OSFL to occupy the area and did not inhibit the bird from breeding successfully, thus highlighting the potential effectiveness of the BMPs in OSFL conservation.

Keywords: Olive-sided Flycatcher, Forestry, Beneficial Management Practices, Bioacoustics, Reproduction

List of Abbreviations

ARU: Autonomous Recording Unit
BMP: Beneficial Management Practices
CHM: Canopy Height Model
COSEWIC: Committee on the Status of Endangered Wildlife in Canada
DSM: Digital Surface Model
DTM: Digital Terrain Model
MBCA: Migratory Birds Convention Act
NS: Nova Scotia
OSFL: Olive-sided Flycatcher
SAR: Species at Risk
SARA: Species at Risk Act
SW: Southwest
UAS: Unmanned Aerial System

Acknowledgements

I would first like to acknowledge the support and assistance of my supervisor Dr. Cindy Staicer throughout this semester. This project would not have been possible without her guidance. I also extend my thanks to other members of Dr. Staicer's team, for the efforts in the collection of the data utilized in this study. Special thanks to DISP Students Maia Baxter and Bridget McPhail for their aid in analysing recordings, Dr. Chris Greene for patiently explaining the same GIS concept to me multiple times, and Dr. Tarah Wright for providing a calming presence during overwhelming periods. I am also extremely grateful for my partner Megan MacDonald, and for all of the emotional (and python related) support she provided throughout the year.

Finally, I must acknowledge the incredible performance of the Olive-sided Flycatchers, which were central to this project

1.0 Introduction

1.1 Background and Context

The Olive-sided Flycatcher (*Contopus cooperi*) is a passerine landbird that has experienced long-term population decline and is currently classed as a species of special concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC, 2018). This flycatcher species breeds in forests across Canada – including in Nova Scotia. The Olive-sided Flycatcher (OSFL) faces threats from habitat loss in both their wintering and breeding grounds, reductions in prey populations, severe weather events, and climate change (COSEWIC, 2018).

Habitat loss from forestry is the greatest threat to this species in the province (COSEWIC, 2018). Previous research has found that while OSFL occupy protected spaces (e.g., National Parks, Conservation Areas), the extent of these areas alone are insufficient in recovering this species, and that future efforts must shift to include habitat conservation in working forests (Westwood et al., 2019).

Beneficial Management Practices (BMPs) are guidelines that aim to reduce the environmental harm associated with a process and are often created and implemented for species at risk (Caskey et al., 2004; François et al., 2021). Recently, species-specific BMPs were developed for the OSFL in the context of forest management in Nova Scotia (LSARFW, 2022) and applied in forest harvesting in Cape Breton, NS. However, no studies have been completed assessing the effectiveness of harvesting with recommendations from species-specific BMPs in Nova Scotia, highlighting the knowledge gap pertaining to their proficiency in conserving OSFL.

1.2 Research Objectives

This project sought to investigate the impact of BMP-compliant forest harvesting on OSFL presence and reproductive outcomes. Specifically, this study will utilize the observed variation in song rate activity as indicators of breeding success (Wright, 1997). By utilizing bioacoustic data collected from ARUs, field-mapped occurrence data, and high-resolution data from unmanned aerial systems (UAS) for a harvested plot in Cape Breton and in an unharvested control area in SW NS, we explored the following question:

To what extent do forestry beneficial management practices (BMPs) impact Olive-sided Flycatcher, a species at risk bird in Nova Scotia?

The findings of this project will contribute to better guidance for future forest harvesting practices in the province, with a focus on conserving OSFL.

2.0 Literature Review

2.1 Biodiversity Loss

From 1970 to 2018, the Global Living Planet Index observed an average decline of 69% in the populations of monitored species worldwide (WWF, 2022). In North America alone, the decrease was noted at 20% during the same period (WWF, 2022). These statistics highlight the severity of biodiversity loss as a current environmental challenge and support the notion that it is among the most significant environmental issues we face today. Furthermore, these results stress the importance of species at risk conservation being a primary focus in scientific research and policy development.

Bird species have been the focus of many conservation efforts in recent years due to their notable decline rates. Globally, it is predicted that approximately 1,400 species are at risk of extinction, which accounts for nearly half of the world's known species (BirdLife, 2022). In North America alone, past research has identified a 2.9 billion net loss in abundance of birds since 1970, considering data on nearly 76% of breeding species in Canada and the United States (Rosenberg et al., 2019).

In Canada, not every bird species faces the same significance and types of threats, resulting in bird population statuses assessed across various groups such as waterfowl, shorebirds, and others. It has been found that shorebirds, grassland birds, and aerial insectivores are among the most threatened groups, with declines of 40%, 57%, and 59% respectively between 1970 and 2016 (NABCI, 2019). Given their significant decline, much research has been completed on the various threats that face aerial insectivores, and have concluded that declining prey abundance, global warming, and habitat loss and degradation all play notable roles (Spiller & Dettmers, 2019). Forest harvesting is a driver of habitat loss in Canada, and it is identified as a threat to the recovery of many bird species at risk (COSEWIC, 2012; COSEWIC, 2018; COSEWIC, 2020; Brazner et al., 2024).

2.2 Forestry Practices in Nova Scotia

Past studies have displayed the critical impact that forest harvesting has on bird species, with Betts et al. (2022) finding that habitat amount had a strong effect on bird abundance for the majority of forest inhabitant birds in the Maritimes. Efforts to mitigate the environmental harms associated with forest harvesting in Nova Scotia are presented in the form of ecological forestry practices (Government of Nova Scotia, n.d.).

Nova Scotia is transitioning to new forest harvesting practices guided by ecological forestry following a review of the current processes (Lahey, 2018). This review was conducted by Lahey

(2018) with the goal of assessing current forestry practices and determining recommendations on how to better meet goals related to the economy, the environment, and society as a whole. They concluded that the value that forests have in regard to the economy, the environment, and society should be considered equally significant. Recognizing that biodiversity and ecosystem health are ultimately the base that the other values depend on, Lahey (2018) suggested that all forestry practices be guided by ecological forestry – an approach that aims to prioritize ecological protection and biodiversity when determining appropriate methods to balance the interests of the economy, the environment, and society.

The province has adopted a triad model in the implementation of ecological forestry (Seymour & Hunter, 1992; Forbes, 2019). This model divides the forests on crown land into three zones that altogether aim to balance various interests and is well supported by past research (MacLean et al., 2009; Messier et al. 2009; Cote et al., 2010; Ward & Erdle, 2015). Forests are either classed as being a high production zone, a conservation zone, or a matrix zone (Government of Nova Scotia, n.d.). The high production zone and conservation zone prioritize timber production and ecosystem health, respectively. Forest practices within a matrix zone aim to balance production and environmental objectives and are described by Lahey (2018) as "forestry with a lighter touch." Harvesting in matrix zones should include selective harvesting methods that reflect natural disturbances and are shown to have low levels of clearcutting. To balance ecological interests with production goals, specific harvesting recommendations must be made. In regard to species at risk conservation in a matrix zone, harvesting may be guided by beneficial management practices.

2.3 Beneficial Management Practices

2.3.1 BMPs in Conservation

Beneficial management practices, also sometimes referred to as best management practices, aim to reduce the environmental harms associated with a process, and are often created and implemented for species at risk conservation (BCMFLNR, 2014; François et al., 2021). Past BMPs developed for species at risk (SAR) conservation in forest harvesting considered understanding of the target species population size, distribution, as well as physical and biological habitat preferences (BCMFLNR, 2014; Stewart, 2017). The recommendations included within BMPs can be updated over time as the success of implementation is assessed, effective alternative methods are identified, or new relevant information about the target species is uncovered (BCMFLNR, 2014). BMPs are a method of supporting the conservation of SAR and may help conserve populations of at-risk bird species and their habitats.

2.3.2 Species-specific BMPs

Existing BMPs created for species at risk consider the maintenance of suitable habitat features and the establishment of buffer zones around areas deemed critical in preserving the target species (BCMLWAP, 2004). These BMPs are designed by an expert with sufficient knowledge of the species (BCMLWAP, 2004). In Canada, the only federal existing management practice for bird conservation on crown lands is the Migratory Birds Convention Act (1994), which is legislation that aims to protect native birds and their nests. Included within this act is a restriction on stand harvesting during the breeding season if a SAR is found to inhabit the area (MBCA, 1994). Additional BMPs for bird conservation have been developed in British Columbia (Demarchi & Bentley, 2005; BCMFLNR, 2014) and Nova Scotia (LSARFW, n.d.).

Currently, five SAR birds in Nova Scotia have species-specific BMPs created in the context of forest harvesting (LSARFW, n.d.). These species include the Canada Warbler (*Cardellina canadensis*), Common Nighthawk (*Chordelies minor*), Eastern Wood-pewee (*Contopus virens*), Olive-sided Flycatcher (*Contopus cooperi*), and the Rusty Blackbird (*Euphagus carolinus*). In addition to specific guidelines for each species, these BMPs all include recommendations to avoid harvesting in the bird's territory or primary area during the breeding season, and to limit use of pesticides or herbicides that have the potential to impact non-pest insects (LSARFW, n.d.). For those that occupy forested wetlands in the province, such as OSFL, there are additional recommendations surrounding road building, harvesting only on snow or frozen ground, leaving a buffer around wetlands, and the avoidance of activities that might impact wetland hydrology (LSARFW, n.d.). To date, no studies have been completed assessing the effectiveness of harvesting with recommendations from species-specific BMPs in Nova Scotia, highlighting the knowledge gap pertaining to their proficiency in conserving these species.

2.3.3 Assessing Implementation of BMPs for Forest Management

In the implementation of BMP guidelines in forest harvesting, specific retention values are often set to restrict the amount of harvesting that can occur within different zones (Stewart, 2017). In Nova Scotia, a standard protocol of 10-30% retention (by basal area) was established for stands where seed tree or overstory removal is recommended (Government of Nova Scotia, 2018). This standard was determined following the review on forestry practices conducted by Lahey (2018).

There are several approaches to quantifying changes in forest coverage metrics, many involving the creation of a canopy height model (CHM) that measures variation in vegetation height across an area. Data gathered using remote sensing techniques and tools like light detection and ranging (LiDAR) and unmanned aerial systems (UAS) (Tang & Shao, 2015) are often used in the creation of a CHM. An elevation model derived from LiDAR currently exists for the province of Nova Scotia (GeoNOVA, 2022), however given its large-scale resolution, it is ineffective at quantifying precise changes at the stand level. Conversely, spatial data obtained from UAS such as drones are more suitable as they can obtain fine-scale imagery (Goodbody et al., 2017).

Past studies have explored the benefits of using CHMs obtained from UAS to measure forest metrics, with Zhang et al. (2022) noting how the distributions of many species were tied to canopy structure metrics. For bird species that prefer to inhabit forests with specific structures, a CHM is a promising method to determine the presence of suitable habitat features. Regarding BMPs, a CHM obtained from UAS imagery can reveal changes in stand structure post-harvesting and assess the application of harvesting recommendations outlined in BMPs, such as retention guidelines.

2.4 Olive-sided Flycatcher

2.4.1 Conservation Status

The Olive-sided Flycatcher is a migratory passerine landbird that breeds in forested areas across much of Canada and is listed as a species of special concern under the Species at Risk Act (SARA) (COSEWIC, 2018) and as threatened in the province of Nova Scotia (NSDLF, 2021). Based on Breeding Bird Survey (BBS) data, the Olive-sided Flycatcher has experienced a cumulative decline of 72% since 1970 with a 2.1% mean annual decline between 2006-2016 (COSEWIC, 2018). There are multiple causes for the decline in population including habitat loss and degradation, declining insect abundance, and changes in the availability of prey during the breeding season (COSEWIC, 2018). Alteration or destruction to suitable habitat impact OSFL in its breeding and wintering grounds. In Canada, fire suppression and forest harvesting are the main drivers of habitat loss (COSEWIC, 2018). As more than half (53% - COSEWIC, 2018) of the breeding range for OSFL occurs in Canada, having a thorough understanding of this species habitat preferences is key in informing effective conservation efforts.

Breeding habitat preferences for OSFL vary throughout their range, but many sources indicate that forest openings, edges, semi-open forest stands, and tall trees or snags are all preferred habitat characteristics (Altman & Sallabanks, 2012). In Eastern Canada, they have been found to more frequently inhabit forested wetlands, or areas that have recently been burned (COSEWIC, 2018). Habitat loss due to forest harvesting is a primary threat to OSFL in their breeding range. As a result, many recent studies have focused on the specific impacts that harvesting and forest loss has on this species, particularly in regard to its reproductive success (Robertson & Hutto, 2007) and its role in potential creation of an ecological trap (Robertson & Hutto, 2006; Brooks, 2020).

2.4.2 Influence of Forestry on OSFL

The impact of forest harvesting on the occupation and reproductive success of OSFL presents contrasting evidence. While selective harvesting practices mimic natural disturbances like fires, which are positively linked to OSFL due to their preference for edge habitats and forest clearings (Kotliar, 2007; Altman & Sallabanks, 2012), numerous studies yield opposing results to this finding.

Specifically, Altman and Sallabanks (2020) found that Mayfield estimates of nest success (e.g., nests fledgling more than one young) were higher in forests with semi-open canopies (>20%) and lower in harvested stands with varied retention rates. Further support is provided by a study in Montana that compared OSFL in post-burn sites to areas where selective harvesting occurred. They found lower daily nest survival rates (Harvest=97%, Post-Burn=99%) and total nest success rates (Harvest=30%, Post-Burn=61%) in harvested sites (Robertson & Hutto, 2007). Additionally, they identified that nest predator species were more than twice as abundant in the harvested area when compared to the post-burn area. Consequently, these findings led to the conclusion that, despite attempts to replicate natural disturbances favored by OSFL, selective harvesting ultimately creates an ecological trap for this species.

An ecological trap is an altered environment that has an increased appeal to organisms but does not contribute to their success (Robertson & Hutto, 2006). According to Robertson and Hutto (2006), an environment becomes an ecological trap when individuals select a habitat that leads to lower fitness outcomes compared to other available habitats. Based on the results noted previously (Robertson & Hutto, 2007), there is evidence that selective harvesting practices may negatively impact OSFL despite appearing to create an ideal habitat for the species.

A study by Brooks (2020) in New Brunswick found opposing results. In assessing whether sites harvested using clear-cut methods created an ecological trap for OSFL, they found that although individual birds preferred harvested sites to non-harvested sites, there was no difference in fitness when using reproductive success as an indicator (Brooks, 2020). The study found that 27% of OSFL assessed were breeding successfully. The typical nest success rate for this species ranges between 30% and 65%, with variations observed between habitat alteration type and region (Robertson & Hutto 2007; Anctil et al., 2017; COSEWIC, 2018). Given this, Brooks (2020) concluded that, accounting for mistakenly classified individuals in their study, the breeding success was within the expected range, indicating that the harvesting did not lead to the creation of an ecological trap (Brooks, 2020).

Despite the contrasting results, it is clear that forest management plays a role in presence and success of OSFL populations. Considering this, it is important to be familiar with the conservation measures in place that relate to protecting OSFL in forested landscapes across their breeding range in Nova Scotia.

2.4.3 Current Conservation Efforts

Currently, the only forestry management practices for OSFL conservation in Nova Scotia are a restriction on stand harvesting on crown land during the breeding season if a SAR has been found to be present. This regulation is based on those described in the Migratory Birds Convention Act, legislation which aims to protect birds' nests, eggs, and fledglings (MBCA, 1994).

Species-specific BMPs were developed for the OSFL in the context of forest management in Nova Scotia (LSARFW, 2022), and include a variety of approaches that aim to best consider OSFL habitat in forest harvesting. The BMPs consist of several recommendations to harvesters that aim to support habitat conservation for OSFL including leaving a buffer of 50 meters around wetlands surrounded by conifers and retaining mature spruce in the area, avoiding activities that will change wetland hydrology, leaving clumps of tall trees in cut areas undisturbed to create perches, use uneven-aged forest management techniques, maintain or increase woody debris such as snags, avoid pesticide and herbicide use near wetlands, maintain open meadow habitat when located near coniferous forest stands, and limit beaver trapping when possible. Considering that this species tends to prefer edge or semi-open habitat in their breeding range (COSEWIC, 2018), and given the contrasting results associated with forestry practices' impacts, it may be possible that harvesting supports the creation of suitable habitat for this species.

These BMP recommendations were implemented in harvesting of a stand in Cape Breton, Nova Scotia, in 2022. However, their effectiveness in conserving OSFL has yet to be assessed. These measures will not be put into effect elsewhere in the province until this is determined. Reproductive success is a suitable way to evaluate how conservation efforts impact OSFL.

2.4.4 Reproduction in OSFL

Past research has used reproduction success and breeding status in assessment of OSFL health and success (Robertson and Hutto 2007; Anctil et al., 2017; Brooks, 2020). As a result, a comprehensive understanding of their reproductive behaviours and patterns is critical when using this as a measure to assess effectiveness of conservation efforts.

OSFL are a socially monogamous species, meaning that males and females will pair and reside in the same territory for a period of time (Altman & Sallabanks, 2012). Territory sizes can be relatively large, with observations from Wright (1997) averaging 18.4 ha (184,000m^2) and high-end predictions ranging from 40 to 45 ha (400,000 – 450,000 m^2) (Altman and Sallabanks, 2012). Although limited research exists on shape of OSFL territories, past work has indicated that established territories may be long narrow rectangles as opposed to the often assumed circular boundary (Wright, 1997). Provided presence of suitable habitat, OSFL territories may border one another, with previous observations of two observed nests on adjacent territories measuring only 720m and 1050m apart (Wright, 1997). Both the male and female in an OSFL pair will defend their territory (Altman and Sallabanks, 2012).

Spring arrival of OSFL varies based on latitude and elevation. For Nova Scotia, recent data on arrival time from eBird, a citizen science platform on avian observations, notes arrivals occurring in late May (eBird, n.d.).

Previous research by Wright (1997) divides the reproductive cycle timeline into three breeding stages: the time frame prior to the arrival of females, the duration of female arrival through egg laying, and the incubation period. Unfortunately, there is little data on duration of various breeding stages, and low sample sizes in data collection pertaining to previous research must be considered. Using physical observations Wright (1997), found that males arrived on breeding grounds first, often detected by song, and commonly remained in in the area through the season. However, there were instances where individuals were identified by sound or sight one day, but then not heard vocalizing for several days after. Females were found to arrive an average of 7-9 days after males (n = 11, range = 6-24), with egg laying beginning 9-10 days later (n = 9, range = 6–14) (Wright, 1997). Wright (1997) assumed that laying of first clutches took four days and observed that incubation lasted between 15 and 16 days. Eggs hatched over two days (n = 6) with fledging occurring 19-20 days following first hatch (Wright, 1997).

2.4.5 Vocalizations

OSFL have a variety of vocalizations, but are most recognized by their distinct song, often remembered by the mnemonic "*quick, THREE BEERS!*" (Altman & Sallabanks, 2020). It is primarily the males of this species that sing, but Wright (1997) observed females singing occasionally and described it as 'soft' or 'lazy'. The OSFL also has a common call, given by both males and females, that is described as a 'pip' and is often a series of two to four notes (Wright, 1997; Altman and Sallabanks, 2020). Similar to other birds, the OSFL is observed to sing at the highest rates earliest in the morning, and the males may alternate between intervals of singing and calling throughout the day (Wright, 1997; Altman & Sallabanks, 2020). In addition to variation in vocalizations between sexes and throughout the day, there is evidence that the song rate of OSFL varies based on breeding status (Wright, 1997; Brooks, 2020; Upham-Mills et al., 2020).

