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Differential Migration by Northern Saw-whet Owls (*Aegolius acadicus*) through Yellowwood State Forest, Indiana

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Abstract: Yellowwood State Forest banding station, located in south-central Indiana, was opened in 2002 as the first Northern Saw-whet Owl (*Aegolius acadicus*) banding station in the state. At the time, the extent to which saw-whet owls migrated through Indiana was unknown. The station's aim was to discover more about the migratory habits of saw-whet owls, and the extent to which they migrate differentially according to sex and age class. Previous studies have found that differential migration in saw-whet owls varies by region, so here, I focus specifically on possible patterns of differential migration through Yellowwood State Forest (YSF). My findings indicate that saw-whet owls in this region migrate differentially according to sex, as 75.60% of owls captured at YSF were female compared to 9.31% male. Differential migration according to age also seems likely, as there was a statistically significant difference between the migration timing of hatch year owls compared to adult owls. Overall, twenty one years after the station opened, the data gathered by YSF continues to answer questions about the migration patterns of this highly enigmatic owl.

1. Introduction:

1.1: Motivation:

Northern Saw-whet Owls (*Aegolius acadicus*) are a tiny owl that is common across much of northern North America, and can be found in the United States during the winter. However, due to being highly nocturnal and hard to see, the migration of saw-whet owls has historically been poorly understood. For this reason, saw-whet owl banding stations have been set up across North America as part of a research effort called Project Owlnet ("Welcome to Project Owlnet," 1994). In particular, this paper focuses on the Yellowwood State Forest banding station, which was established by Dr. Ross Brittain and Jess Gwinn in 2002 ("Northern Saw-whet Owl banding," 2023).

Banding is important for studying seldom-seen species such as saw-whet owls. Individually numbering and recording each owl allows researchers to understand which areas saw-whet owls migrate through, and where they overwinter. If banding stations encounter already-banded owls, they can determine when the owl was banded, if that owl was caught and banded somewhere else, or if that owl was caught and banded locally. Furthermore, banding allows researchers to take measurements assessing the condition of individual owls, and gather data on things such as lifespan and survival rate. More broadly, banding allows researchers to monitor how well the species is doing and

assess responses over time toward threats such as global climate change.

Migration is not a phenomenon that looks the same in every species of bird. Therefore, assessing the migration habits of specific species or populations can reveal valuable information and trends that might not be observed otherwise.

In particular, I am looking at a phenomenon called differential migration. Differential migration occurs when the members of a population migrate, but do not necessarily migrate at the same time or for the same distance. These differences in migration are often based on age or sex. Differential migration has been observed in more than 150 bird species (Payevsky, 2021). Findings indicate that saw-whet owls are one of them.

In addition to differential migration, I am looking at a second phenomenon called irruptive migration. This phenomenon occurs when a species migrates to an area in larger-than-typical numbers based mainly on food supply rather than a hormonal change. In saw-whet owls, irruption tends to take the form of cyclical cycles with a larger-than-normal influx of owls occurring approximately every four years.

1.2: Related Work:

Fall migration in Northern Saw-whet Owls is typically variable across different regions, and can change according to age, sex, and magnitude. East of the Mississippi River, saw-whet owl migration seems to be indicative of partial migration with a four-year irruption cycle. During irruption years, it is possible for the number of saw-whets captured to be ten times higher than the long-term average (Weir et al. 1980, Swengel & Swengel 1995, Whalen & Watts 2002). Banding stations in eastern North America have noticed a large increase in the proportion of hatch year owls banded in irruption years (Whalen & Watts 2002, Beckett & Proudfoot 2011).

Work on saw-whet owl migration in Indiana has been previously conducted. Brittain et al. (2009) analyzed data from three banding stations located across south-central Indiana, including YSF, from 2002 to 2007. In particular, Brittain et al. (2009) report that the proportion of hatch-year owls captured was 54.8% on average, with hatch year owls arriving consistently earlier than adult owls by about four to five days. Additionally, 80% of the owls captured were female, while 7% were male.