Past research on song rate and breeding status in other birds has found that, generally, paired males will sing at lower rates as the breeding season progresses, while unpaired males will sing continuously at high rates throughout (Dussourd & Ritchison, 2003; Staicer et al., 2006; Liu et al., 2007). Wright (1997) and Upham-Mills et al. (2020) found that OSFL song activity patterns align with this finding.

Wright (1997) and Upham-Mills et al. (2020) used brief listening intervals to assess song rate and visited sites to obtain behavioural evidence of breeding status. The latter study addressed the proficiency of using three different models (multinomial logistic regression, hierarchical model, and classification tree) to predict breeding status from song rate, and concluded that the hierarchical model was most effective, but noted that all models overpredicted some breeding statuses (Upham-Mills et al., 2020). However, Wright (1997) calculated average song rate over time and linked it to male status (e.g. paired, unpaired, failed nest), showcasing the potential of using a simplistic method of predicting breeding success.

Wright's (1997) findings, highlighted in Figures 1 and 2, identified distinct patterns in singing behaviour of male OSFL. They found that individual males that never paired sang at relatively high rates throughout the entire season, whereas the rates from those that paired and nested successfully decreased as time went on. For males that experienced nest failure, Wright (1997) found that their song rate decreased gradually before increasing again, likely as a result of reinitiating courtship behaviour. In addition to this, it was observed that paired males that experienced a failed nest would have more variation in diurnal song rate. Male singing was generally highest earliest in the morning and declined through the day, regardless of whether or not they were paired. However, they noted that for those with failed nests, this pattern was more variable, including instances of higher singing rates occurring later in the day.

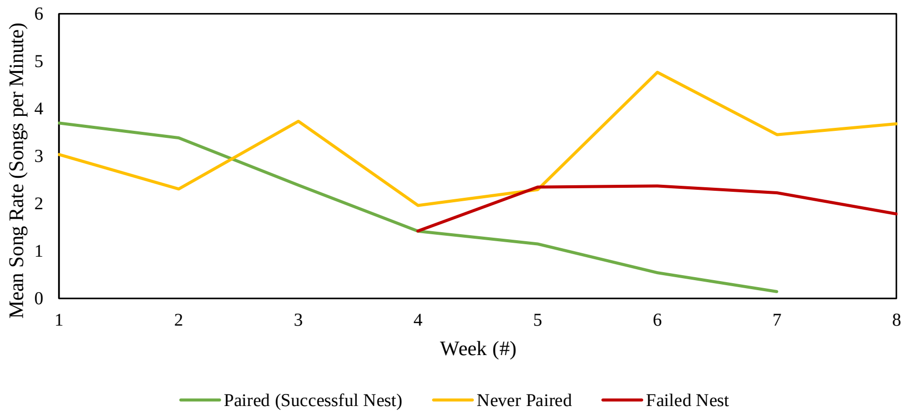


Figure 1 Mean song rate of OSFL across different breeding success categories (produced with data from Wright, 1997).

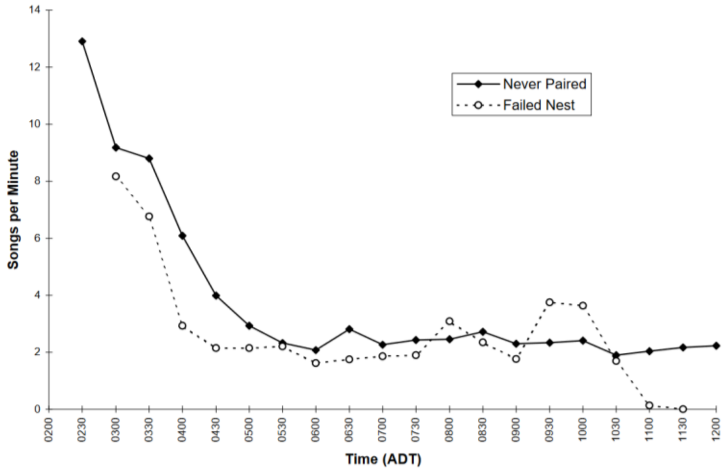


Figure 2 Diurnal song rate of OSFL for unpaired males and those that experienced failed nests. (Source: Wright, 1997)

The outcomes of similar research based in New Brunswick found contradictory results (Brooks, 2020). As opposed to the aforementioned studies that utilized listening intervals, this project assessed vocalizations obtained using autonomous recording units (ARUs) and totalled counts of both songs and pips identified using an automated signal recognition program. Brooks (2020) utilized changepoint analysis in the determination of reproductive success, and classed individuals whose vocalization pattern resulted in four change-points as breeding successfully. Those with less than four changes were classed as unsuccessful (Brooks, 2020). For example, one individual that produced four change points had vocalization rates that started high, and decreased gradually, before increasing rapidly at the end (Figure 3). This was described as being indicative of successful breeding in spite of it contrasting with the outcomes of the observational study by Wright (1997).

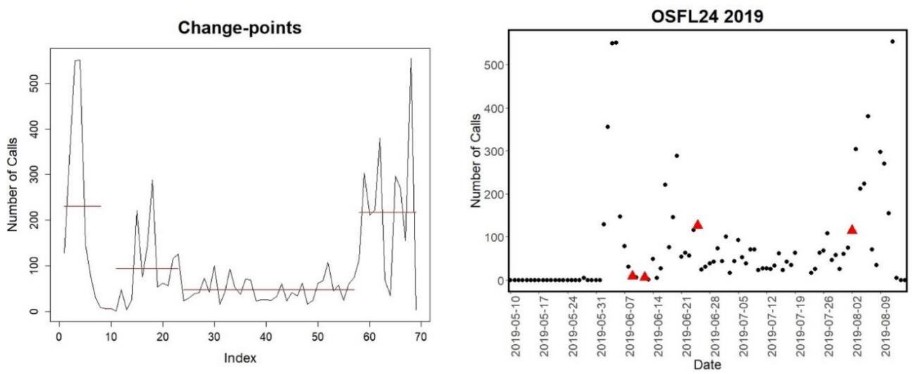


Figure 3 Vocalization rates and identified change-points of an individual OSFL predicted to successfully breeding. On the right, red triangles indicate change-point locations.
(Source: Brooks, 2020)

Another OSFL studied was found to have three change-points and vocalization rates that appeared to decrease through the season (Brooks, 2020, Figure 4) This male was predicted to be breeding unsuccessfully but was later found to have produced fledglings (Brooks, 2020). This outcome provides partial support to other findings that OSFL song rates decrease in the case of successful breeding (Wright, 1997). It is important to highlight that Brooks (2020) utilized the total vocalization rate, including calls and songs, to predict breeding success (D. Brooks, personal communication, January 29, 2024). However, there is currently no research that indicates that call and song rate combined predict reproductive success. Therefore, there is reason to question the validity of these results.

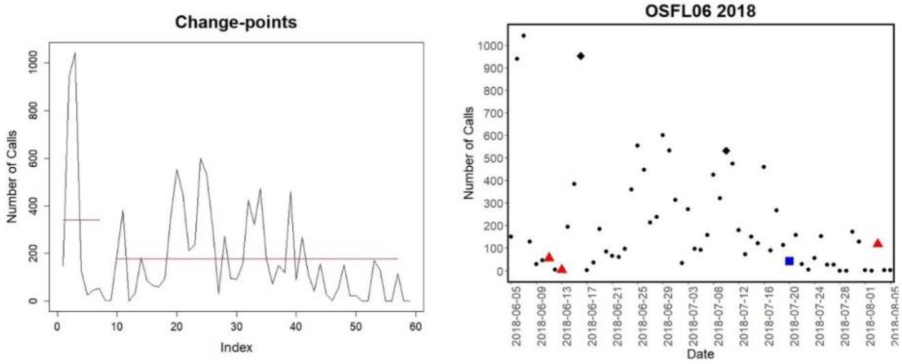


Figure 4 Vocalization rates and identified change-points of an individual OSFL predicted to be unsuccessfully breeding. On the right, red triangles indicate change-point locations, black diamonds indicate removed data, and the blue square indicates the date when a fledgling was observed. (Source: Brooks, 2020)

Considering the shortcomings associated with the methodology employed by Brooks (2020), the limitations of the hierarchal model approach (Upham-Mills et al., 2020), and the complex statistical calculations required for the later, it may be beneficial to assess OSFL song rate and breeding success using more straightforward methodologies. However, obtaining vocalization data in the field has its downfalls, and may not be the ideal choice when studying a SAR birds such as the OSFL. Given this, exploring the potential of ARUs in future research on this species may be advantageous.

2.5 Autonomous Recording Units

Autonomous recording units (ARUs) are devices that can be programmed to record sound on a predefined schedule while unattended in the field (Shonfield & Bayne, 2017). Vocalizations are studied for a variety of animals including anurans (Annich, 2017), marine mammals (Castellote et al., 2012), and birds (Staicer et al., 2006; Upham-Mills et al., 2020; Brooks, 2020). Given the associated benefits of employing ARUs in research, there has been an increased interest in using them in avian conservation studies (Shonfield & Bayne, 2017).

Birds are oftentimes detected more by sound rather than sight. As a result, ARUs have recently gained more popularity in avian conservation research due to their numerous benefits (Shonfield & Bayne, 2017).

2.5.1 Benefits and Limitations

There are many advantages to employing ARUs in avian research including their ability to monitor rare or uncommon species, require less time in the field, limit impact on species, and lessen bias associated with point count data (Shonfield & Bayne, 2017). In the field, set up and take down of ARU devices can be done quickly, but units may require additional visits to replace batteries or storage cards. Holmes et al. (2014) found that while studying at-risk birds the use of ARUs resulted in less effort in the field when compared to point counts completed by human observers. For studying rare or uncommon species, past studies on Kirtland's Warbler (*Setophaga kirklandii*) (Holmes et al., 2015) and Nightjars (Zwart et al., 2014) found that ARUs may be better at species detection when compared to human observers. ARUs provide a further advantage over human observers as they can be deployed in remote locations and simplify data collection in areas more difficult to frequently access on foot (Shonfield & Bayne, 2017). Additionally, ARUs create a permanent record that can be analyzed numerous times by multiple individuals, which allows for in-depth study.

Several studies have explored how ARUs perform when compared to human observers. Borker et al. (2015) found that humans were better are determining call counts of marbled murrelets, while Digby et al. (2013) found that ARUs and human observers performed equally in determining call counts of Little Spotted Kiwi (*Apteryx owenii*). Another study concluded that both humans and ARUs were equally effective in detecting several species (Van Wilgenburg et al., 2017). Shonfield and Bayne (2017) argue that ARUs generally perform equally to human observation but that ARUs have several advantages in the field and can be successfully used for surveying birds.

The use of ARUs is limited by factors relating to cost, spatial and temporal coverage, and processing time (Shonfield & Bayne, 2017). Utilizing ARUs in research has a high initial cost, given that many of the devices are quite expensive (Shonfield & Bayne, 2017). For example, the Song Meter SM4 Acoustic Recorder, which is considered to be the industry standard, is sold for around $900 USD (Wildlife Acoustics, n.d.). However, it is still less than what the cost would be to employ trained technicians to perform surveys to obtain the same quantity of data. When utilizing ARUs in research, there is a necessary tradeoff between spatial coverage (e.g., moving device periodically) and temporal coverage (e.g., for an extended period in one location), and either spatial or temporal coverage must be prioritized (Shonfield & Bayne, 2017). Processing time for data obtained from ARUs can be a limitation based on the amount of data that must be analyzed. However, technologies like the creation of a trained recognition program, such as the one created by Brooks (2020), or the application of existing deep artificial neural networks like BirdNET (Kahl et al. 2021), may be valuable in lessening the required processing time.

2.6 Automated Species Identification

There are two primary approaches to using technology to automatically identify a bird species by song: the creation and training of a model using a collected dataset or the application of an existing deep artificial neural networks. The first approach was utilized by Brooks (2020). The model in this study created an automated signal recognition program on R using a package designed for this purpose (monitoR: Hafner & Katz, 2018) and required the creation of templates for each OSFL vocalization. Brooks (2020) formed templates using recordings from the Macauley Library from The Cornell Lab of Ornithology (n.d.), and when applied to the data collected, it resulted in over 670,000 detections within audio files from 2600 days. Manual assessment on the effectiveness of the model identified that of the detections, only a quarter were true positives. The remaining false positives were often deemed to be Alder Flycatchers, due to the visual similarity of their songs, and American Squirrels, due to their loud vocalizations (Brooks, 2020).

BirdNET is a deep neural network that has been used in many avian studies since its creation (Wood et al., 2022; Bota et al., 2023). While its success rate of identification has been found to vary by species (Perez-Granados, 2023), past research has found its accuracy to be extremely high on well-known species (91.5%; Arif et al., 2020). In a study in the Yukon, OSFL was detected in recordings both by BirdNET and by manual analysis of spectrograms, hinting that OSFL may be a species easily detected by BirdNET (Ware et al., 2023).

Considering the low accuracy of species identification in acoustic data using a trained model, and the time involved in the formation of the model (Brooks, 2020), utilizing existing applications such as BirdNET may address the processing time limitation presented by ARUs while not compromising precision in the results. However, in all studies utilizing automatic identification, it is important to manually assess the accuracy of the outputs for results to be considered valuable.

3.0 Methods

3.1 Study Areas

Two areas were studied, one experimental site in Cape Breton and one control site in Southwestern Nova Scotia (Figure 5). The experimental site, where BMP recommendations were considered in the development of a harvesting plan, will hereafter be referred to as River Tillard (RT). The control site, where no BMP harvesting was completed, is referred to as North of Harvest Block 13 (NHB13). These areas were selected due to the presence of OSFL in Spring/Summer 2022 field surveys and, for River Tillard, the intention to harvest the area with BMPs.

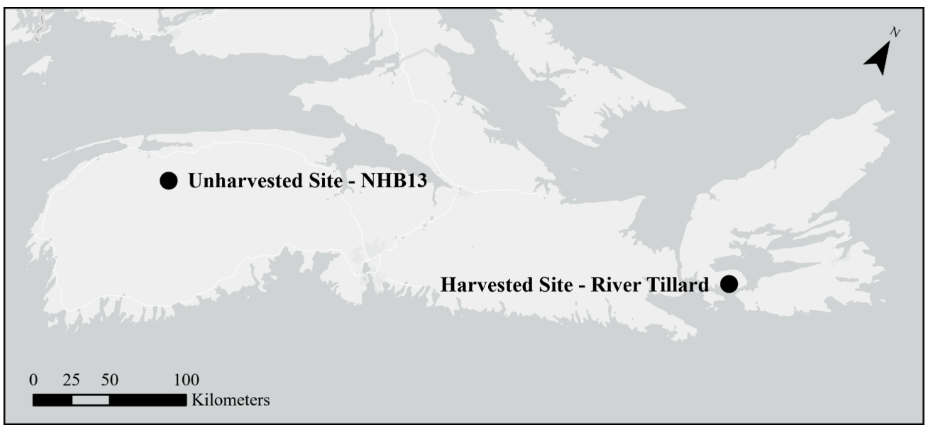


Figure 5 Map of Nova Scotia with control site (NHB13) and experimental site (RT).

Vegetation transect surveys were conducted by Dr. Cindy Staicer's team in 2022 near the two ARUs used in the study. At the experimental site, the SW ARU at River Tillard was used (Figure 6). Tree composition was 51.5% Black Spruce (*Picea mariana*), 14.8% Balsam Fir (*Abies balsamea*), 13.5% Red Maple (*Acer rubrum*), 5.2% Eastern Larch (*Larix laricina*), and 0.4% White Birch (*Betula papyrifera*). The canopy cover averaged 54.2%, and the sphagnum moss cover averaged 8.3%. At the control site, NHB13, the tree composition was 58% Balsam Fir, 37% Red Spruce (*Picea rubens*), and 0.05% Eastern Larch. Canopy cover averaged 42.5% and the sphagnum cover averaged 1.7%.

Harvesting of River Tillard occurred in Winter of 2022, and followed the retention guide displayed in Figure 6. Specific retention amounts were selected based on buffered locations of

SAR observations following 2022 field surveys. Both OSFL and Canada Warbler (*Cardellina canadensis*) observations were accounted for, though OSFL buffers made up the majority of the area. The first buffer zone (25m radius from observation) had a planned retention of 100%, with the second zone (25-100m radius from observation) having a planned retention of 30%. BMPs guidelines were applied in these 100m buffers and are thus referred to as BMP zones. Areas outside of this 100m buffer are considered non-BMP zones, as recommendations were not considered here. The retention plan for the remaining area was 10%.

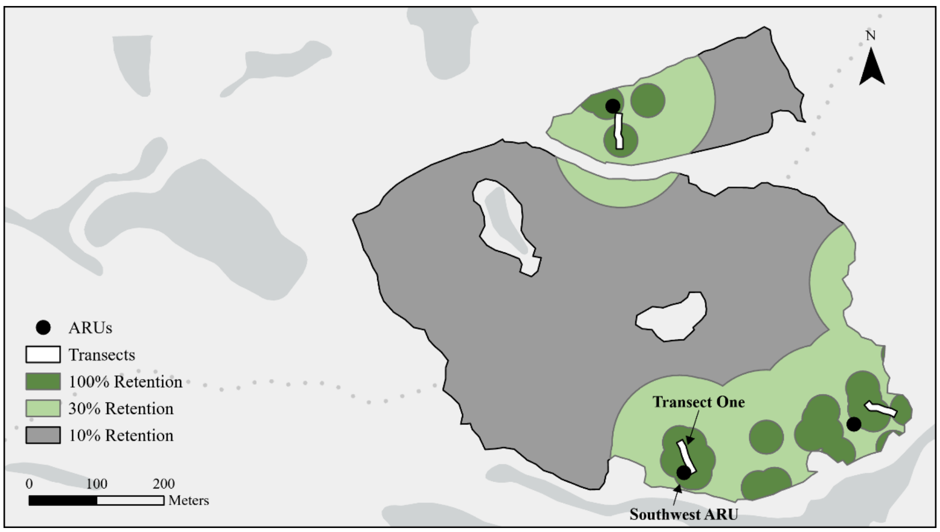


Figure 6 Map displaying harvesting retention guidelines for RT, locations of transects, and locations of ARUs.

3.2 Spatial Data

3.2.1 Collection and Pre-processing

Spatial data was collected and analyzed to determine how tree coverage changed from pre- to post-harvest in River Tillard. An unmanned aerial system (UAS) was used to obtain high-resolution imagery of River Tillard. A Phantom 4 Real Time Kinematics drone was flown approximately 100m above the ground across the site during the growing season pre-harvest (21 July 2022) and post-harvest (25 August 2023). This study used UAS as they can obtain imagery at a finer spatial resolution (Goodbody et al., 2017). The imagery obtained from the UAS was first used to create a digital terrain model (DTM) and a digital surface model (DSM) in the AgiSoft Metashape software. The output raster DTM and DSM have a spatial resolution of approximately 8cm. The operation of the UAS as well as the processing to create the high-resolution image and the DTM and DSM rasters was completed by a member of Dr. Cindy Staicer's team.

3.2.2 Treetop Detection

A canopy height model (CHM) was created by subtracting the DTM from the DSM in ArcGIS Pro using the raster calculator tool. The CHM was loaded into R and tree canopy analysis was performed using the 'ForestTools' package to identify treetops and tree height (Plowright, 2023). The locations of treetops with a height of at least 5 m were loaded into ArcGIS and the density per polygon calculated pre- and post-harvest for the three sections (25m radius no-harvest BMP buffers, 25-100m BMP buffers, and the remainder of the area where the harvest was not modified). These values were compared, and the percent difference calculated. Roads were excluded from calculations. The outcomes were compared with the retention levels described in the harvesting plan to determine the percentage difference.