A second time point, analyzed by Brittain and Jones (2014), included data from saw-whet owls captured at two different banding stations in south-central Indiana, again including YSF. This study focused specifically on differential migration by age in Northern Saw-whet Owls across the years 2002 to 2012. Overall, this study found that hatch year owls migrated on average three days earlier than adult owls. Additionally, 57% of owls captured at YSF were hatch years, while 43% were adults.

In a more comprehensive study, Beckett and Proudfoot (2011) compiled data from the U.S. Geological Survey's Bird Banding Laboratory and geographic information systems (GIS) in order to identify trends in annual saw-whet owl movement across North America. Rather than focusing on a specific location, this study focused mainly on the eastern United States and

southeastern Canada. Although their results did not show unambiguous evidence of age-differentiated migration based on latitude, they did find that the proportion of adult to hatch year owls wasn't uniform across all banding stations, which suggests age-differentiated migration patterns that vary according to region.

Beckett and Proudfoot (2012) conducted a similar study to the one mentioned above, this time looking at sex-specific trends in Northern Saw-whet Owl migration across North America. They found that males are caught in greater proportion at northern latitudes, and that females often greatly outnumber males in terms of proportion of captures during fall migration. Thus, it seems likely that saw-whet owls migrate differentially according to sex, with females generally migrating and overwintering farther south than males.

With all of this research in mind, it is worth noting that the trends from the Indiana studies do not hold true across every banding station in North America. For instance, saw-whet owls migrating through Canadian breeding grounds did not show age-related differences in migration timing (De Ruyck et al. 2012). In New Jersey, contrary to both the Canadian and the Indiana findings, adults migrated earlier than hatch year owls (Duffy and Kerlinger 1992).

1.3: Goals:

As demonstrated by previous work, Northern Saw-whet Owl migration is highly variable according to region. Although the work by Brittain et al. (2009) and Brittain and Jones (2014) established clear trends in south-central Indiana, it has been a decade since saw-whet owl migration in the region has been analyzed. Therefore, using their work as previous time points for comparison, I will look at similar questions regarding saw-whet owl migration, and will investigate if what was discovered ten years ago remains true today.

First, I will look at how many owls have been banded each year, and examine if the four-year irruption trend is present in my data. Second, I will look at the sex of owls captured at YSF, and examine if one sex is more common than the other, and if one sex migrates earlier than the other. Finally, I will examine the proportion of hatch year versus adult owls, and will look for evidence of age-differentiated migration. Overall, I will ask:

- *Do the saw-whet owls migrating through YSF show signs of irruption?*
- *Do they migrate differentially in respect to sex class?*
- *Do they migrate differentially in respect to age class?*

With the results to my questions in mind, I will then attempt to answer the question of whether or not Northern Saw-whet Owls at Yellowwood State Forest show signs of differential migration.

2. Materials and Methods

2.1 Banding:

All data comes from the Yellowwood State Forest banding station, located in Brown County, Indiana. Saw-whet owls were

Figure 1: Northern Saw-whet Owl banding. 1a: A Northern Saw-whet Owl with a metal band on its left leg. 1b: Measuring the wing. Females are often larger than males, so this can help determine sex. 1c: Using UV light to age an owl. The porphyrin in owls' feathers fades over time, so new feathers glow brighter than old feathers. Since owls lose feathers in a predictable order, their molts can help determine their age.

captured via an audiolure placed in the middle of an array of mist nets. Once captured and removed from the nets, owls were given metal bands (if they hadn't been banded before) listing unique numbers that would identify them as having been banded at YSF (figure 1a). Additionally, measurements such as sex (figure 1b), age (figure 1c), capture time, wing chord, flat wing, weight, tail, eye color, and fat were taken.

2.2: The Data:

The data consists of 1,136 owls captured at YSF from the years 2002 to 2022. However, since the years 2011, 2012, and 2013 did not contain all the information necessary to analyze sex and age, the majority of the analysis was done using 881 owls captured from 2002 to 2010, and 2014 to 2022. Thus, 18 years of banding are examined in this paper.

The 881 owls analyzed consist of both new birds (never banded before) and foreign recaptures (either banded somewhere else or banded at YSF in a previous year). Local recaptures (owls banded and then caught again later that same night or later that same season) were excluded, as they would have led to an overestimate of how many individual owls were captured each year.

The data was converted into a series of CSV files and then imported into Jupyter Notebook. The analysis was done in the Python programming language. Figures were generated using libraries such as Matplotlib and Seaborn, so that trends in owl captures could be easily visualized. Pandas, NumPy, and Datetime were used in the process of generating and transforming dataframes. SciPy was used to perform statistical calculations and determine if results were statistically different from each other.

3. Results:

3.1: Examining Trends by Year:

3.1.1: Total Owls:

From 2002 to 2022, 1,136 owls were captured at YSF (figure 2). There was a

statistically significant difference in the number of owls captured during irruption years (2003, 2007, 2012, 2016, 2020) compared to non-irruption years (two-sample t-test, p = 0.0148).

From 2002 to 2022 (looking at 1,136 owls over 21 years), an average of 54.1 owls were captured per year. From 2002 to 2010 and 2014 to 2022 (looking at 881 owls over 18 years), an average of 48.9 owls were captured per year.

3.1.2: Sex by Year:

Sex was determined for 881 Northern Saw-whet Owls from 2002 to 2010 and 2014 to 2022 (figure 3). 75.60% (666 owls) were female, 9.31% (82 owls) were male, and 15.10% (133 owls) were unknown (sex could not be determined). There was a statistically significant difference between the number of females and males captured, with females being more abundant (two-sample t-test, p = 0.0001).

3.1.3: Age by Year:

Age was determined for 880 Northern Saw-whet Owls from 2002 to 2010 and 2014 to 2022 (figure 4). (One owl had to be dropped because it did not have an age listed.) 56.14% (494 owls) were hatch years and 43.86% (386 owls) were adults. There was not a statistically significant difference between the number of hatch year and adult owls captured (two-sample t-test, p = 0.4355).

However, the proportion and number of hatch year owls was noticeably higher in irruption years compared to non-irruption years. Looking only at irruption years, the percentage of hatch year owls was 73.20% (284 owls), while the percentage of adult owls was 26.80% (104 owls). However, in non-irruption years, the percentage of hatch year owls was 42.68% (210 owls), while the percentage of adult owls was 57.32% (282 owls). Additionally, there was a statistically significant difference in the number of hatch years between irruption and non-irruption years (two-sample t-test, p = 0.0000), while there was not a statistically significant difference in the number of adults between irruption and non-irruption years (two-sample t-test, p = 0.2083).

3.2: Examining Trends by Date:

The banding season generally occurred from the middle of October to the end of November. The earliest banding date was October 12, while the latest banding date was December 4. Overall, a total of 54 banding dates (October 12 through December 4) are examined in this dataset. Banding did not occur on every date equally — some dates, over the 18-year period this paper is examining, were banded on more than others, since conditions such as rain or high winds would cause the station to close. This difference in the number of times dates were banded on is accounted for in the figures and statistics.