3.3 Acoustic Data

3.3.1 Collection

Acoustic data was collected with Song Meter Minis, a model of ARU designed by Wildlife Acoustics (Wildlife Acoustics, n.d.). Three ARUs were deployed in River Tillard and one in NHB13, all prior to OSFL arrival. The units were placed on trees of a suitable diameter that were not blocked by any vegetation and were near locations where OSFL were observed in 2022 surveys. They were scheduled to record in 10min on, 10min off intervals beginning before sunrise and ending after sunrise. Units were collected at the end of the season when OSFL had left for fall migration. No OSFL were observed at either site the day of ARU collection. Scheduling, deployment, and collection of ARUs was completed by Dr. Cindy Staicer and her team.

To identify any within-day variation, four recordings were selected for analysis. For RT, these recordings started 20min before sunrise, at sunrise, 1h after sunrise, and 1h 20min after sunrise (Table 1). For NHB13, the recordings started 40min before sunrise, 20min before sunrise, 40min after sunrise, and 1h after sunrise (Table 1). Two of the four recordings for each site occur at the same time relative to sunrise, to allow for comparison between sites for these specific time frames.

Table 1 Start times of recordings analyzed relative to sunrise for RT and NHB13.

Recording (#)	River Tillard	NHB13
1	**20min Before Sunrise**	40min Before Sunrise
2	Sunrise	**20min Before Sunrise**
3	**1h After Sunrise**	40min After Sunrise
4	1h 20min After Sunrise	**1h After Sunrise**

3.3.2 Analysis of Field Recordings

The four recordings from each day selected for analysis were first run through BirdNET analyzer to obtain a prediction of how many OSFL vocalizations were present in each recording. The recordings were then viewed as spectrograms in Raven Pro/Lite along with the BirdNET output files that highlighted vocalizations identified as being OSFL. The audio files were divided for analysis among Hannah Freeman and research assistants from the Dalhousie Integrated Science Program (Maia Baxter and Bridget McPhail). Songs and calls were identified using visual and auditory indicators as well as detections identified by BirdNET (Figure 7 & 8).

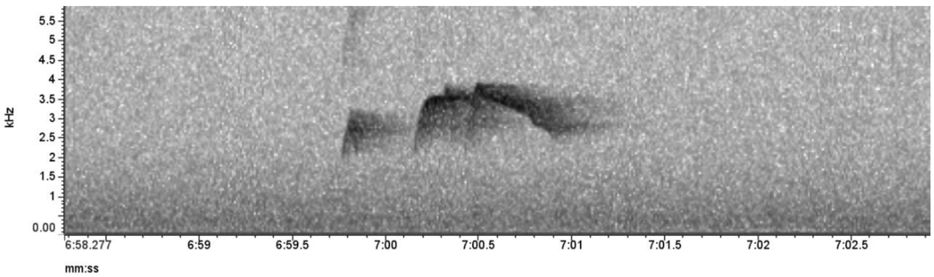


Figure 7 Clear spectrogram of an OSFL song.

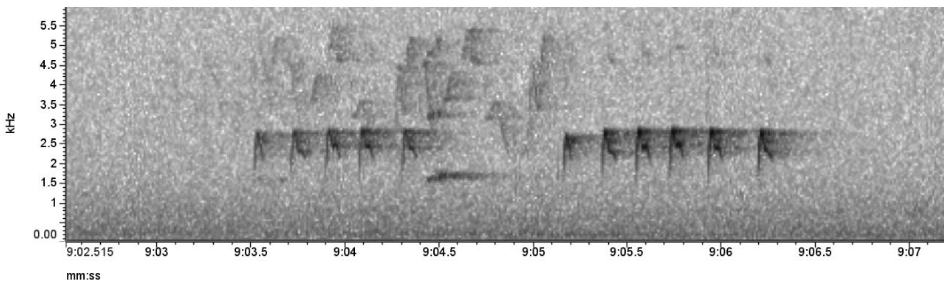


Figure 8 Clear spectrogram of OSFL pips.

Vocalizations that were indicative of both a male and female being present (e.g., loud songs with quieter pips or songs overlapping pips), or two males being present (e.g., songs overlapping or songs of varied volumes) was noted where applicable. Additionally, instances of uncommon calls were marked and counted if present. When possible, all researchers analyzed recordings at the same time, to ensure that multiple opinions could be considered in times of uncertainty.

3.3.3 Analysis of Outputs

Once final song and pip counts were totalled for all recordings from RT and NHB13, the average songs per minute and pips per minute were calculated for each day. This was done by summing the values across the four recordings and dividing by 40 (the sum of minutes in four recordings). These values were then plotted in Python using the Matplotlib package with mean song/pip count on the vertical axis and date on the horizontal axis. To obtain a more smoothed variation of these results, and one that would be easily comparable to results of Wright (1997) in Figure 1, the mean song rate averaged across weeks was calculated and visualized. In addition to these outputs, emphasis was placed on examining recordings where males and females were thought to be present, or where uncommon calls were observed.

To compare values determined by manual analysis to those obtained by BirdNET, similar plots were generated using the BirdNET vocalization counts. In addition, total vocalization rate per recording was obtained for results found using manual analysis and using BirdNET. These values were compared using a two-tailed paired t-test in order to identify potentially significant differences. To gain further insight into discrepancies between BirdNET values and observed values, spectrograms of recordings with high variation were evaluated to identify possible contributing factors.

Commented [HF1]: Updated to reflect paired t test use

The statistical procedure for acoustic analysis employed primarily descriptive statistics and followed a relatively straightforward approach similar to that of Wright (1997).

3.4 Climate Data

Given that rainy weather can be a barrier to effective analysis of ARU recordings, data on total precipitation was obtained from weather stations nearest to RT and NHB13. Data for RT was obtained from the Government of Canada Port Hawkesbury Station (Government of Canada 2023a), and data for NHB13 from the Kejimkujik National Park Station (Government of Canada, 2023b).

4.0 Results

4.1 Experimental Site: River Tillard

4.1.1 Harvesting Retention

The CHMs made from the DTM and DSM generated from pre- and post- harvest data from RT is displayed in Figure 9. Variation in height across pixels was highlighted by dividing the CHM into three sections using a manual classification system. Light green pixels have a measured height between 0m and 5m, and dark green pixels have a height between 5m and 25m. This division was selected so that areas that met the minimum height for treetops (5m) were differentiated from vegetation that did not meet that value. There were also instances where a pixel had a height value below zero, which indicates that the generated DTM was greater than the DSM. This is more prominent in the 2023 post-harvest CHM.

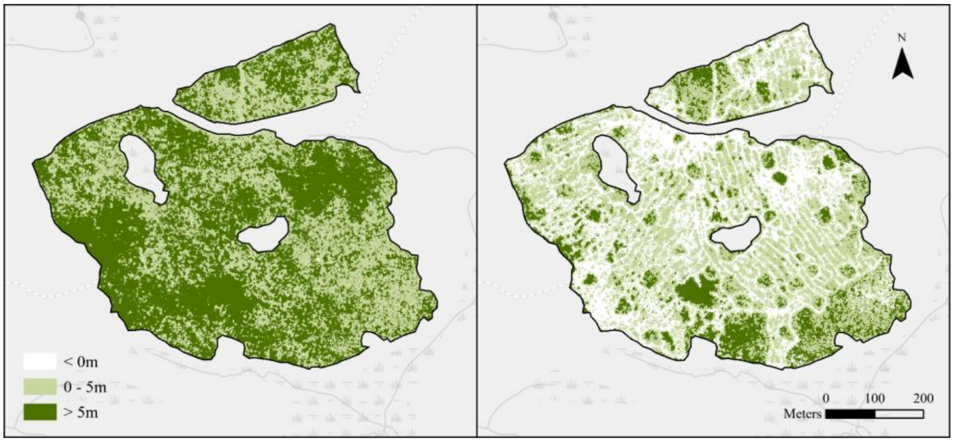
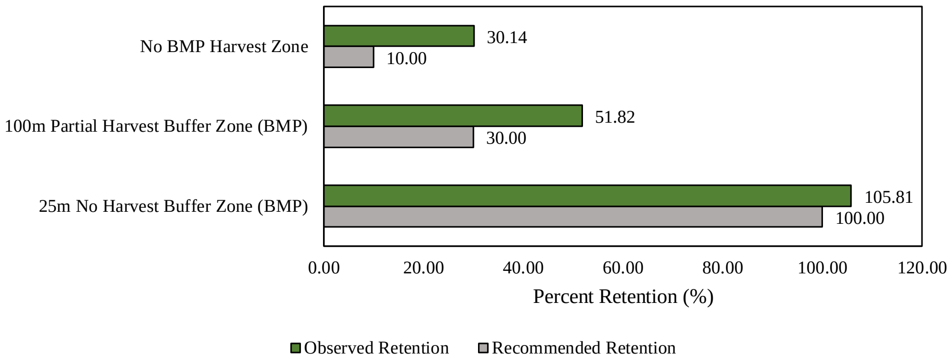


Figure 9 CHMs generated for River Tillard for 2022 (left) and 2023 (right).

The outcomes of the comparison between planned and observed tree retention for RT are highlighted in Figure 10. Across all zones, the observed retention rates exceeded the



recommended rates. Specifically, in the non-BMP harvest zone, where a 10% retention was advised, an observed retention rate of 30.15% was recorded. Similarly, in the 25m buffer zone and the 25-100m buffer zone, the recommended rates were 100% and 30%, respectively, with observed rates of 105.81% and 51.82%, respectively.

Figure 10 Comparison of recommended and observed tree retention in RT.

4.1.2 Field Observations

Field observations in 2022 and 2023 observed OSFL in the locations identified in Figure 11. The observations are compiled from several days in 2023, and from only one day in 2022.

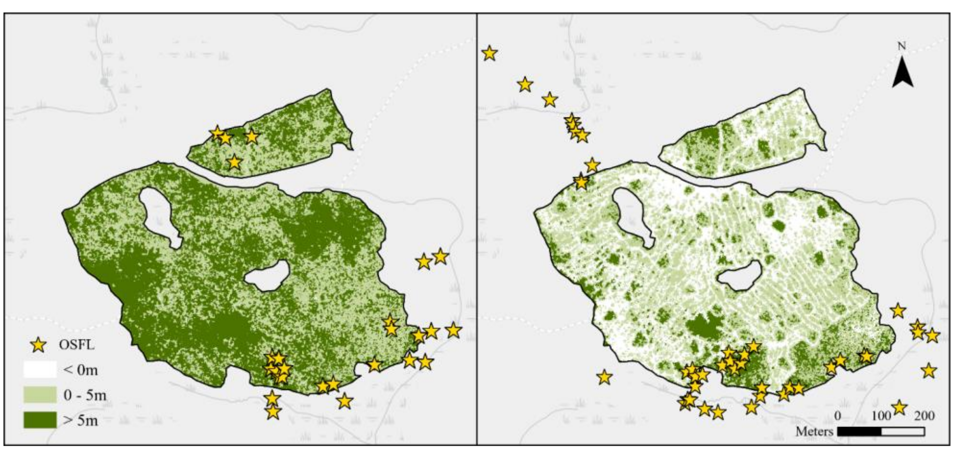


Figure 11 Map of OSFL Observations in RT in 2022 (left) and 2023 (right)

Data on behaviour was also recorded on the OSFL observed most near the SW ARU in 2022 and 2023 and is displayed in Appendix 1. Twice in 2023 (21 June 2023 & 13 July 2023), paired OSFL were observed in RT following playback. There were no pairs observed on the only survey day in 2022.

4.1.3 Vocal Activity Pattern (Manual Analysis)

The total song count from manual identification is shown for each of the four recordings analyzed in Figure 12. Song and pip counts for each individual recording period analysed are in Appendix A. The number of songs for the recordings prior to and at sunrise are notably higher than those following sunrise.

The vocal pattern in Figure 13 represents mean daily song rate and was obtained by calculating the mean song rate per day by considering song counts in all four 10min recordings. In this data, there is a notable period between June 12, 2023, and July 16, 2023, where there seems to be the highest rates. There is also a period near the end of the season (3 August 2023 – 16 August 2023) where singing resumes following a more silent period. When comparing this to Figure 12, it is seen that these songs later in the season were mostly observed in the post-sunrise recordings.

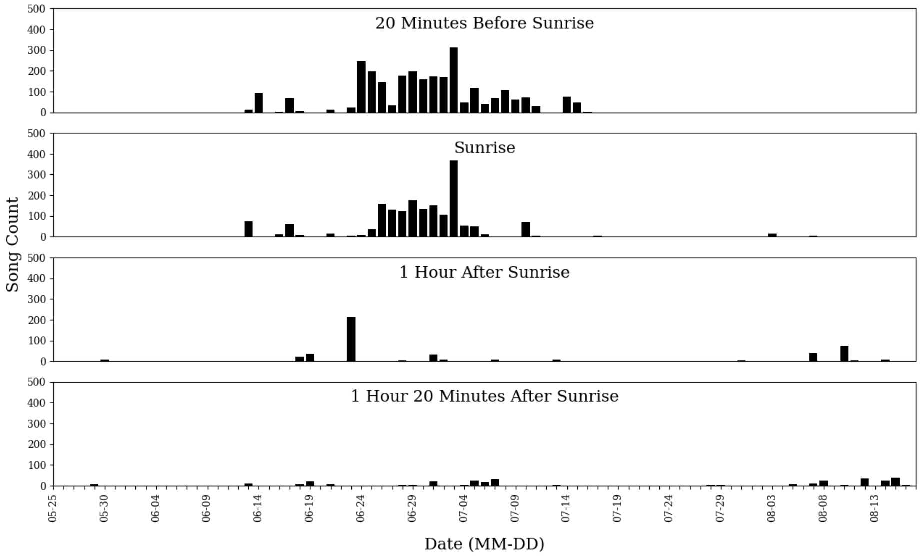


Figure 12 Total song count from manual identification for each of the four recordings in RT.

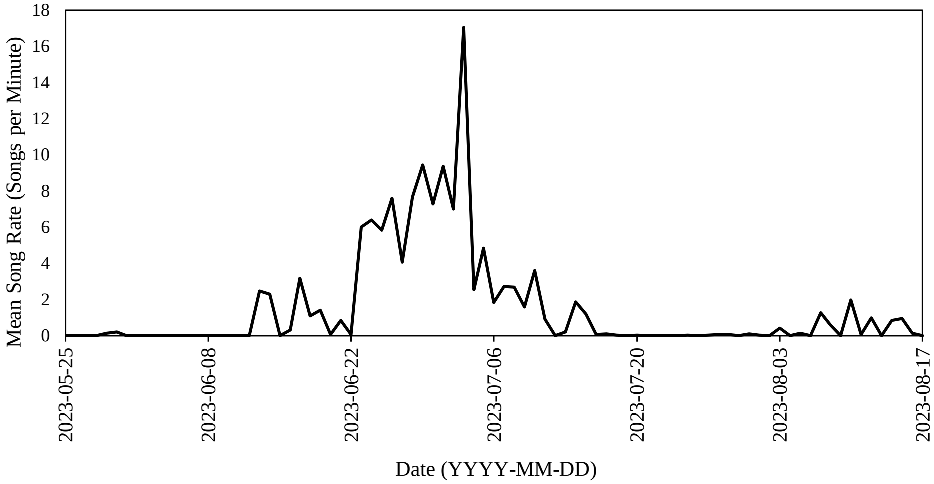


Figure 13 Mean daily song rate from manual identification for RT.

When averaged into week-long periods shown in Figure 14, beginning with 25 May 2023, the mean rates follow a similar pattern as seen in Figure 12 and 13, with a peak occurring at week 6. Due to unequal division of dates, week 12 is the mean value of the last eight days.

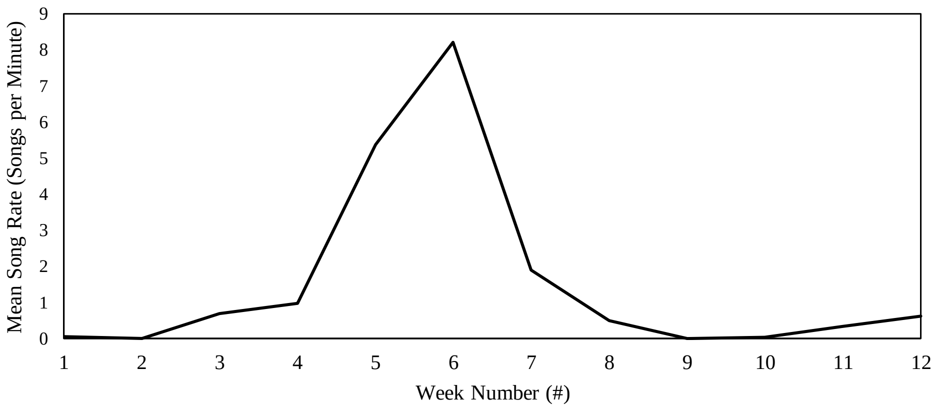


Figure 14 Mean song rate averaged by week for River Tillard.

Figure 15 displays the mean daily pip rate is overlayed with the mean daily song rate. From this it is visible that pip rate reaches much higher levels overall. OSFL seem to be pipping at the highest points later in the season, beginning before the singing resumes, and continuing until the end of the recorded season. Pipping is also observed at lower rates between June 20, 2023, and June 29, 2023, before the singing rate peaks on July 3, 2023. Figure 16, generated from the Port Hawkesbury station data, is shown to display periods of high precipitation that might have impacted the number of vocalizations identified.

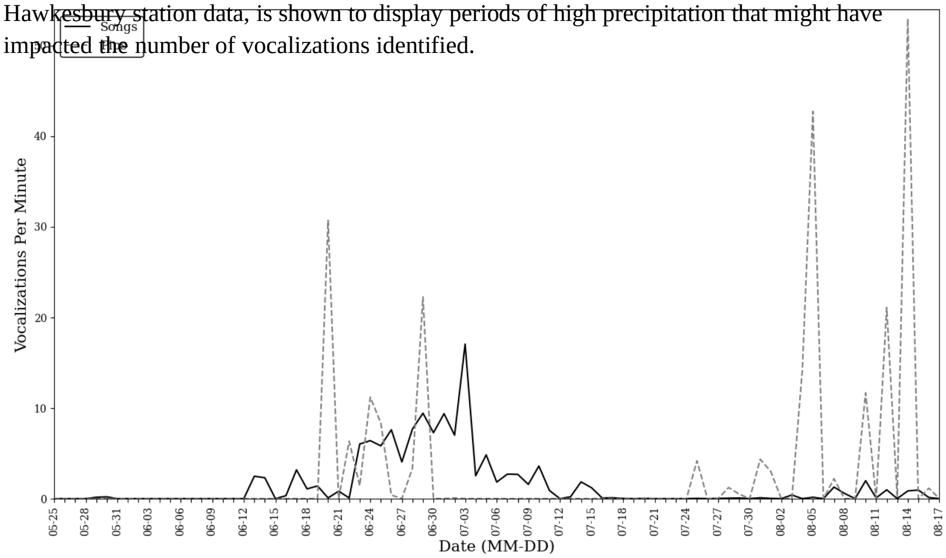


Figure 15 Mean song and pip rate found by manual identification for RT

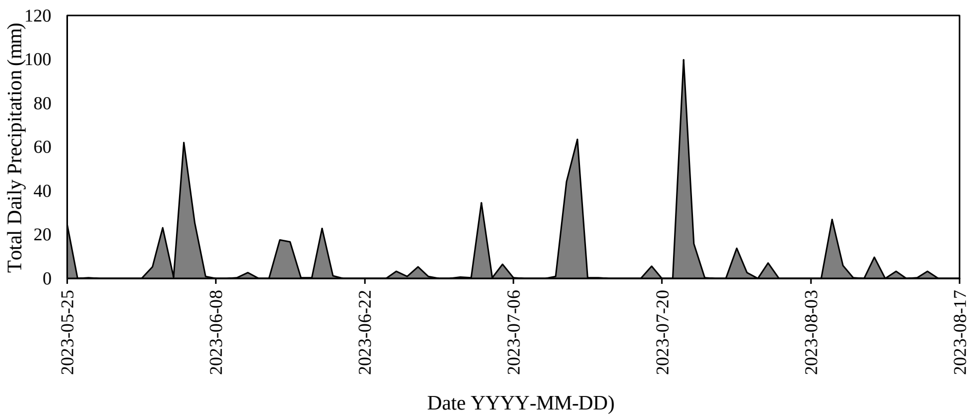


Figure 16 Total precipitation observed at the Port Hawkesbury Weather Station during Spring/Summer 2023. (Source: Government of Canada, 2023a)

4.1.4 Vocalization Pattern (BirdNET)

The mean vocalization rate per day calculated from BirdNET counts is shown in Figure 17. Vocalization counts for each individual recording period analysed are in Appendix A. BirdNET includes both songs, pips, as well as potential uncommon calls in its output, contributing to variation present between these results and those of the song rates or pip rates manually identified.