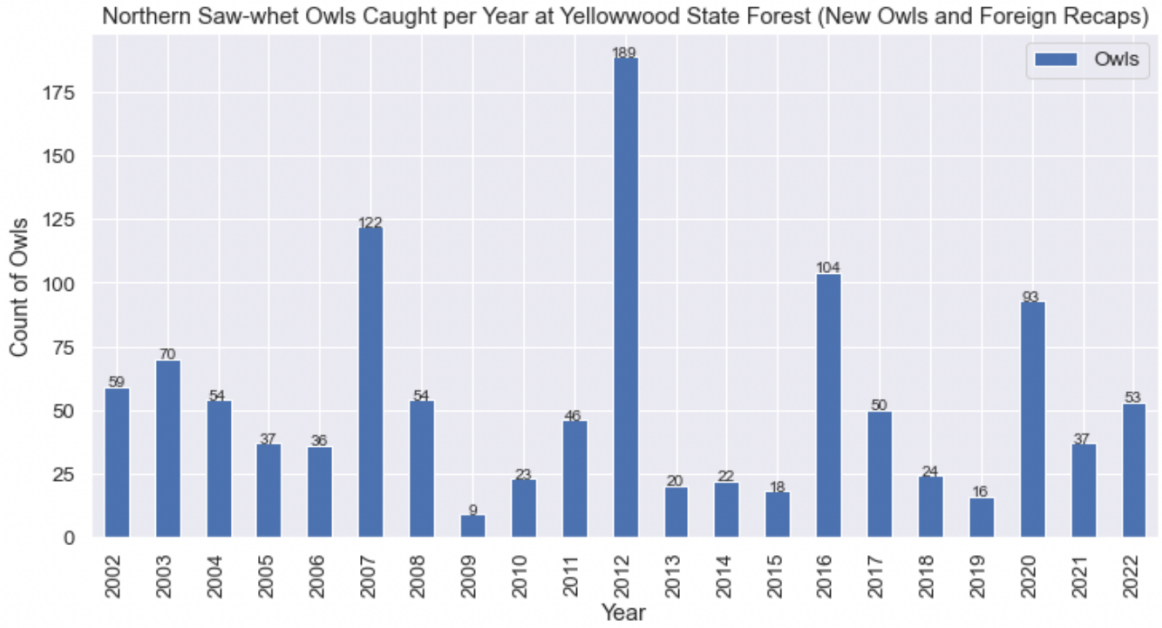

Figure 2: The total number of Northern Saw-whet Owls (1,136) captured per year at YSF. These include new owls and foreign recaptures, but exclude local recaptures that had been captured at YSF at some point earlier in the same season.

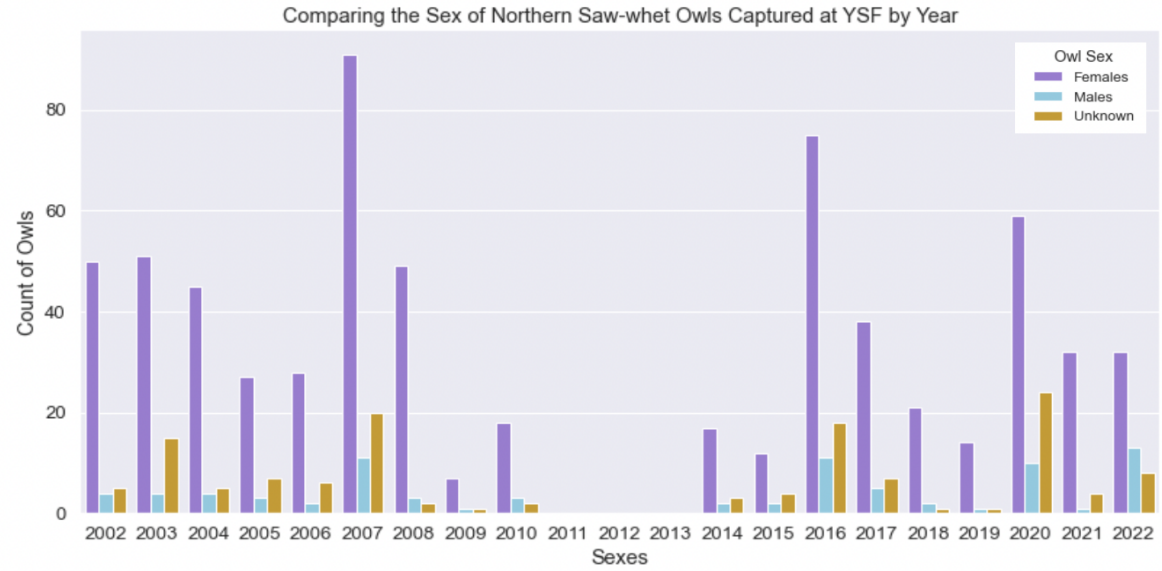

Figure 3: The sex of 881 owls captured at YSF. Years 2011, 2012, and 2013 are not included due to missing information in the data.

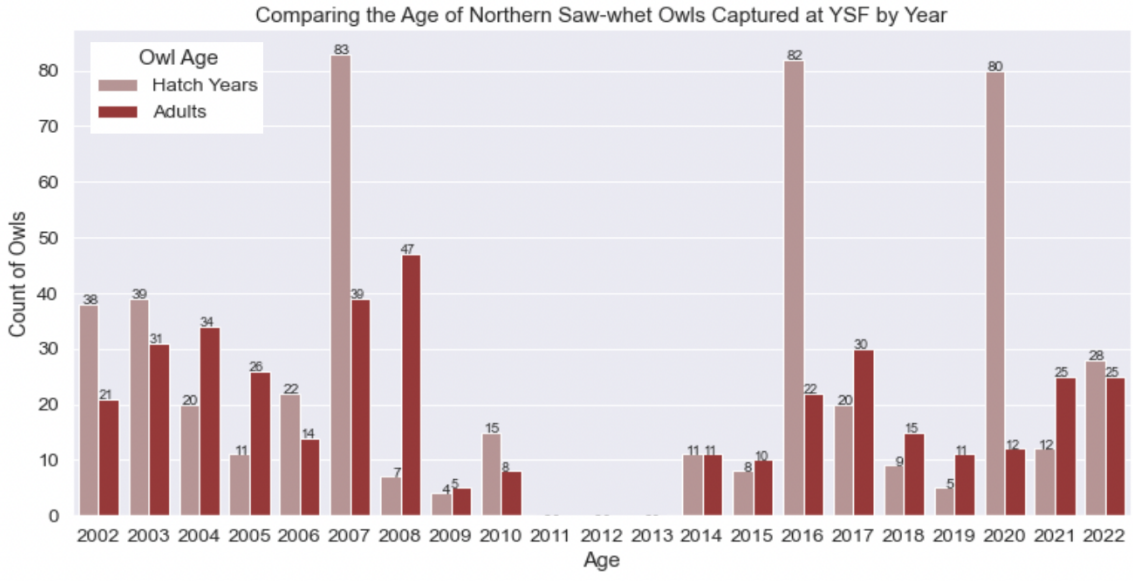

Figure 4: The age of 880 owls captured at YSF. Years 2011, 2012, and 2013 are not included due to missing information in the data.