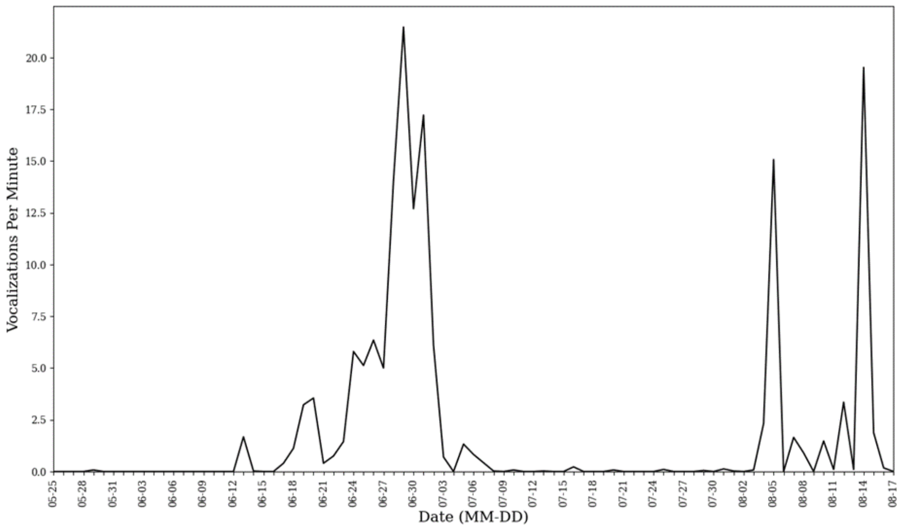


Figure 17 Mean daily vocalization rate found by BirdNET for RT.

The pip and song rate total for each recording found from manually identification was summed to obtain a total vocalization count per recording. These values were compared to the vocalization counts found using BirdNET using a two-tailed paired t-test. The resulting p-value was 3.57E-05 (n = 340) indicating a significant difference between the manually observed vocalization count and those identified by BirdNET.

4.2 Control Site: NHB13

4.2.1 Vocal Activity Pattern (Manual Analysis)

The total song count from manual identification is shown for each of the four recording periods analyzed in Figure 18. Song and pip counts for each individual recording period analysed are in Appendix B. The number of songs for the recordings prior to and at sunrise are notably higher than those following sunrise. However, there is a greater number of songs identified after sunrise when compared to RT.

The pattern in Figure 19 was obtained by calculating the mean song rate per day by considering song counts in all four recordings for each day. In this data, there appears to be three peaks in the data occurring around 27 May, 12 June, and 20 July.

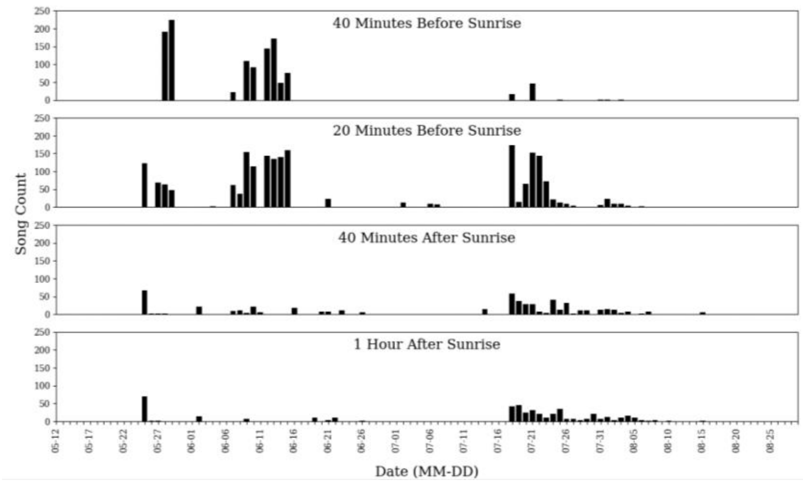


Figure 18 Total song count from manual identification for each of the four recordings for NHB13.

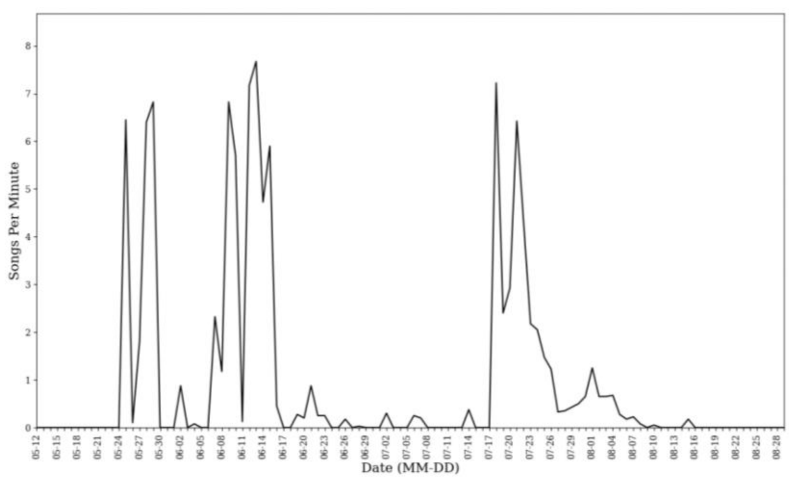
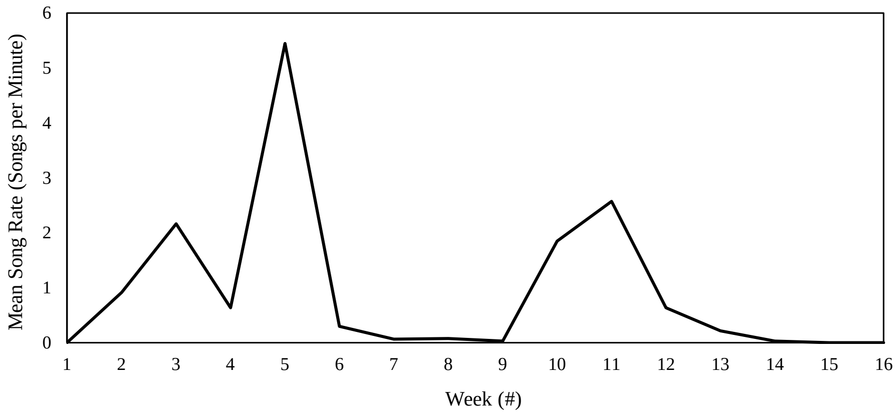


Figure 19 Mean daily song rate from manual identification for NHB13.

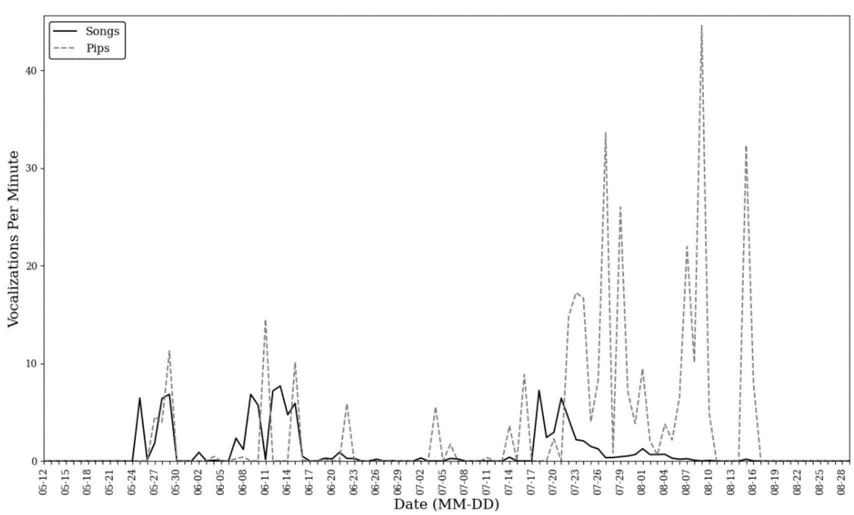
When averaged into week-long periods as shown in Figure 20, beginning with May 25, 2023, the



mean rates follow a similar pattern as seen in Figure 18 and 19, with a peak occurring at weeks three, 5, and 11. Due to unequal division of dates, week 16 is the mean value of the last five days.

Figure 20 Weekly mean song rate by manual identification for NHB13.

Figure 21 displays the mean daily pip rate overlayed with the mean daily song rate. From this it is visible that the pip rate reaches much higher levels overall. OSFL seem to be pipping at the highest points later in the season. Figure 22, generated from the Kejimkujik weather station data, is shown to display periods of high precipitation that might have impacted the number of vocalizations identified.



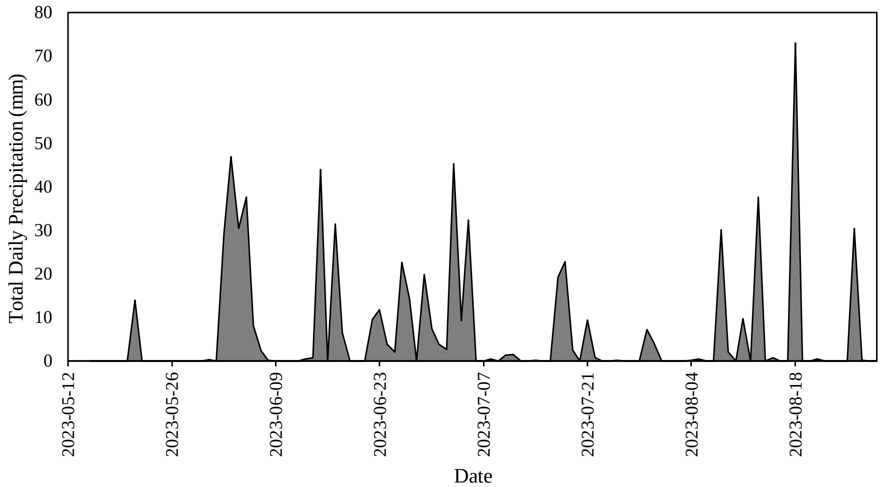


Figure 21 Mean daily song and pip rate found by manual identification for NHB13

Figure 22 Total daily precipitation observed at the Kejimkujik weather station during Spring/Summer of 2023 (Government of Canada, 2023b)

4.2.2 Vocalization Pattern (BirdNET)

The mean vocalization rate per day calculated from BirdNET counts is shown in Figure 23. Vocalization counts for each individual recording period analysed are in Appendix B. BirdNET includes both songs, pips, as well as potential uncommon calls in its output, contributing to variation present between these outputs and that of the song rates or pip rates manually identified.

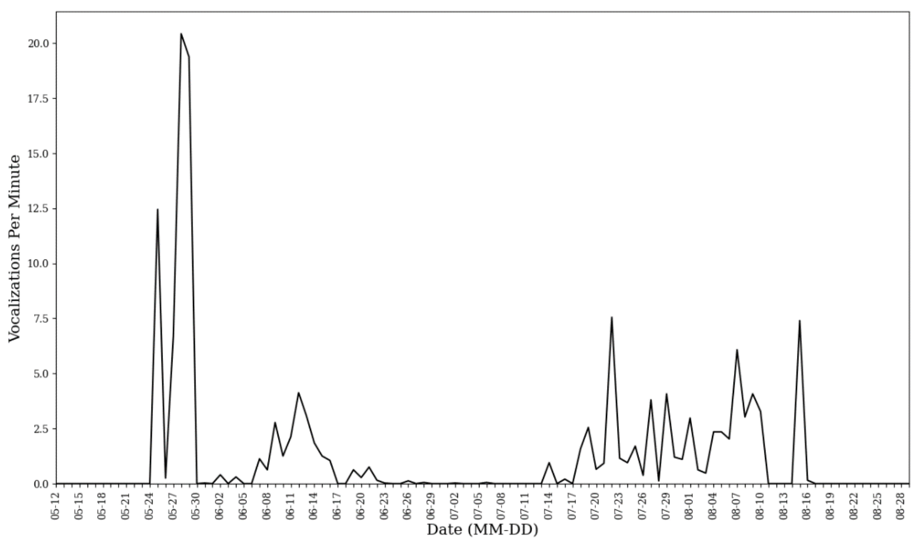


Figure 23 Mean daily vocalizations found by BirdNET in NHB13.

The pip and song rate total for each recording found from manually identification was summed to obtain a total vocalization count per recording. These values were compared to the vocalization counts found using BirdNET using a two-tailed paired t-test. The resulting p-value was 1.1E-06 indicating a significant difference between the manually observed vocalization count and those identified by BirdNET.

5.0 Discussion

5.1 Harvesting with BMP Recommendations

According to the analysis, the retention guidelines provided to the harvesting company were not only met, but exceeded in all zones in RT. This was observed most in the non-BMP harvest zone, that had a recommended retention rate of 10%, and an observed retention of around 30% in analysis of the CHM. The other guidelines included within the BMP recommendations (e.g., maintenance of tall snags, maintenance or increase of woody debris) are more challenging to measure quantitively from the results produced from the UAS data. However, the CHM does demonstrate that retention harvesting was done by leaving small areas of undisturbed trees (Figure 9), which aligns with the BMP guideline that includes leaving clumps of tall trees in cut areas in other to create perches for the OSFL.

5.2 Shortcomings of BirdNET in Researching OSFL Vocalizations

5.2.1 BirdNET in OSFL Identification

Given the success of the BirdNET program noted in past research (Arif et al., 2020; Ware et al., 2023), it was initially anticipated that BirdNET would be relatively accurate in identifying OSFL vocalizations in recordings, and that manual analysis would involve primarily viewing the BirdNET highlighted observations and differentiating them between songs and pips. However, this study found contradictory results, as there were many instances where songs and pips were missed by BirdNET. Looking further at the recordings revealed that this was either due to weather conditions (Figure 24), overlapping vocalizations (Figure 25), being too faint (Figure 26), or for other unknown reasons (Figure 27).

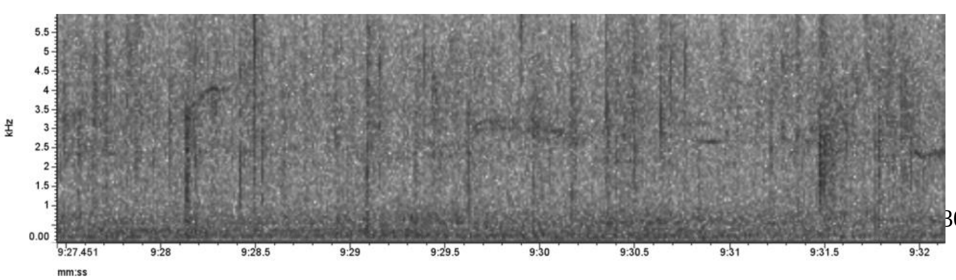


Figure 24 Spectrogram of OSFL song missed by BirdNET, likely due to noise from rainfall. [Recording: RT – 18 July 2023, 6:32]

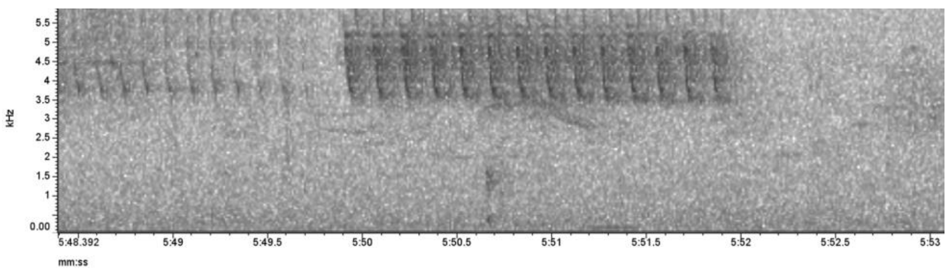


Figure 25 Spectrogram of OSFL song missed by BirdNET, likely due to other overlapping bird song. [Recording: RT – 10 July 2023, 5:04]

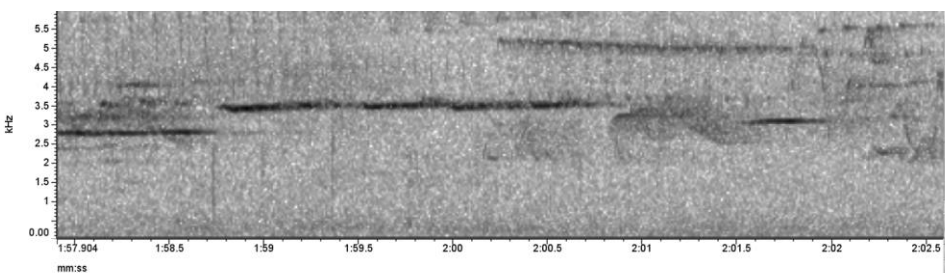


Figure 26 Spectrogram of OSFL song missed by BirdNET, likely due to being faint. [Recording: RT – 3 July 2023, 4:59]

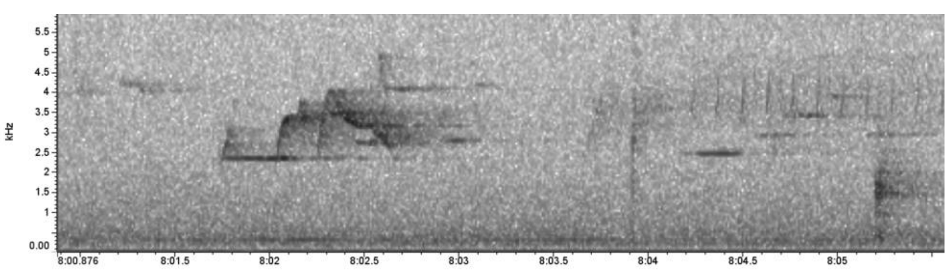


Figure 27 Spectrogram of OSFL song missed by BirdNET for unknown reasons. [Recording – RT: 6 July 2023, 6:41]

There was one occurrence where BirdNET misidentified a Hermit Thrush (*Catharus guttatus*) as an OSFL, but this was the only misidentification observed in all recordings (Figure 28). This indicates that while BirdNET often failed to detect OSFL vocalizations, it rarely confused other bird species with OSFL.