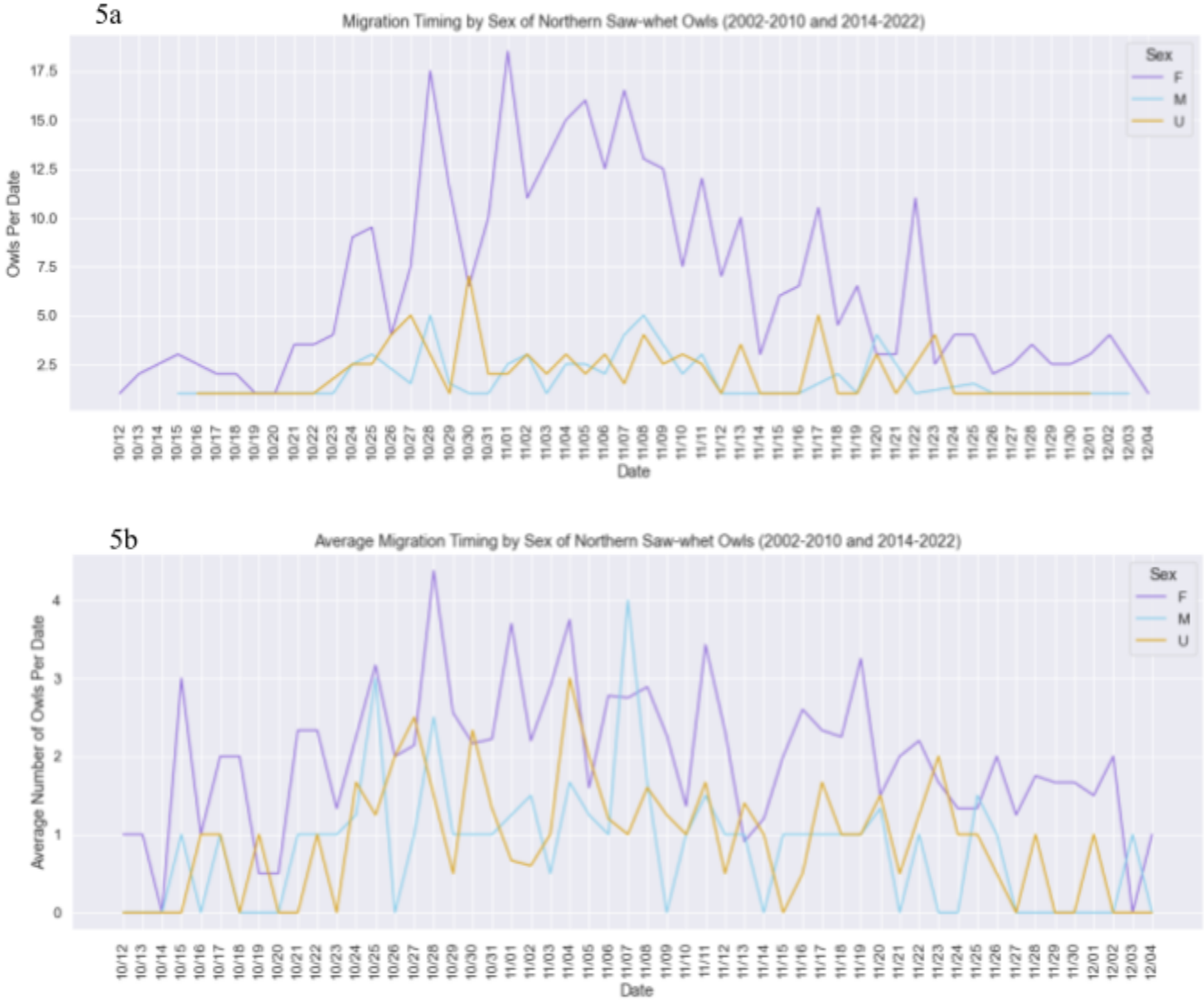

Figure 5: Timing of migration of 881 Northern Saw-whet Owls according to sex. 5a: Total count of female, male, and unknown owls captured per date. 5b: Average number of female, male, and unknown owls captured per date, calculated because banding did not occur on all dates equally over the 18-year period examined.

3.2.1: Sex by Date:

There was not a statistically significant difference in the timing of migration of males and females (two-sample t-test, p = 0.3696). An average of 3.9 females, 0.5 males, and 0.8 unknown owls were banded per date. (Figure 5a and figure 5b.)

3.2.2: Age by Date:

There was a statistically significant difference in the timing of migration of hatch year and adult owls (two-sample t-test, p = 0.0228), with hatch year owls migrating slightly earlier than adult owls. An average of 4.5 hatch year owls and 3.3 adult owls were banded per date. (Figure 6a and 6b).

4. Discussion:

4.1 Do the saw-whet owls migrating through YSF show signs of irruption?

My findings indicate that the population of Northern Saw-whet Owls that

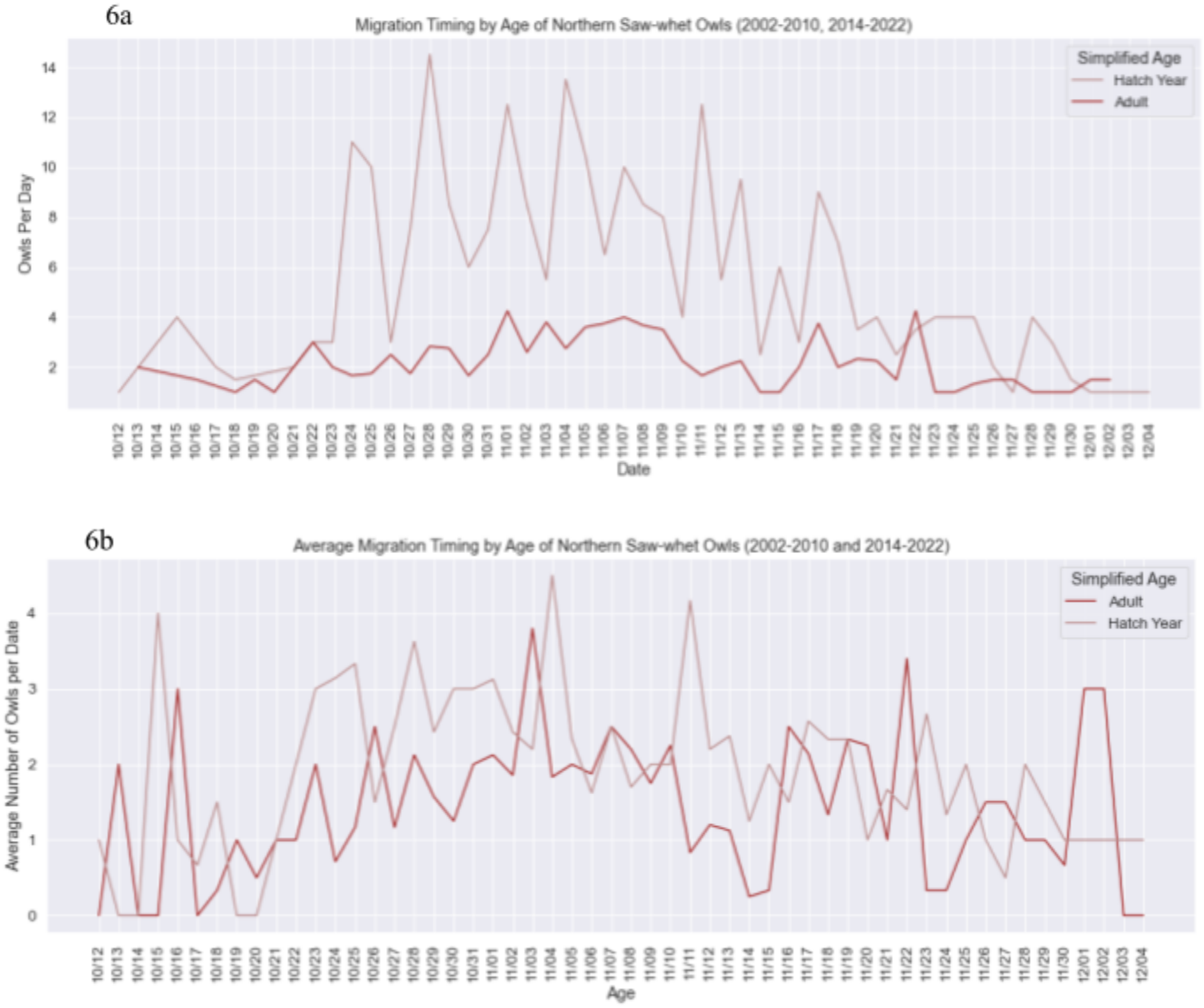

Figure 6: Timing of migration of 880 Northern Saw-whet Owls according to age. 6a: Total count of hatch year and adult owls captured per date. 6b: Average number of hatch year and adult owls captured per date, calculated because banding did not occur on all dates equally over the 18-year period examined.

migrate through Yellowwood State Forest does experience irruptions approximately every four years, with the years 2003, 2007, (2012), 2016, and 2020 having significantly more owls than non-irruption years. Additionally, findings by previous studies that irruption years entail a large increase in the proportion of hatch year owls were also confirmed by my results. There were significantly more hatch year owls captured in irruption years compared to non-irruption years, but not significantly more adult owls captured in irruption years compared to non-irruption years.

4.2: Do the saw-whet owls migrating through YSF migrate differentially in regards to sex class?

Regarding the sex of saw-whet owls migrating through YSF, my results line up well with those by Brittain et al. (2009). Examining the years 2002 to 2007, Brittain et al. (2009) found that 80% of owls migrating

through south-central Indiana were female, while 7% were male. This is similar to my results indicating that 75.60% of owls migrating through YSF were female, while 9.31% were male. Thus, it can be concluded that the long-term sex ratio of Northern Saw-whet Owls in south-central Indiana has remained similar over the years.