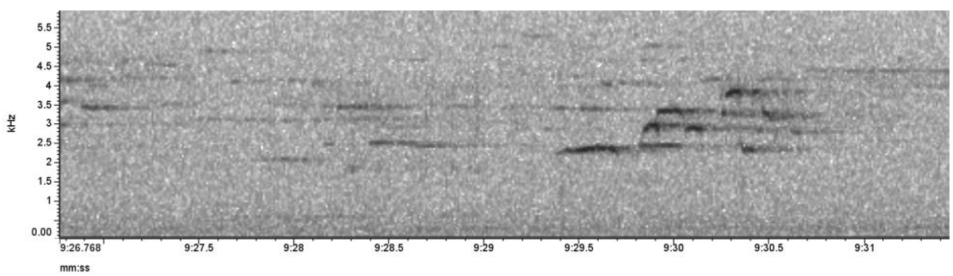


Figure 28 Spectrogram of a Hermit Thrush song misidentified as being an OSFL by BirdNET. [Recording: NHB13 – 20 June 2023, 5:15]

There were also instances where BirdNET output more identifications than was observed manually, due to double or triple counting songs or pips (Figure 29). This is a result of the two second overlap parameter that was selected when the recordings were run in the BirdNET program.

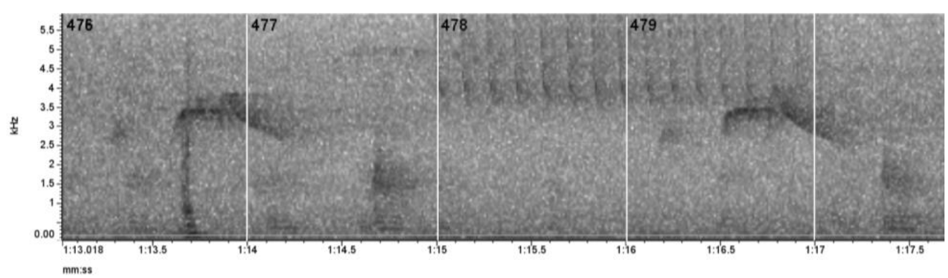


Figure 29 Spectrogram of two OSFL songs being counted as four by BirdNET. [Recording: RT – 29 June 2023, 5:17]

While BirdNET was for the most part successful at identifying OSFL vocalizations in ideal conditions, there were observed limitations in its capabilities that limited its benefit to this study. It was valuable at first at aiding analysts in becoming familiar with the spectrogram of an OSFL song, but had it been more accurate, the time required for analysis would have been less, and more recordings could have been viewed.

5.2.2 Song Detection with BirdNET

As noted above, BirdNET was moderately successful in identifying when OSFL was heard vocalizing in a recording. However, for studies such as this one, when it is critical to differentiate between songs and pips, relying only on automatic identification models such as BirdNET may not be as beneficial.

When comparing vocalization counts identified manually and by BirdNET, there was a statistically significant difference ($p < 0.05$) observed for both River Tillard ($p = 3.57E-05$, $n=340$) and NHB13 ($p = 1.1E-06$, $n = 440$). This indicates that for studies that aim to accurately quantity total vocalization count, using BirdNET may not be the most effective tool.

5.3 River Tillard

5.3.1 OSFL Presence

When viewing the OSFL observations with the CHMs for 2022 and 2023, it is clear that the birds were, for the most part, found in the same general area (Figure 10). This supports the understanding that OSFL exhibit site fidelity (Wright, 1997). The exceptions to this are found in the lack of the Northeast individual found in 2022 being observed in 2023, and the presence of a Northwest individual found in 2023 that was absent in 2022. It is possible that these are the same individual that selected to occupy a nearby unharvested area in 2023 after its territory was impacted by harvesting.

However, the outcomes of the field surveys are not the primary focus of this study, and instead act to provide support to interpretations on pairing and breeding success inferred from song activity patterns.

5.3.2 Vocalizations and Reproduction

In River Tillard, the pattern of song rates through the breeding season do not align directly with outcomes of either of the two past studies that assessed this relationship (Wright 1997, Brooks, 2020). Brooks (2020) inferred breeding success based on total vocalization rate using changepoint analysis. However, as previously discussed (see 2.4.5), there has been no observational studies that support this relationship, so the results from this study were primarily compared to the findings of Wright (1997).

The plots depicting mean daily and weekly song rates display that the highest rates occurred in the middle of the recording period, around week six, with a slight period of higher song rates near the end of the period, around week 11. Outside of these times, the mean rate was zero or relatively close to zero. While this pattern does not directly conform with any observed by Wright (1997), it is possible to use their findings to provide support to a prediction regarding breeding success.

Pairing Status

Findings from Wright (1997) indicate that paired males will sing at highest rates earliest in the season, and that their song rates decline over time following female arrival and the start of nest building (Figure 1). On the other hand, male OSFL that remained unpaired sang at relatively high rates through the season (Wright, 1997). This is supported by the understanding that, like many bird species (Dussourd & Ritchison, 2003; Staicer et al., 2006; Liu et al., 2007), the song of the OSFL is used primarily for mate attraction.

While the song rate activity pattern observed from the SW ARU doesn't begin with the highest rates and then decline, as seen in paired males, it also doesn't display consistent high rates of singing, as displayed by those that remain unpaired. Given the unimodal output for song rate through the breeding season in RT, the song rate indicates that the male OSFL in this area paired.

This is supported by observations from field surveys that identified a pair in the SW area of the harvest block on both 21 June 2023, and 13 July 2023. Referring back to the plot depicting mean daily song rate data for these dates (Figure 13) highlights that these dates occurred during the period of higher mean song rates that ranged from 13 June 2023 to 16 July 2023.

While uncommon, there were also instances in the recordings where vocalizations indicate the presence of both a male and female, which was noted in analysis. Considering the knowledge that OSFL pips are given by both males and females have been are used as contact calls during various activities (e.g., pairing, nest construction, foraging, incubation, and feeding nestlings; Altman & Sallabanks, 2020), it is reasonable to assume that when pips of two different volumes are present, or when pipping is heard alongside singing, that a paired male and female are present. One example of this is shown in Figure 30, where series of pips of two different volumes are present. This recording is from 23 June 2023, a day when higher pip rates were observed, at 5:15, and reinforces the prediction that the OSFL in this area paired.

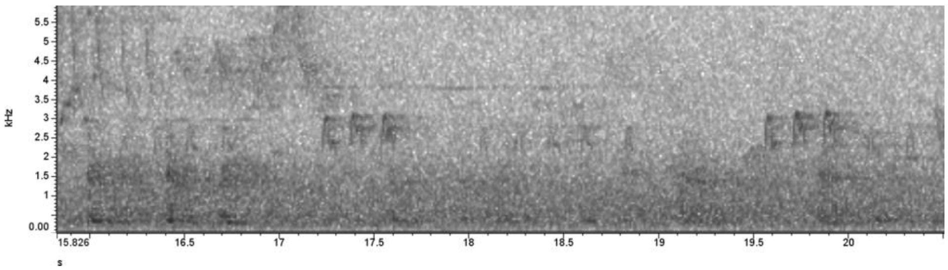


Figure 30 Spectrogram of OSFL pips of varied volumes, indicating the presence of a paired male and female. [Recording: RT – 23 June 2023, 5:15]

Based on the evidence described above, and summarized in Figure 31, it is predicted that the male OSFL occupying the SW area of RT was paired in 2023.

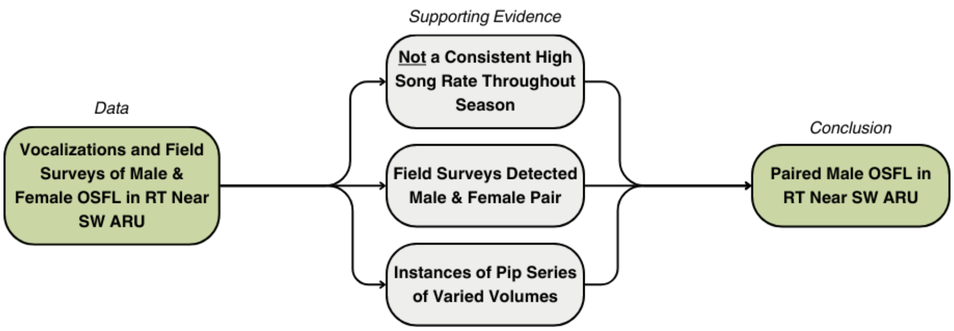


Figure 31 Flowchart of evidence supporting the prediction that the male OSFL in RT SW paired.

Nest Success

Wright (1997) discovered that in the case of nest failure, often due to predation, male OSFL increased their singing rate. This increase was attributed to efforts to resume courting behaviors with their existing mate or, in case of a lost female, attract a new partner. In this situation, mean singing rates would follow the same initial pattern as paired males, but would increase at a point where those that paired and nested successfully would see a continuous decline (Figure 1).

The plots displaying mean daily and weekly song rate for RT identify a slight increase in song rate later in the recording period, following a period of relative silence (16 July 2023 – 1 August 2023). However, this not an extreme increase, as is seen to occur for failed nests (Figure 1; Wright, 1997). This is the first supporting factor that may indicate successful nesting.

Further support is provided to this prediction due to lack of variation in diurnal singing patterns. The total song counts for each recording analysed is shown in Figure 11, and highlights that most singing occurred either before or at sunrise, and rarely occurred after that, as might be expected of a failed nest (Wright, 1997).

Finally, additional analysis of the songs found in the recordings late in the season displayed what appeared to be songs uttered by different males, based on the variation in volumes (Figure 26). Unfortunately, there is little research available on song development in fledglings, but Wright (1997) found that, while uncommon, some fledglings would attempt singing, though they sounded more "wheezy" and were often only two syllables. Findings of others support this, with C. Melcher noting that they were weaker and often incomplete (C. Melcher, personal communication, as cited in Altman & Sallabanks, 2020). While it is not possible to confirm that these are the vocalizations of fledglings, the fact that these are likely the songs of various males, and that they are the two syllable variation of the song (*THREE-BEERS!*), supports the idea that these may be vocalizations of young.

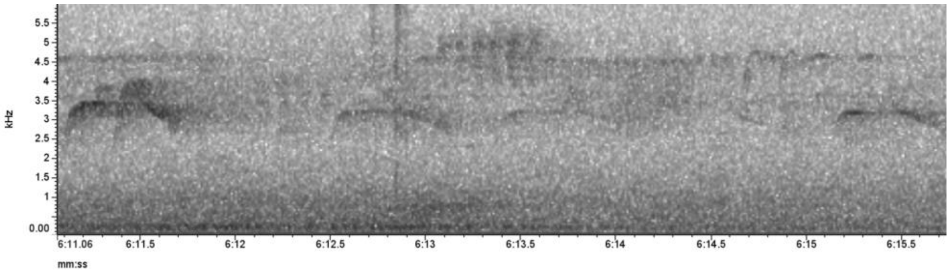


Figure 32 Spectrogram of multiple OSFL songs of varying volumes, potentially indicating the presence of different males. [Recording: RT – 10 August 2023, 6:57]

Considering the evidence outlined above and summarized in Figure 33, it is predicted that the paired male OSFL occupying the SW area of RT nested successfully.

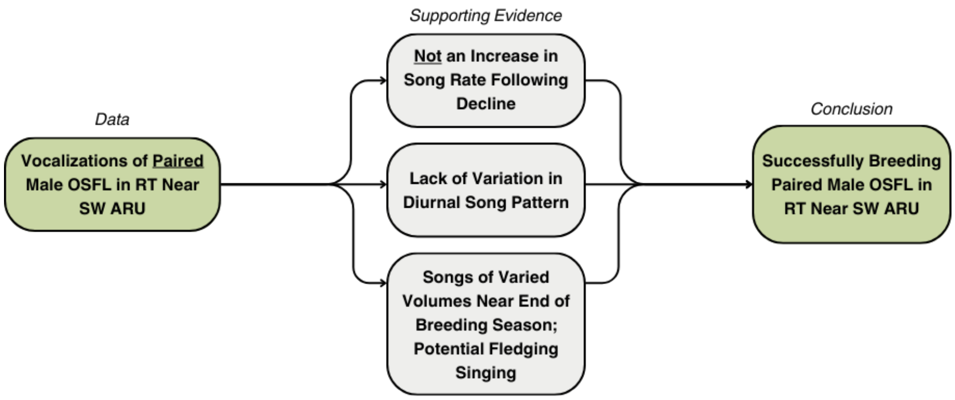


Figure 33 Flowchart of evidence supporting the prediction that the OSFL in RT was nesting successfully.

5.4 NHB13

5.4.1 Vocalizations and Reproduction

Similar to RT, the song rate pattern observed in NHB13 did not align with directly with the results of Wright (1997) or Brooks (2020). Once again, the results will be compared primarily to conclusions from Wright (1997) as there are fewer shortcomings in their research.

The plots depicting mean daily and weekly song rate identify that there are three notable peaks within the data, occurring around weeks three, 5, and 11. In Figure 19, it is evident that apart from these periods, the song rate is near to or at zero. While this pattern does not conform with any of the patterns observed by Wright (1997), it is possible to use their findings to provide support to a prediction regarding breeding success.

Pairing Status

The song rate activity patterns observed do not appear to follow a consistent high rate across the season, as one would expect of unpaired males based on evidence found for OSFL (Wright, 1997) and other bird species (Dussourd & Ritchison, 2003; Staicer et al., 2006; Liu et al., 2007). In NHB13, the song rate exhibits a trimodal distribution over the breeding season, with distinct periods of increased and decreased singing activity. This variability suggests that the male OSFL in this area is likely paired, as their song rates do not consistently remain high as seen in unpaired males.

There were also instances in the recordings where vocalizations indicated the presence of both a female and male, evident by either pip series of varied volumes or pips overlapping with a song. In NHB13, this was first observed in recordings from July, which signifies that, at least at that point, there was a pair.

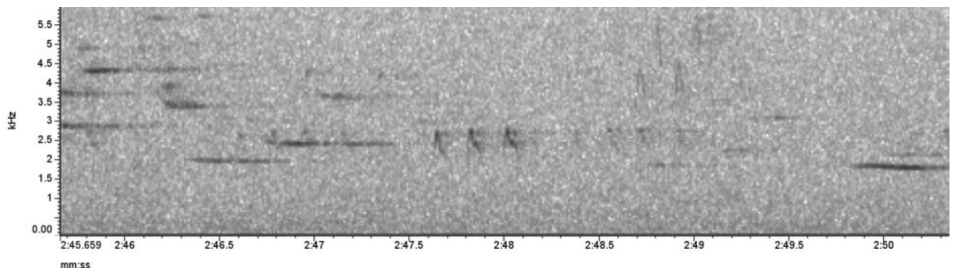


Figure 34 Spectrogram of OSFL pips of varied volumes, indicating the presence of a paired male and female. [Recording NHB13 – 23 July 2023, 6:38]

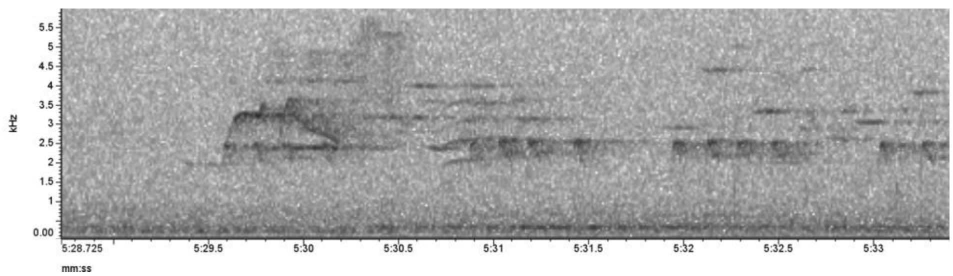


Figure 35 Spectrogram of OSFL pips overlayed with a song, indicating the presence of a paired male and female. [Recording: NHB13 – 29 July 2023 6:45]

Based on the evidence described above and summarized in Figure 36, it is predicted that the male OSFL occupying NHB13 was paired in 2023.

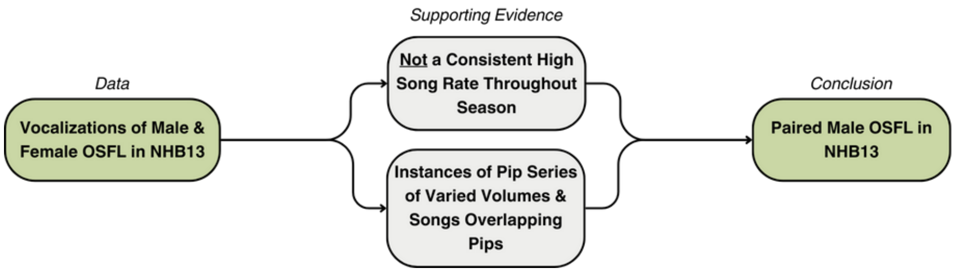


Figure 36 Flowchart of evidence supporting the prediction that the male OSFL in NHB13 was paired.

Nest Success

In the case of nest failure, it is anticipated that mean singing rate would increase following a period of lower rates as the male resumes courting behaviours (Wright, 1997). Conversely, if nesting was successful, there would be a general decrease overtime, without a sudden increase in singing later in the season. This pattern is seen in Figure 1, as well as in the results from River Tillard. The trimodal pattern observed in the song rate of NHB13 suggests that, when considering the overall daily song rate across the season, this pair likely experienced a failed nest.

Additional support is provided to this claim due to the observed diurnal variation in mean song rate. Wright (1997) found that those that had failed nests had more variation, including higher song rates later in the day. Figure 18, which notes the total song count through the season for each of the four recording periods analysed each day, highlights the increased number of songs heard after sunrise as the season progressed. Particularly, these later songs began 18 July, which was when the third peak of singing began.

Unlike as was seen in RT, there were no instances where there was vocalizations indicative of multiple males in the later parts of the season. For RT, this was predicted to be the vocalizations of fledglings, given that they were varied volume, weak, and only two syllables. However, past research indicates that singing of fledglings is uncommon (Wright, 1997; Altman & Sallabanks, 2020), so it is not possible to use a lack of this occurrence as a significant indicator of a failed nest.

Nevertheless, given the diurnal song rate variation, as well as the rapid increase in the rate following a period of decreased singing, there is sufficient evidence to predict that the paired male OSFL occupying NHB13 in 2023 had a failed nest (Figure 37).

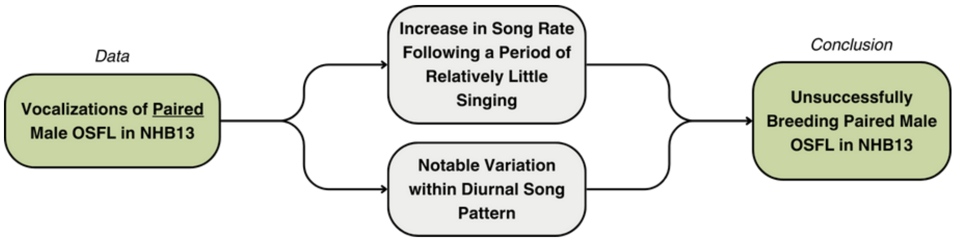


Figure 37 Flowchart of evidence to support the prediction that the paired male in NHB13 nested unsuccessfully.

Unusual Vocalizations

There was also an instance on 22 July 2023, when unusual OSFL vocalizations were observed (Figure 38). There has been no mention of calls specifically resembling these in the literature, though they were identified as OSFL by BirdNET, indicating that they have been found in other recordings in the Macaulay Library. In this recording, these calls were only given after a Blue Jay (*Cyanocitta* cristata) began calling. It may be possible that the Blue Jay was acting in a predatory manner, and that these vocalizations are a response by the OSFL. While there has been no studies that identify Blue Jays as a predator to OSFL, past research has recorded predation by other species in the Corvid Family including the Canada Jay (*Perisoreus canadensis*) (Wright, 1997; Altman, 1999 as cited in Altman & Sallabanks, 2020), Steller's Jay (*Cyanocitta stelleri*) (Altman, 1999 as cited in Altman & Sallabanks, 2020), and the Common Raven (*Corvus corax*) (Altman, 1999 as cited in Altman & Sallabanks, 2020).

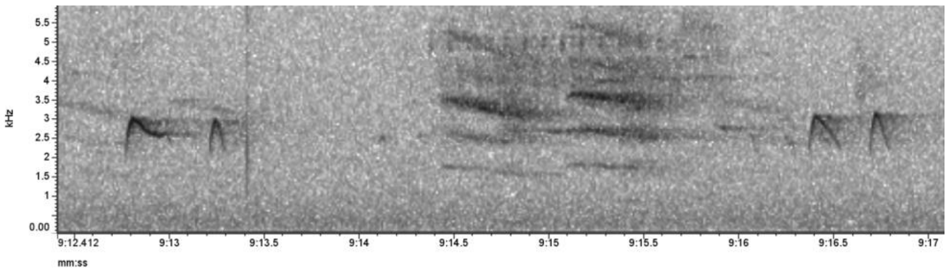


Figure 38 Spectrogram of unusual vocalizations by OSFL in NHB13. [Recording: NHB13 – 22 July 2023 6:37]

5.5 Effectiveness of Species-specific BMPs

When using reproductive success as a measure of the effectiveness of conservation efforts, it is evident that harvesting completed in accordance with BMP guidelines does not negatively impact OSFL. This research found that the male OSFL in RT exhibited song rate activity patterns expected of pairing and successful nesting, indicating that the harvesting was successful in preserving habitat characteristics that support the occupation of OSFL, and their apparent successful reproduction.

On the other hand, OSFL occupying the non-BMP site, NHB13, were found to be paired but experienced a failed nest. This contrasts findings of other research relating to forest harvesting and OSFL nest success, including Altman and Sallabanks (2020) that noted Mayfield estimates of nest success (e.g., nest that fledges more than one young) were highest in forests with semi-open canopy (>20%) and lower in harvested stands that retained trees. However, given that only one pair was analysed per site, the nest success rates of 100% (RT) and 0% (NHB13) are based on an extremely small sample size, which limits the extent that the results should inspire future implementation of BMPs. This is only one of the several limitations associated with this study.

5.5 Limitations

5.5.1 Sample Size

Harvesting with consideration the OSFL species-specific BMPs was implemented only in one harvest block in Nova Scotia. In addition to this, there has only been one breeding season following this harvesting. As a result, there are spatial and temporal limitations regarding the available data. For instance, the application of BMPs might have yielded different impacts on reproductive success if applied in other regions of the province, and outcomes in River Tillard may differ in the upcoming breeding season (Spring/Summer 2024).

Moreover, due to time constraints associated with manual processing of recordings, only 40 minutes a day were analysed from one of the three ARUs deployed in RT in 2023. Data for the other two pairs observed in the harvest block was not assessed.

5.5.2 Assessment of BMP Implementation

The BMPs included several other guidelines not related to the retention amounts, which were the only spatial characteristics addressed in this study. These additional guidelines are difficult to quantify from derivatives of UAS data, and thus the study relies on the harvesters having integrated BMP recommendations wherever feasible. Furthermore, there were errors associated with the classification of ground points in the DTM, which resulting in areas of RT having a CHM that was less than zero. This indicates some vertical inaccuracy in the CHM which might have impacted the tree counts and subsequent retention calculations.

6.0 Conclusions and Future Works

This study aimed to determine the impact that forestry with consideration to species-specific BMPs had on OSFL. In Nova Scotia, habitat loss due to forestry activities poses a significant threat to this species, and the BMPs were developed as a strategy to mitigate this threat.

To test the effectiveness of these BMPs, this study elected to use song activity patterns to infer reproductive success due to the understanding that song rates will follow a specific structure during successful breeding and will deviate from this in the case of failed pairing or nesting. Four recording periods per day were analysed manually to limit the error introduced by relying on automatic identification programs such as BirdNET, which was found to have numerous shortcoming regardless of its success in past research. Song and pips were totaled separately, and instances where vocalizations indicated the presence of a male and a female, multiple males, or were uncommon were marked for further analysis. The results were plotted and compared to expected song activity patterns outlined by Wright (1997) to determine reproductive success of OSFL in RT and NHB13.

The result displays that OSFL was able to occupy and reproduce successfully following harvesting with BMPs in RT. Additionally, OSFL inhabiting the non-BMP control site exhibited song rate activity data consistent with what is expected for unsuccessful reproduction. However, it's crucial to note that the limitations related to the temporal and spatial extent of the available and analyzed data constrain the extent to which the findings of this study should influence future implementation of BMPs for OSFL conservation in Nova Scotia.

Future work assessing the effectiveness of these BMPs should be completed before definitively confirming their success in supporting OSFL. Both this study and previous research suggest that using song rate is an appropriate method for inferring reproductive success. This understanding, along with the benefits of using ARUs to obtain acoustic data for SAR in remote areas, demonstrate the potential in utilizing a modified version of this methodology in future work.

To reduce the processing time associated with manual identification of songs/pips, and thus increase the quantity of data that can be analysed, future work should involve the creation of a trained model similar to that created by Brooks (2020). However, this model should specifically focus on identifying and counting songs, as the established relationship between vocalizations and reproductive success for OSFL pertains solely to song rate.

References

Altman, B. & R. Sallabanks. (2020). Olive-sided Flycatcher (*Contopus cooperi*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi-org.ezproxy.library.dal.ca/10.2173/bow.olsfly.01

Altman, B. (1999). Nest success and habitat relationships of the Olive-sided Flycatcher in managed forests of northwestern Oregon. Oregon State Office, Portland: Unpublished. report submitted to U.S. Fish and Wildlife Service.

Anctil, A., Johansen, H. M., & Tremblay, J. A. (2017). Écologie de nidification du moucherolle à côtés olive dans un paysage sous aménagement forestier de la forêt boréale de l'Est. *Naturaliste Canadien, 141*(2), 53–60. https://doi.org/10.7202/1039736ar

Annich, N.C. (2017). Use of bioacoustics technologies to evaluate habitat use and road effects on two anuran amphibians in the boreal region of Northeastern Alberta. University of Alberta, Edmonton, AB. https://era.library.ualberta.ca/items/cd53b0f2-c542-476d-820a-87af3bf350c0/view/9b1ca563-a216-405d-a5bc-b87a5efb0702/Annich_Natasha_C_201705_MSc.pdf

Arif, M., Hedley, R. & Bayne, E. (2020, July 31). Testing the Accuracy of BirdNET, Automatic bird song Classifier. Education and Research Archive. https://doi.org/10.7939/r3-6khb-kz18

Betts, M. G., Yang, Z., Hadley, A. S., Smith, A. C., Rousseau, J. S., Northrup, J. M., Nocera, J. J., Gorelick, N., & Gerber, B. D. (2022). Forest degradation drives widespread avian habitat and population declines. *Nature Ecology & Evolution, 6*(6), 709–719. https://doi.org/10.1038/s41559-022-01737-8

BirdLife International. (2022). *State of the World's Birds*. https://www.birdlife.org/wp-content/uploads/2022/09/SOWB2022_EN_compressed.pdf

Borker, A. L., P. Halbert, M. W. McKown, B. R. Tershy, & D. A. Croll. (2015). A comparison of automated and traditional monitoring techniques for marbled murrelets using passive acoustic sensors. *Wildlife Society Bulletin 39*:813-818. https://doi.org/10.1002/wsb.608

Bota, G., Manzano-Rubio, R., Catalán, L., Gómez-Catasús, J., & Pérez-Granados, C. (2023). Hearing to the unseen: AudioMoth and BirdNET as a cheap and easy method for monitoring cryptic bird species. *Sensors (Basel, Switzerland), 23*(16), 7176. https://doi.org/10.3390/s23167176

Brazner, J., MacKinnon, F., Walker, J., Cameron, R., & Crewe, T. (2024). The influence of clearcut harvesting on bird communities in an adjacent protected area in Nova Scotia: Implications for buffer implementation. *Forest Ecology and Management, 559*(121818), 121818. https://doi.org/10.1016/j.foreco.2024.12181

British Columbia Ministry of Water, Land and Air Protection Ecosystem Standards and Planning Biodiversity Branch [BCMLWAP]. (2004) Environmental Best Management Practices for Urban and Rural Land Development. https://www.env.gov.bc.ca/wld/documents/bmp/urban_ebmp/EBMP%20PDF%205.pdf

Brooks, D. R. (2020). Reproductive activity of olive-sided flycatchers (*Contopus cooperi*) in commercial forests of central New Brunswick. [Master's Thesis, University of New Brunswick]. https://unbscholar.lib.unb.ca/handle/1882/14522n
canadensis) in Canada.

Caskey, M., Cox, B., Bracher, G., Latimer, S., Law, P., Polster, D., Cullington, J., & Dennis, N. (2004). Environmental Best Management Practices for Urban and Rural Land Development in British Columbia. Ministry of Water, Land and Air Protection. https://www.env.gov.bc.ca/wld/documents/bmp/urban_ebmp/EBMP%20PDF%201.pdf

Castellote, M. Clark, C. W. & Lammers, M.O. (2012).Acoustic and behavioural changes by fin whales (*Balaenoptera physalus*) in response to shipping and airgun noise. *Biological Conservation 147*(1): 115-122. https://doi-org/10.1016/j.biocon.2011.12.021

COSEWIC. (2018). COSEWIC assessment and status report on the Olive-sided Flycatcher (*Contopus cooperi*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. ix + 52 pp.
http://www.registrelep-sararegistry.gc.ca/default.asp?lang=en&n=24F7211B-1

COSEWIC. (2020). IN PRESS. COSEWIC assessment and status report on the Canada Warbler (*Cardellina canadensis*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xi + 54 pp.
https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html

COSEWIC. (2012). COSEWIC assessment and status report on the Eastern Wood-pewee (*Contopus virens*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. x + 39 pp. www.registrelep-sararegistry.gc.ca/default_e.cfm

Cote, P., R. Tittler, C. Messier, D.D. Kneeshaw, A. Fall, and M-J. Fortin. 2010. Comparing different forest zoning options for landscape-scale management of the boreal forest: Possible benefits of the TRIAD. *Forest Ecology and Management 259*(3): 418–27

Demarchi, M.W. & Bentley, M.D. (2005, March 31). Best Management Practices for Raptor Conservation during Urban and Rural Land Development in British Columbia. https://www.env.gov.bc.ca/lower-mainland/electronic_documents/raptor_bmp_final.pdf

Digby, A., M. Townsey, B. D. Bell, and P.D. Teal. (2013). A practical comparison of manual and autonomous methods of acoustic monitoring. *Methods in Ecology and Evolution* 4:675-683. https://doi.org/10.1111/2041-210X.12060

eBird. (n.d.) Bird Observations – Olive-sided Flycatcher. https://ebird.org/barchart?r=CA-NS&bmo=3&emo=5&byr=2000&eyr=2024&spp=olsfly

Forbes, G. (2019). Triad – A New Vision. https://www.novascotia.ca/ecological-forestry/Triad-A-New-Vision-for-NS-Forests.pdf

François, B., Wilmshurst, J. F., Harder, J., Bloom, R., Johns, D. W., & Watson, P. (2021). Prioritizing Beneficial Management Practices for Species at Risk in Agricultural Lands. *Environmental Management 68*(6), 937–952. https://doi.org/10.1007/s00267-021-01525-3

GeoNOVA. (2022, October 6). LiDAR Derived Contours – Data Release. https://geonova.novascotia.ca/news-blog/LiDAR-Derived-Contours-Data-Release#:~:text=The%20Government%20of%20Nova%20Scotia,resolution%20LiDAR%20digital%20elevation%20models.

Goodbody, T. R. H., Coops, N. C., Marshall, P. L., Tompalski, P., & Crawford, P. (2017). Unmanned aerial systems for precision forest inventory purposes: A review and case study. The *Forestry Chronicle, 93*(01), 71–81. https://doi.org/10.5558/tfc2017-012

Government of Canada (2023a). Historical Data Port Hawkesbury. https://climate.weather.gc.ca/historical_data/search_historic_data_e.html

Government of Canada. (2023b). Historical Data Kejimkujik 1. https://climate.weather.gc.ca/historical_data/search_historic_data_e.html

Government of Nova Scotia. (2018, December). Interim Retention Guide. https://novascotia.ca/natr/forestry/forest_review/Retention-Guide-NS-Crown-Land.pdf

Government of Nova Scotia. (n.d.) Ecological Forestry. https://novascotia.ca/ecological-forestry/

Hafner, S.D. & Katz, J. (2018, February 14). A short introduction to acoustic template matching with monitoR. CRAN. https://cran.r-project.org/web/packages/monitoR/vignettes/monitoR_QuickStart.pdf

Holmes, S.B. , K. Tuininga, K.A. McIlwrick, M. Carruthers, & E. Cobb. (2015). Using an integrated recording and sound analysis system to search for Kirkland's Warbler (Setophaga kirklandii) in *Ontario Field-Naturalist 129*:115-120. https://doi.org/10.22621/cfn.v129i2.1688

Kahl, S. Wood, C.M. Eibl, M. and Klinck, H. (2021). BirdNET: A deep learning solution for avian diversity monitoring. *Ecological Informatics 61*. https://doi.org/10.1016/j.ecoinf.2021.101236

Lahey, W. (2018). An independent review of forest practices in Nova Scotia. https://novascotia.ca/natr/forestry/Forest_Review/

Landbird Species at Risk in Forested Wetlands [LSARFW]. (n.d.). BMP Examples. https://landbirdsar.merseytobeatic.ca/

Liu, W.-C., Kroodsma, D. E., & Yasukawa, K. (2007). Dawn and Daytime Singing Behavior of Chipping Sparrows (Spizella passerina) (Comportamiento de Canto al. Amanecer y Durante el Día en Spizella passerina). *The Auk, 124*(1), 44–52. http://www.jstor.org/stable/25150248

LSARFW [Landbird Species at Risk in Forested Wetlands]. 2022 Olive-sided Flycatcher. Nova Scotia Species at Risk Beneficial Management Practices Series. https://landbirdsar.merseytobeatic.ca/wp/wp-content/uploads/2022/05/OSFL_March30-22-FINAL.pdf

MacLean, D.A., R.S. Seymour, M.K. Montigny, & C. Messier. (2009). Allocation of conservation efforts over the landscape: the TRIAD approach. in Setting Conservation

Targets for Managed Forest Landscapes. M.A. Villard and B.G. Jonsson (eds.), 283– 303. NY: Cambridge University Press.

Messier, C., R. Tittler, D.D. Kneeshaw, N. Gélinas, A. Paquette, K. Berninger, H. Rheault, P. Meek, and N. Beaulieu. (2009). TRIAD zoning in Quebec: Experiences and results after 5 years. *The Forestry Chronicle 85*(6): 885–96

Migratory Birds Convention Act [MBCA] (S.C. 1994, c. 22). https://laws-lois.justice.gc.ca/PDF/M-7.01.pdf

Morissette, J. L., Cobb, T. P., Brigham, R. M., & James, P. C. (2002). The response of boreal forest songbird communities to fire and post-fire harvesting. *Canadian Journal of Forest Research, 32*(12), 2169–2183. https://doi.org/10.1139/x02-134

Natalie Dussourd, & Ritchison, G. (2003). Singing behavior of male Yellow-breasted chats: Repertoires, rates, reproductive success, and a comparison with other wood-warblers. *The Wilson Bulletin, 115*(1), 52–57. http://www.jstor.org/stable/4164517

North American Bird Conservation Initiative [NABCI]. (2019) The State of Canada's Birds. http://nabci.net/wp-content/uploads/2019-State-of-Canadas-Birds-1.pdf

Nova Scotia Department of Lands and Forestry [NSDLF]. 2021. Recovery Plan for the Olive-sided Flycatcher (*Contopus cooperi*) in Nova Scotia [Final]. Nova Scotia Endangered Species Act Recovery Plan Series. https://novascotia.ca/natr/wildlife/species-at-risk/docs/RECOVERY_PLAN_Adopted_Olive_sided_flycatcher_10Feb21.pdf

Pérez-Granados, C. (2023). BirdNET: applications, performance, pitfalls and future opportunities. *The Ibis, 165*(3), 1068–1075. https://doi.org/10.1111/ibi.13193

Plowright, A. (2023). ForestTools: Tools for Analyzing Remote Sensing Forest Data. R package version 1.0.0, https://github.com/andrew-plowright/ForestTools.

Stewart, B. (2017). Beneficial Management Practices for Southwestern Ontario Forest Birds at Risk: A Guide for Woodlot Owners and Other Forest Practitioners. Published by Bird Studies Canada. Pp. 21. https://birdscanada.org/wp-content/uploads/2021/03/Beneficial-Management-Practices-for-Southwestern-Ontario-Forest-Birds-at-Risk-1.pdf

Robertson, B. A., & Hutto, R. L. (2007). Is selectively harvested forest an ecological trap for Olive-sided Flycatchers? *The Condor (Los Angeles, Calif.), 109*(1), 109–121. https://doi.org/10.1650/0010-5422(2007)109[109:ISHFAE]2.0.CO;2

Robertson, B.A. & Hutto, R.L. 2006. A framework for understanding ecological traps and an evaluation of existing evidence. *Ecology. 87*:1075-1085. https://doi.org/10.1890/0012-9658(2006)87[1075:affuet]2.0.co;2

Rosenberg, K. V., Dokter, A. M., Blancher, P. J., Sauer, J. R., Smith, A. C., Smith, P. A., Stanton, J. C., Panjabi, A., Helft, L., Parr, M., & Marra, P. P. (2019). Decline of the North American avifauna. *Science (New York, N.Y.), 366*(6461), 120–124. https://doi.org/10.1126/science.aaw1313

Sanderfoot, O. V., & Holloway, T. (2017). Air pollution impacts on avian species via inhalation exposure and associated outcomes. *Environmental Research Letters, 12*(8), 083002. https://doi.org/10.1088/1748-9326/aa8051

Seymour, R.S., & M.L. Hunter, Jr. (1992). New Forestry in Eastern Spruce-Fir Forests: Principles and Applications to Maine. Orono, ME: University of Maine.

Shonfield, J. & E. M. Bayne. (2017). Autonomous recording units in avian ecological research; current use and future applications. *Avian Conservation and Ecology 12*(1):14. https://doi.org/10.5751/ACE-00974-120114

Spiller, K. J., & Dettmers, R. (2019). Evidence for multiple drivers of aerial insectivore declines in North America. *The Condor, 121*(2). https://doi.org/10.1093/condor/duz010

Staicer, C.A. Ingalls, V. Sherry, T.W. (2006). Singing behaviour varies with breeding status of American Redstarts (*Setophaga reticilla*). *The Wilson Journal of Ornithology, 118*(4): 439-451. https://doi.org/10.1676/05-056.1

Stewart, B. (2017). Beneficial Management Practices for Southwestern Ontario Forest Birds at
Tang, L., & Shao, G. (2015). Drone remote sensing for forestry research and practices. *Journal of Forestry Research, 26*(4), 791–797. https://doi.org/10.1007/s11676-015-0088-y

The Cornell Lab of Ornithology. (n.d.) Macaulay Library – Olive-sided Flycatcher [Database]. https://search.macaulaylibrary.org/catalog?taxonCode=olsfly&view=grid

Upham-Mills, E. J., J. R. Reimer, S. Hache, S. R. Lele, & E. M. Bayne. (2020). Can singing rate be used to predict male breeding status of forest songbirds? A comparison of three calibration models. *Ecosphere 11*(1): e03005. 10.1002/ ecs2.3005 https://doi.org/10.1002/ecs2.3005

Van Wilgenburg, S.L., P. Solymos, K.J. Kardynal, and M.D. Frey. (2017). Paired sampling standardizes point count data from humans and acoustic recorders. Avian Conservation and *Ecology 12*(1):13. http://dx.doi.org/10.5751/ACE-00975-120113

Ward, C. & T. Erdle. 2015. Evaluation of forest management strategies based on Triad zoning. *The Forestry Chronicle 91*(1): 40–51.