While I found no evidence of a timing difference between male and female saw-whet owls, the highly female-skewed proportion of owls migrating through YSF seems to indicate that this population of owls migrates differentially according to sex. This holds true with the findings by Beckett and Proudfoot (2012), which indicate that males are caught in greater proportion at northern latitudes, while females represent a much larger proportion of overall captures in the eastern United States, and tend to migrate further south. These findings are also in line with the documented sex-specific migration of other small forest owls, such as Tengmalm's Owls (Hipkiss, 2002).

This large difference in the migration of male and female owls might be due to different resource demands on males and females. For instance, female saw-whet owls, being bigger, might need to migrate south in search of more abundant food. Additionally, males might overwinter closer to their breeding grounds in the north so as to more quickly establish territories come spring (Beckett and Proudfoot, 2012).

4.3: Do the saw-whet owls migrating through YSF migrate differentially in regards to age class?

My results regarding the proportion of adult and hatch year owls once again line up similarly to previous results. Brittain and Jones (2014) reported that 57% of owls captured at YSF in the years 2002 to 2012 were hatch years, while 43% of owls were adults. Meanwhile, I found that 56.14% of the owls migrating through YSF were hatch years and 43.86% were adults. Once again, this seems to indicate that the long-term age ratio of Northern Saw-whet Owls in south-central Indiana has remained similar over the years.

Interestingly, non-irruption years (which were the majority of years) had a higher proportion of adult owls than hatch year owls captured (57.32% adults compared to 42.68% hatch years). However, since hatch years represented a much higher proportion of the total number of owls during irruption years (73.20% hatch years versus 26.80% adults), it is likely these irruption years that lead the overall proportion of hatch year owls to be higher than the overall proportion of adult owls.

When it comes to differential migration, I did not find a statistically significant difference in the abundance of hatch year versus adult owls over all 18 years. However, I did find that the timing of migration of hatch year owls was statistically different from the timing of migration of adult owls, with hatch year owls migrating slightly earlier. This seems in line with the results of Brittain et al. (2009), which indicated that hatch year owls arrive on average four to five days earlier than adult owls, and the results of Brittain and Jones (2014), which indicate that hatch year owls arrive on average three days earlier than adult owls.

This difference in migration timing might be because, by arriving first, hatch year owls are able to exploit prey resources along their migration route, and avoid competition with adult owls. Additionally, hatch year saw-whet owls might simply be being forced to depart earlier than adult owls, due to density-dependent adult competition (Brittain & Jones, 2014).

5. Conclusions and Future Directions:

5.1: Differential migration:

In conclusion, the Northern Saw-whet Owls that migrate through YSF do seem to migrate differentially. In terms of sex-related differential migration, females migrate farther south than males, and are much more abundant in south-central Indiana. However, there is no difference in the timing of migration between males and females.

In terms of age-related differential migration, the long-term abundance of both hatch year and adult owls is not statistically different. However, there is a difference in timing, with hatch year owls arriving slightly earlier than adult owls.

These results support much of the previous research done on this area of Indiana, as well as overall migration trends observed across the eastern United States.

5.2: Future Directions:

Of course, there is still much that could be done with this study set. In particular, I only looked at the relationship between hatch year and adult owls, and between female and male owls. More insights could be gleaned by breaking the owls down into further groups — adult female, adult male, hatch year female, and hatch year male. Perhaps then, more trends relating to the combination of the effects of sex and age on migration might be revealed.

Additionally, there is lots to explore in terms of irruption versus non-irruption years. I found that hatch year owls are more abundant during irruption years — do they migrate significantly earlier during irruption years? Furthermore, does sex ratio change during irruption years? All of these questions and more remain to be explored while working with my dataset on YSF Northern Saw-whet Owl migration.

Twenty one years ago, researchers were uncertain if Northern Saw-whet Owls even passed through south-central Indiana. Now, with data being collected each year by YSF and other banding stations, more and more is being discovered about the migratory behavior of Northern Saw-whet Owls. Lots of questions still remain about the variety of migratory strategies used by different saw-whet owls in different regions, but my paper has helped contribute to building an even more comprehensive understanding of Northern Saw-whet Owls' migration.

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