Ware, L., Mahon, C. L., McLeod, L., & Jetté, J.-F. (2023). Artificial intelligence (BirdNET) supplements manual methods to maximize bird species richness from acoustic data sets generated from regional monitoring. *Canadian Journal of Zoology*, *101*(12), 1031–1051. https://doi.org/10.1139/cjz-2023-0044

Westwood, A. R., Staicer, C., Sólymos, P., Haché, S., Fontaine, T., Bayne, E. M., & Mazerolle, D. (2019). Estimating the conservation value of protected areas in Maritime Canada for two species at risk: The Olive-sided Flycatcher (*Contopus cooperi*) and Canada Warbler (*Cardellina canadensis*). *Avian Conservation and Ecology*, *14*(1), 1-. https://doi.org/10.5751/ACE-01359-140116

Wildlife Acoustics. (n.d.) Song Meter Mini 2 AA. https://www.wildlifeacoustics.com/products/song-meter-mini-2-aa

Wood, C. M., Kahl, S., Rahaman, A., & Klinck, H. (2022). The machine learning–powered BirdNET App reduces barriers to global bird research by enabling citizen science participation. *PLoS Biology*, *20*(6), e3001670. https://doi.org/10.1371/journal.pbio.3001670

Wright, J.M. 1997. Preliminary study olive-sided flycatchers, July 1994-April 1997. Alaska Department of Fish and Game. Final research report. Endangered species conservation fund federal aid studies. SE-3-3, 4 and 5. Juneau, Alaska. 34 pp.

WWF (2022) Living Planet Report 2022 – Building a nature-positive society. Almond, R.E.A., Grooten, M., Juffe Bignoli, D. & Petersen, T. (Eds). WWF, Gland, Switzerland. https://wwf.ca/wp-content/uploads/2022/10/lpr_2022_full_report_en.pdf

Zhang, J., Zhang, Z., Lutz, J. A., Chu, C., Hu, J., Shen, G., Li, B., Yang, Q., Lian, J., Zhang, M., Wang, X., Ye, W., & He, F. (2022). Drone-acquired data reveal the importance of forest canopy structure in predicting tree diversity. *Forest Ecology and Management*, *505*, 119945. https://doi.org/10.1016/j.foreco.2021.119945

Zwart, M. C., Baker, A., McGowan, P. J., & Whittingham, M. J. (2014). The use of automated bioacoustic recorders to replace human wildlife surveys: an example using nightjars. *PloS one*, *9*(7), e102770. https://doi.org/10.1371/journal.pone.0102770

Appendix A Vocalization Counts River Tillard (BirdNET & Manual)

date	time	birdnet	song_count_manual	pip_count_manual
2023-05-25	05:03:00	0	0	0
2023-05-25	05:23:00	0	0	0
2023-05-25	06:23:00	0	0	0
2023-05-25	06:43:00	0	0	0
2023-05-26	05:02:00	0	0	0
2023-05-26	05:22:00	0	0	0
2023-05-26	06:22:00	0	0	0
2023-05-26	06:42:00	0	0	0
2023-05-27	05:01:00	0	0	0
2023-05-27	05:21:00	0	0	0
2023-05-27	06:21:00	0	0	0
2023-05-27	06:41:00	0	0	0
2023-05-28	05:01:00	0	0	0
2023-05-28	05:21:00	0	0	0
2023-05-28	06:21:00	0	0	0
2023-05-28	06:41:00	0	0	0
2023-05-29	05:00:00	0	0	0
2023-05-29	05:20:00	0	0	0
2023-05-29	06:20:00	0	0	0
2023-05-29	06:40:00	3	6	0
2023-05-30	04:59:00	0	0	0
2023-05-30	05:19:00	0	0	0
2023-05-30	06:19:00	0	8	0
2023-05-30	06:39:00	0	0	0
2023-05-31	04:59:00	0	0	0
2023-05-31	05:19:00	0	0	0
2023-05-31	06:19:00	0	0	0
2023-05-31	06:39:00	0	0	0
2023-06-01	04:58:00	0	0	0
2023-06-01	05:18:00	0	0	0
2023-06-01	06:18:00	0	0	0

2023-06-01	06:38:00	0	0	0
2023-06-02	04:57:00	0	0	0
2023-06-02	05:17:00	0	0	0
2023-06-02	06:17:00	0	0	0
2023-06-02	06:37:00	0	0	0
2023-06-03	04:57:00	0	0	0
2023-06-03	05:17:00	0	0	0
2023-06-03	06:17:00	0	0	0
2023-06-03	06:37:00	0	0	0
2023-06-04	04:56:00	0	0	0
2023-06-04	05:16:00	0	0	0
2023-06-04	06:16:00	0	0	0
2023-06-04	06:36:00	0	0	0
2023-06-05	04:56:00	0	0	0
2023-06-05	05:16:00	0	0	0
2023-06-05	06:16:00	0	0	0
2023-06-05	06:36:00	0	0	0
2023-06-06	04:56:00	0	0	0
2023-06-06	05:16:00	0	0	0
2023-06-06	06:16:00	0	0	0
2023-06-06	06:36:00	0	0	0
2023-06-07	04:55:00	0	0	0
2023-06-07	05:15:00	0	0	0
2023-06-07	06:15:00	0	0	0
2023-06-07	06:35:00	0	0	0
2023-06-08	04:55:00	0	0	0
2023-06-08	05:15:00	0	0	0
2023-06-08	06:15:00	0	0	0
2023-06-08	06:35:00	0	0	0
2023-06-09	04:55:00	0	0	0
2023-06-09	05:15:00	0	0	0
2023-06-09	06:15:00	0	0	0
2023-06-09	06:35:00	0	0	0
2023-06-10	04:54:00	0	0	0
2023-06-10	05:14:00	0	0	0
2023-06-10	06:14:00	0	0	0
2023-06-10	06:34:00	0	0	0
2023-06-11	04:54:00	0	0	0
2023-06-11	05:14:00	0	0	0
2023-06-11	06:14:00	0	0	0

2023-06-11	06:34:00	0	0	0
2023-06-12	04:54:00	0	0	0
2023-06-12	05:14:00	0	0	0
2023-06-12	06:14:00	0	0	0
2023-06-12	06:34:00	0	0	0
2023-06-13	04:54:00	0	13	0
2023-06-13	05:14:00	44	76	0
2023-06-13	06:14:00	0	0	0
2023-06-13	06:34:00	23	10	0
2023-06-14	04:54:00	1	92	0
2023-06-14	05:14:00	0	0	0
2023-06-14	06:14:00	0	0	0
2023-06-14	06:34:00	0	0	0
2023-06-15	04:54:00	0	0	0
2023-06-15	05:14:00	0	0	0
2023-06-15	06:14:00	0	0	0
2023-06-15	06:34:00	0	0	0
2023-06-16	04:54:00	0	2	0
2023-06-16	05:14:00	0	11	0
2023-06-16	06:14:00	0	0	0
2023-06-16	06:34:00	0	0	0
2023-06-17	04:54:00	3	68	0
2023-06-17	05:14:00	13	59	0
2023-06-17	06:14:00	0	0	0
2023-06-17	06:34:00	0	0	0
2023-06-18	04:54:00	0	6	0
2023-06-18	05:14:00	0	9	0
2023-06-18	06:14:00	43	23	0
2023-06-18	06:34:00	2	5	0
2023-06-19	04:54:00	0	0	0
2023-06-19	05:14:00	0	0	0
2023-06-19	06:14:00	96	34	0
2023-06-19	06:34:00	33	22	0
2023-06-20	04:54:00	0	0	0
2023-06-20	05:14:00	7	3	0
2023-06-20	06:14:00	126	0	1086
2023-06-20	06:34:00	9	0	142
2023-06-21	04:54:00	0	13	0
2023-06-21	05:14:00	4	15	0
2023-06-21	06:14:00	0	0	0

2023-06-21	06:34:00	12	5	0
2023-06-22	04:54:00	0	0	0
2023-06-22	05:14:00	0	2	0
2023-06-22	06:14:00	30	1	254
2023-06-22	06:34:00	0	0	0
2023-06-23	04:55:00	0	23	0
2023-06-23	05:15:00	6	4	57
2023-06-23	06:15:00	52	214	0
2023-06-23	06:35:00	0	0	0
2023-06-24	04:55:00	232	248	0
2023-06-24	05:15:00	0	8	436
2023-06-24	06:15:00	0	0	0
2023-06-24	06:35:00	0	0	12
2023-06-25	04:55:00	191	198	0
2023-06-25	05:15:00	14	35	149
2023-06-25	06:15:00	0	0	0
2023-06-25	06:35:00	0	0	185
2023-06-26	04:56:00	89	144	0
2023-06-26	05:16:00	164	159	0
2023-06-26	06:16:00	1	1	0
2023-06-26	06:36:00	0	0	16
2023-06-27	04:56:00	51	32	0
2023-06-27	05:16:00	149	130	0
2023-06-27	06:16:00	0	0	0
2023-06-27	06:36:00	0	0	0
2023-06-28	04:57:00	209	177	4
2023-06-28	05:17:00	346	124	130
2023-06-28	06:17:00	7	4	0
2023-06-28	06:37:00	1	2	0
2023-06-29	04:57:00	317	196	0
2023-06-29	05:17:00	500	177	0
2023-06-29	06:17:00	34	1	475
2023-06-29	06:37:00	8	3	415
2023-06-30	04:58:00	175	158	0
2023-06-30	05:18:00	333	133	0
2023-06-30	06:18:00	0	0	0
2023-06-30	06:38:00	0	0	0
2023-07-01	04:58:00	270	172	0
2023-07-01	05:18:00	410	152	0
2023-07-01	06:18:00	9	32	0

2023-07-01	06:38:00	0	19	0
2023-07-02	04:59:00	194	168	0
2023-07-02	05:19:00	50	106	0
2023-07-02	06:19:00	0	6	3
2023-07-02	06:39:00	0	0	0
2023-07-03	04:59:00	0	314	0
2023-07-03	05:19:00	28	367	0
2023-07-03	06:19:00	0	1	0
2023-07-03	06:39:00	0	0	0
2023-07-04	05:00:00	0	47	0
2023-07-04	05:20:00	0	52	0
2023-07-04	06:20:00	0	0	0
2023-07-04	06:40:00	0	2	0
2023-07-05	05:01:00	0	118	0
2023-07-05	05:21:00	5	50	0
2023-07-05	06:21:00	4	2	0
2023-07-05	06:41:00	44	23	0
2023-07-06	05:01:00	0	42	0
2023-07-06	05:21:00	0	13	0
2023-07-06	06:21:00	1	1	0
2023-07-06	06:41:00	32	17	0
2023-07-07	05:02:00	0	67	0
2023-07-07	05:22:00	1	1	0
2023-07-07	06:22:00	14	9	0
2023-07-07	06:42:00	2	31	0
2023-07-08	05:03:00	0	106	0
2023-07-08	05:23:00	1	1	0
2023-07-08	06:23:00	0	0	0
2023-07-08	06:43:00	0	0	0
2023-07-09	05:04:00	0	62	0
2023-07-09	05:24:00	0	1	0
2023-07-09	06:24:00	0	0	0
2023-07-09	06:44:00	0	0	0
2023-07-10	05:04:00	0	72	0
2023-07-10	05:24:00	3	72	0
2023-07-10	06:24:00	0	0	0
2023-07-10	06:44:00	0	0	0
2023-07-11	05:05:00	0	30	0
2023-07-11	05:25:00	0	6	0
2023-07-11	06:25:00	0	0	0

2023-07-11	06:45:00	0	0	0
2023-07-12	05:06:00	0	0	0
2023-07-12	05:26:00	0	0	0
2023-07-12	06:26:00	0	0	0
2023-07-12	06:46:00	0	0	0
2023-07-13	05:07:00	0	0	0
2023-07-13	05:27:00	0	0	0
2023-07-13	06:27:00	1	6	0
2023-07-13	06:47:00	0	2	0
2023-07-14	05:08:00	0	74	0
2023-07-14	05:28:00	0	0	0
2023-07-14	06:28:00	0	0	0
2023-07-14	06:48:00	0	0	0
2023-07-15	05:09:00	0	48	0
2023-07-15	05:29:00	0	0	0
2023-07-15	06:29:00	0	0	0
2023-07-15	06:49:00	0	0	0
2023-07-16	05:10:00	9	3	0
2023-07-16	05:30:00	0	0	0
2023-07-16	06:30:00	0	0	0
2023-07-16	06:50:00	0	0	0
2023-07-17	05:11:00	0	0	0
2023-07-17	05:31:00	0	4	0
2023-07-17	06:31:00	0	0	0
2023-07-17	06:51:00	0	0	0
2023-07-18	05:12:00	0	0	0
2023-07-18	05:32:00	0	0	0
2023-07-18	06:32:00	0	1	0
2023-07-18	06:52:00	0	0	0
2023-07-19	05:13:00	0	0	0
2023-07-19	05:33:00	0	0	0
2023-07-19	06:33:00	0	0	0
2023-07-19	06:53:00	0	0	0
2023-07-20	05:14:00	0	0	0
2023-07-20	05:34:00	0	0	0
2023-07-20	06:34:00	3	1	0
2023-07-20	06:54:00	0	0	0
2023-07-21	05:15:00	0	0	0
2023-07-21	05:35:00	0	0	0
2023-07-21	06:35:00	0	0	0

2023-07-21	06:55:00	0	0	0
2023-07-22	05:16:00	0	0	0
2023-07-22	05:36:00	0	0	0
2023-07-22	06:36:00	0	0	0
2023-07-22	06:56:00	0	0	0
2023-07-23	05:17:00	0	0	0
2023-07-23	05:37:00	0	0	0
2023-07-23	06:37:00	0	0	0
2023-07-23	06:57:00	0	0	0
2023-07-24	05:18:00	0	0	0
2023-07-24	05:38:00	0	0	0
2023-07-24	06:38:00	0	0	0
2023-07-24	06:58:00	0	0	0
2023-07-25	05:19:00	0	0	0
2023-07-25	05:39:00	0	0	0
2023-07-25	06:39:00	4	1	12
2023-07-25	06:59:00	0	0	155
2023-07-26	05:20:00	0	0	0
2023-07-26	05:40:00	0	0	0
2023-07-26	06:40:00	0	0	0
2023-07-26	07:00:00	0	0	0
2023-07-27	05:21:00	0	0	0
2023-07-27	05:41:00	0	0	0
2023-07-27	06:41:00	0	0	0
2023-07-27	07:01:00	0	1	0
2023-07-28	05:22:00	0	0	0
2023-07-28	05:42:00	0	0	0
2023-07-28	06:42:00	0	0	49
2023-07-28	07:02:00	0	2	0
2023-07-29	05:23:00	0	0	0
2023-07-29	05:43:00	0	0	0
2023-07-29	06:43:00	0	0	20
2023-07-29	07:03:00	2	3	0
2023-07-30	05:24:00	0	0	0
2023-07-30	05:44:00	0	0	0
2023-07-30	06:44:00	0	0	0
2023-07-30	07:04:00	0	0	0
2023-07-31	05:26:00	0	0	0
2023-07-31	05:46:00	0	0	0
2023-07-31	06:46:00	5	3	174

2023-07-31	07:06:00	0	1	0
2023-08-01	05:27:00	0	0	0
2023-08-01	05:47:00	0	0	0
2023-08-01	06:47:00	0	0	0
2023-08-01	07:07:00	1	1	120
2023-08-02	05:28:00	0	0	0
2023-08-02	05:48:00	0	0	0
2023-08-02	06:48:00	0	0	0
2023-08-02	07:08:00	0	0	0
2023-08-03	05:29:00	0	0	0
2023-08-03	05:49:00	1	15	0
2023-08-03	06:49:00	2	1	0
2023-08-03	07:09:00	0	0	0
2023-08-04	05:30:00	0	0	0
2023-08-04	05:50:00	0	0	0
2023-08-04	06:50:00	0	0	0
2023-08-04	07:10:00	93	0	570
2023-08-05	05:31:00	0	0	0
2023-08-05	05:51:00	0	0	0
2023-08-05	06:51:00	307	1	1018
2023-08-05	07:11:00	296	5	691
2023-08-06	05:33:00	0	0	0
2023-08-06	05:53:00	0	0	0
2023-08-06	06:53:00	0	0	0
2023-08-06	07:13:00	0	0	0
2023-08-07	05:34:00	9	0	88
2023-08-07	05:54:00	0	4	0
2023-08-07	06:54:00	45	38	0
2023-08-07	07:14:00	12	9	0
2023-08-08	05:35:00	0	0	0
2023-08-08	05:55:00	0	0	0
2023-08-08	06:55:00	0	0	0
2023-08-08	07:15:00	36	23	0
2023-08-09	05:36:00	0	0	0
2023-08-09	05:56:00	0	0	0
2023-08-09	06:56:00	0	0	0
2023-08-09	07:16:00	0	0	0
2023-08-10	05:37:00	0	0	0
2023-08-10	05:57:00	0	0	383
2023-08-10	06:57:00	57	75	44

2023-08-10	07:17:00	2	4	40
2023-08-11	05:39:00	0	0	0
2023-08-11	05:59:00	0	0	0
2023-08-11	06:59:00	4	3	0
2023-08-11	07:19:00	0	0	0
2023-08-12	05:40:00	0	0	0
2023-08-12	06:00:00	0	2	334
2023-08-12	07:00:00	1	2	4
2023-08-12	07:20:00	133	35	505
2023-08-13	05:41:00	0	0	0
2023-08-13	06:01:00	0	0	0
2023-08-13	07:01:00	0	0	0
2023-08-13	07:21:00	4	0	9
2023-08-14	05:42:00	0	0	0
2023-08-14	06:02:00	0	0	0
2023-08-14	07:02:00	572	9	1223
2023-08-14	07:22:00	209	25	895
2023-08-15	05:44:00	0	0	0
2023-08-15	06:04:00	0	0	0
2023-08-15	07:04:00	0	0	0
2023-08-15	07:24:00	75	38	0
2023-08-16	05:45:00	0	0	0
2023-08-16	06:05:00	0	1	0
2023-08-16	07:05:00	7	2	46
2023-08-16	07:25:00	0	2	0
2023-08-17	05:46:00	0	0	0
2023-08-17	06:06:00	0	0	0
2023-08-17	07:06:00	0	0	0
2023-08-17	07:26:00	0	0	0

Appendix B Vocalization Counts NHB13 (BirdNET & Manual)

date	time	birdnet	song_count_manual	pip_count_manual
2023-05-12	5:18:00	0	0	0
2023-05-12	5:38:00	0	0	0
2023-05-12	6:38:00	0	0	0
2023-05-12	6:58:00	0	0	0
2023-05-13	5:17:00	0	0	0
2023-05-13	5:37:00	0	0	0
2023-05-13	6:37:00	0	0	0
2023-05-13	6:57:00	0	0	0
2023-05-14	5:16:00	0	0	0
2023-05-14	5:36:00	0	0	0
2023-05-14	6:36:00	0	0	0
2023-05-14	6:56:00	0	0	0
2023-05-15	5:14:00	0	0	0
2023-05-15	5:34:00	0	0	0
2023-05-15	6:34:00	0	0	0
2023-05-15	6:54:00	0	0	0
2023-05-16	5:13:00	0	0	0
2023-05-16	5:33:00	0	0	0
2023-05-16	6:33:00	0	0	0
2023-05-16	6:53:00	0	0	0
2023-05-17	5:12:00	0	0	0
2023-05-17	5:32:00	0	0	0
2023-05-17	6:32:00	0	0	0
2023-05-17	6:52:00	0	0	0
2023-05-18	5:11:00	0	0	0
2023-05-18	5:31:00	0	0	0
2023-05-18	6:31:00	0	0	0
2023-05-18	6:51:00	0	0	0
2023-05-19	5:10:00	0	0	0
2023-05-19	5:30:00	0	0	0
2023-05-19	6:30:00	0	0	0
2023-05-19	6:50:00	0	0	0

2023-05-20	5:09:00	0	0	0
2023-05-20	5:29:00	0	0	0
2023-05-20	6:29:00	0	0	0
2023-05-20	6:49:00	0	0	0
2023-05-21	5:08:00	0	0	0
2023-05-21	5:28:00	0	0	0
2023-05-21	6:28:00	0	0	0
2023-05-21	6:48:00	0	0	0
2023-05-22	5:07:00	0	0	0
2023-05-22	5:27:00	0	0	0
2023-05-22	6:27:00	0	0	0
2023-05-22	6:47:00	0	0	0
2023-05-23	5:06:00	0	0	0
2023-05-23	5:26:00	0	0	0
2023-05-23	6:26:00	0	0	0
2023-05-23	6:46:00	0	0	0
2023-05-24	5:06:00	0	0	0
2023-05-24	5:26:00	0	0	0
2023-05-24	6:26:00	0	0	0
2023-05-24	6:46:00	0	0	0
2023-05-25	5:05:00	0	0	0
2023-05-25	5:25:00	188	123	0
2023-05-25	6:25:00	148	66	0
2023-05-25	6:45:00	162	69	0
2023-05-26	5:04:00	0	0	0
2023-05-26	5:24:00	0	0	0
2023-05-26	6:24:00	4	2	0
2023-05-26	6:44:00	6	2	0
2023-05-27	5:03:00	0	0	0
2023-05-27	5:23:00	263	68	35
2023-05-27	6:23:00	0	2	0
2023-05-27	6:43:00	5	2	145
2023-05-28	5:03:00	569	191	0
2023-05-28	5:23:00	187	63	0
2023-05-28	6:23:00	3	2	0
2023-05-28	6:43:00	58	0	158
2023-05-29	5:02:00	584	225	0
2023-05-29	5:22:00	135	48	0
2023-05-29	6:22:00	8	0	50
2023-05-29	6:42:00	48	0	400

2023-05-30	5:01:00	0	0	0
2023-05-30	5:21:00	0	0	0
2023-05-30	6:21:00	0	0	0
2023-05-30	6:41:00	0	0	0
2023-05-31	5:01:00	0	0	0
2023-05-31	5:21:00	0	0	0
2023-05-31	6:21:00	0	0	0
2023-05-31	6:41:00	1	0	0
2023-06-01	5:00:00	0	0	0
2023-06-01	5:20:00	0	0	0
2023-06-01	6:20:00	0	0	0
2023-06-01	6:40:00	0	0	0
2023-06-02	5:00:00	0	0	0
2023-06-02	5:20:00	0	0	0
2023-06-02	6:20:00	14	22	0
2023-06-02	6:40:00	2	13	0
2023-06-03	4:59:00	0	0	0
2023-06-03	5:19:00	0	0	0
2023-06-03	6:19:00	0	0	0
2023-06-03	6:39:00	0	0	0
2023-06-04	4:59:00	0	0	0
2023-06-04	5:19:00	12	3	18
2023-06-04	6:19:00	0	0	0
2023-06-04	6:39:00	0	0	0
2023-06-05	4:58:00	0	0	0
2023-06-05	5:18:00	0	0	0
2023-06-05	6:18:00	0	0	0
2023-06-05	6:38:00	0	0	0
2023-06-06	4:58:00	0	0	0
2023-06-06	5:18:00	0	0	0
2023-06-06	6:18:00	0	0	0
2023-06-06	6:38:00	0	0	0
2023-06-07	4:57:00	27	22	0
2023-06-07	5:17:00	1	62	0
2023-06-07	6:17:00	17	9	9
2023-06-07	6:37:00	0	0	0
2023-06-08	4:57:00	0		
2023-06-08	5:17:00	2	37	0
2023-06-08	6:17:00	23	10	16
2023-06-08	6:37:00	0	0	0

2023-06-09	4:57:00	16	110	0
2023-06-09	5:17:00	93	154	0
2023-06-09	6:17:00	0	3	0
2023-06-09	6:37:00	2	6	0
2023-06-10	4:57:00	1	91	0
2023-06-10	5:17:00	26	115	0
2023-06-10	6:17:00	23	22	0
2023-06-10	6:37:00	0	0	0
2023-06-11	4:56:00	0	0	0
2023-06-11	5:16:00	0	0	0
2023-06-11	6:16:00	9	5	48
2023-06-11	6:36:00	76	0	532
2023-06-12	4:56:00	52	144	0
2023-06-12	5:16:00	113	143	0
2023-06-12	6:16:00	0	0	0
2023-06-12	6:36:00	0	0	0
2023-06-13	4:56:00	94	172	0
2023-06-13	5:16:00	29	135	0
2023-06-13	6:16:00	0	0	0
2023-06-13	6:36:00	0	0	0
2023-06-14	4:56:00	5	49	0
2023-06-14	5:16:00	69	140	0
2023-06-14	6:16:00	0	0	0
2023-06-14	6:36:00	0	0	0
2023-06-15	4:56:00	16	76	2
2023-06-15	5:16:00	34	160	0
2023-06-15	6:16:00	0	0	0
2023-06-15	6:36:00	0	0	402
2023-06-16	4:56:00	0	0	0
2023-06-16	5:16:00	0	0	0
2023-06-16	6:16:00	42	18	2
2023-06-16	6:36:00	0	0	0
2023-06-17	4:56:00	0	0	0
2023-06-17	5:16:00	0	0	0
2023-06-17	6:16:00	0	0	0
2023-06-17	6:36:00	0	0	0
2023-06-18	4:56:00	0	0	0
2023-06-18	5:16:00	0	0	0
2023-06-18	6:16:00	0	0	0
2023-06-18	6:36:00	0	0	0

2023-06-19	4:56:00	0	0	0
2023-06-19	5:16:00	0	0	0
2023-06-19	6:16:00	0	0	0
2023-06-19	6:36:00	25	11	7
2023-06-20	4:57:00	0	0	0
2023-06-20	5:17:00	0	0	0
2023-06-20	6:17:00	11	8	0
2023-06-20	6:37:00	0	0	0
2023-06-21	4:57:00	0	0	0
2023-06-21	5:17:00	29	24	0
2023-06-21	6:17:00	1	7	0
2023-06-21	6:37:00	0	4	0
2023-06-22	4:57:00	0	0	0
2023-06-22	5:17:00	0	0	0
2023-06-22	6:17:00	5	0	235
2023-06-22	6:37:00	1	10	0
2023-06-23	4:57:00	0	0	0
2023-06-23	5:17:00	0	0	0
2023-06-23	6:17:00	1	10	0
2023-06-23	6:37:00	0	0	0
2023-06-24	4:57:00	0	0	0
2023-06-24	5:17:00	0	0	0
2023-06-24	6:17:00	0	0	0
2023-06-24	6:37:00	0	0	0
2023-06-25	4:58:00	0	0	0
2023-06-25	5:18:00	0	0	0
2023-06-25	6:18:00	0	0	0
2023-06-25	6:38:00	0	0	0
2023-06-26	4:58:00	0	0	0
2023-06-26	5:18:00	0	0	0
2023-06-26	6:18:00	5	6	0
2023-06-26	6:38:00	0	1	0
2023-06-27	4:59:00	0	0	0
2023-06-27	5:19:00	0	0	0
2023-06-27	6:19:00	0	0	0
2023-06-27	6:39:00	0	0	0
2023-06-28	4:59:00	0	0	0
2023-06-28	5:19:00	0	0	0
2023-06-28	6:19:00	2	1	0
2023-06-28	6:39:00	0	0	0

2023-06-29	4:59:00	0	0	0
2023-06-29	5:19:00	0	0	0
2023-06-29	6:19:00	0	0	0
2023-06-29	6:39:00	0	0	0
2023-06-30	5:00:00	0	0	0
2023-06-30	5:20:00	0	0	0
2023-06-30	6:20:00	0	0	0
2023-06-30	6:40:00	0	0	0
2023-07-01	5:00:00	0	0	0
2023-07-01	5:20:00	0	0	0
2023-07-01	6:20:00	0	0	0
2023-07-01	6:40:00	0	0	0
2023-07-02	5:01:00	0	0	0
2023-07-02	5:21:00	1	12	0
2023-07-02	6:21:00	0	0	0
2023-07-02	6:41:00	0	0	0
2023-07-03	5:02:00	0	0	0
2023-07-03	5:22:00	0	0	0
2023-07-03	6:22:00	0	0	0
2023-07-03	6:42:00	0	0	0
2023-07-04	5:02:00	0	0	0
2023-07-04	5:22:00	0	0	0
2023-07-04	6:22:00	0	0	210
2023-07-04	6:42:00	0	0	12
2023-07-05	5:03:00	0	0	0
2023-07-05	5:23:00	0	0	0
2023-07-05	6:23:00	0	0	0
2023-07-05	6:43:00	0	0	0
2023-07-06	5:04:00	0	0	0
2023-07-06	5:24:00	2	9	0
2023-07-06	6:24:00	0	1	0
2023-07-06	6:44:00	0	0	68
2023-07-07	5:04:00	0	0	0
2023-07-07	5:24:00	0	8	0
2023-07-07	6:24:00	0	0	0
2023-07-07	6:44:00	0	0	0
2023-07-08	5:05:00	0	0	0
2023-07-08	5:25:00	0	0	0
2023-07-08	6:25:00	0	0	0
2023-07-08	6:45:00	0	0	0

2023-07-09	5:06:00	0	0	0
2023-07-09	5:26:00	0	0	0
2023-07-09	6:26:00	0	0	0
2023-07-09	6:46:00	0	0	0
2023-07-10	5:06:00	0	0	0
2023-07-10	5:26:00	0	0	0
2023-07-10	6:26:00	0	0	0
2023-07-10	6:46:00	0	0	0
2023-07-11	5:07:00	0	0	0
2023-07-11	5:27:00	0	0	13
2023-07-11	6:27:00	0	0	0
2023-07-11	6:47:00	0	0	0
2023-07-12	5:08:00	0	0	0
2023-07-12	5:28:00	0	0	0
2023-07-12	6:28:00	0	0	0
2023-07-12	6:48:00	0	0	0
2023-07-13	5:09:00	0	0	0
2023-07-13	5:29:00	0	0	0
2023-07-13	6:29:00	0	0	0
2023-07-13	6:49:00	0	0	0
2023-07-14	5:10:00	0	0	0
2023-07-14	5:30:00	0	0	0
2023-07-14	6:30:00	38	15	144
2023-07-14	6:50:00	0	0	0
2023-07-15	5:11:00	0	0	0
2023-07-15	5:31:00	0	0	0
2023-07-15	6:31:00	0	0	0
2023-07-15	6:51:00	0	0	0
2023-07-16	5:11:00	0	0	0
2023-07-16	5:31:00	0	0	0
2023-07-16	6:31:00	0	0	0
2023-07-16	6:51:00	8	0	354
2023-07-17	5:12:00	0	0	0
2023-07-17	5:32:00	0	0	0
2023-07-17	6:32:00	0	0	0
2023-07-17	6:52:00	0	0	0
2023-07-18	5:13:00	0	16	0
2023-07-18	5:33:00	5	174	0
2023-07-18	6:33:00	41	58	0
2023-07-18	6:53:00	17	41	0

2023-07-19	5:14:00	0	0	0
2023-07-19	5:34:00	0	14	0
2023-07-19	6:34:00	45	37	0
2023-07-19	6:54:00	57	45	0
2023-07-20	5:15:00	1	0	0
2023-07-20	5:35:00	1	65	0
2023-07-20	6:35:00	14	28	0
2023-07-20	6:55:00	10	24	90
2023-07-21	5:16:00	0	46	0
2023-07-21	5:36:00	0	152	0
2023-07-21	6:36:00	7	28	0
2023-07-21	6:56:00	30	31	0
2023-07-22	5:17:00	0	0	0
2023-07-22	5:37:00	52	144	0
2023-07-22	6:37:00	54	7	385
2023-07-22	6:57:00	196	21	207
2023-07-23	5:18:00	0	0	0
2023-07-23	5:38:00	0	72	0
2023-07-23	6:38:00	39	4	689
2023-07-23	6:58:00	7	11	0
2023-07-24	5:19:00	0	0	1
2023-07-24	5:39:00	0	22	239
2023-07-24	6:39:00	24	40	0
2023-07-24	6:59:00	14	20	427
2023-07-25	5:20:00	0	1	0
2023-07-25	5:40:00	5	12	86
2023-07-25	6:40:00	4	12	74
2023-07-25	7:00:00	59	34	0
2023-07-26	5:21:00	0	0	0
2023-07-26	5:41:00	0	10	0
2023-07-26	6:41:00	12	32	334
2023-07-26	7:01:00	3	7	0
2023-07-27	5:22:00	0	0	0
2023-07-27	5:42:00	1	4	45
2023-07-27	6:42:00	20	2	295
2023-07-27	7:02:00	131	7	1004
2023-07-28	5:24:00	0	0	0
2023-07-28	5:44:00	0	0	0
2023-07-28	6:44:00	2	10	33
2023-07-28	7:04:00	3	4	0

2023-07-29	5:25:00	0	0	0
2023-07-29	5:45:00	0	1	16
2023-07-29	6:45:00	157	10	1024
2023-07-29	7:05:00	6	6	0
2023-07-30	5:26:00	0	0	0
2023-07-30	5:46:00	0	0	0
2023-07-30	6:46:00	11	0	250
2023-07-30	7:06:00	37	20	33
2023-07-31	5:27:00	3	1	0
2023-07-31	5:47:00	0	6	120
2023-07-31	6:47:00	34	13	21
2023-07-31	7:07:00	7	6	12
2023-08-01	5:28:00	3	1	0
2023-08-01	5:48:00	59	23	0
2023-08-01	6:48:00	35	14	347
2023-08-01	7:08:00	22	12	31
2023-08-02	5:29:00	0	0	0
2023-08-02	5:49:00	20	10	0
2023-08-02	6:49:00	2	13	54
2023-08-02	7:09:00	3	3	28
2023-08-03	5:30:00	0	1	0
2023-08-03	5:50:00	5	10	0
2023-08-03	6:50:00	6	4	24
2023-08-03	7:10:00	8	11	0
2023-08-04	5:31:00	0	0	0
2023-08-04	5:51:00	8	4	0
2023-08-04	6:51:00	47	7	150
2023-08-04	7:11:00	39	16	0
2023-08-05	5:32:00	0	0	0
2023-08-05	5:52:00	74	1	77
2023-08-05	6:52:00	2	0	9
2023-08-05	7:12:00	18	10	0
2023-08-06	5:34:00	0	0	0
2023-08-06	5:54:00	4	2	0
2023-08-06	6:54:00	67	2	165
2023-08-06	7:14:00	10	3	99
2023-08-07	5:35:00	0	0	0
2023-08-07	5:55:00	0	0	0
2023-08-07	6:55:00	77	8	275
2023-08-07	7:15:00	166	1	603

2023-08-08	5:36:00	0	0	0
2023-08-08	5:56:00	12	0	173
2023-08-08	6:56:00	1	0	8
2023-08-08	7:16:00	108	3	222
2023-08-09	5:37:00	0	0	0
2023-08-09	5:57:00	0	0	0
2023-08-09	6:57:00	102	0	1222
2023-08-09	7:17:00	61	0	562
2023-08-10	5:38:00	0	0	0
2023-08-10	5:58:00	0	0	0
2023-08-10	6:58:00	38	0	80
2023-08-10	7:18:00	93	2	117
2023-08-11	5:39:00	0	0	0
2023-08-11	5:59:00	0	0	0
2023-08-11	6:59:00	0	0	0
2023-08-11	7:19:00	0	0	0
2023-08-12	5:40:00	0	0	0
2023-08-12	6:00:00	0	0	0
2023-08-12	7:00:00	0	0	0
2023-08-12	7:20:00	0	0	0
2023-08-13	5:42:00	0	0	0
2023-08-13	6:02:00	0	0	0
2023-08-13	7:02:00	0	0	0
2023-08-13	7:22:00	0	0	0
2023-08-14	5:43:00	0	0	0
2023-08-14	6:03:00	0	0	0
2023-08-14	7:03:00	0	0	0
2023-08-14	7:23:00	0	0	0
2023-08-15	5:44:00	0	0	0
2023-08-15	6:04:00	0	0	0
2023-08-15	7:04:00	273	6	1162
2023-08-15	7:24:00	23	1	132
2023-08-16	5:45:00	0	0	0
2023-08-16	6:05:00	0	0	0
2023-08-16	7:05:00	6	0	249
2023-08-16	7:25:00	0	0	67
2023-08-17	5:46:00	0	0	0
2023-08-17	6:06:00	0	0	0
2023-08-17	7:06:00	0	0	0
2023-08-17	7:26:00	0	0	0

2023-08-18	5:47:00	0	0	0
2023-08-18	6:07:00	0	0	0
2023-08-18	7:07:00	0	0	0
2023-08-18	7:27:00	0	0	0
2023-08-19	5:49:00	0	0	0
2023-08-19	6:09:00	0	0	0
2023-08-19	7:09:00	0	0	0
2023-08-19	7:29:00	0	0	0
2023-08-20	5:50:00	0	0	0
2023-08-20	6:10:00	0	0	0
2023-08-20	7:10:00	0	0	0
2023-08-20	7:30:00	0	0	0
2023-08-21	5:51:00	0	0	0
2023-08-21	6:11:00	0	0	0
2023-08-21	7:11:00	0	0	0
2023-08-21	7:31:00	0	0	0
2023-08-22	5:52:00	0	0	0
2023-08-22	6:12:00	0	0	0
2023-08-22	7:12:00	0	0	0
2023-08-22	7:32:00	0	0	0
2023-08-23	5:53:00	0	0	0
2023-08-23	6:13:00	0	0	0
2023-08-23	7:13:00	0	0	0
2023-08-23	7:33:00	0	0	0
2023-08-24	5:54:00	0	0	0
2023-08-24	6:14:00	0	0	0
2023-08-24	7:14:00	0	0	0
2023-08-24	7:34:00	0	0	0
2023-08-25	5:56:00	0	0	0
2023-08-25	6:16:00	0	0	0
2023-08-25	7:16:00	0	0	0
2023-08-25	7:36:00	0	0	0
2023-08-26	5:57:00	0	0	0
2023-08-26	6:17:00	0	0	0
2023-08-26	7:17:00	0	0	0
2023-08-26	7:37:00	0	0	0
2023-08-27	5:58:00	0	0	0
2023-08-27	6:18:00	0	0	0
2023-08-27	7:18:00	0	0	0
2023-08-27	7:38:00	0	0	0

2023-08-28	5:59:00	0	0	0
2023-08-28	6:19:00	0	0	0
2023-08-28	7:19:00	0	0	0
2023-08-28	7:39:00	0	0	0
2023-08-29	6:00:00	0	0	0
2023-08-29	6:20:00	0	0	0
2023-08-29	7:20:00	0	0	0
2023-08-29	7:40:00	0	0	0