Utilizing stable isotope analysis (δ^2H) to determine natal origins and migratory patterns of raptors during fall migration in Duluth, MN

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Project Overview:

Effective conservation of migratory species requires the knowledge of a species' habitat use throughout its full annual lifecycle. The aim of this project was to determine the breeding origin and migratory patterns of raptors using hydrogen stable isotope analysis (δ^2H) of feathers collected during fall migration at Hawk Ridge Duluth, Minnesota. Analysis of hydrogen stable isotope ratios in keratinous materials (e.g. feathers, δ^2H_f) allows researchers to assign geographic origins based on patterns of local average growing-season precipitation (δ^2H_p). We assessed whether stable isotope analysis will be a useful technique for determining breeding origin and temporal migratory patterns of raptors caught during fall migration in Duluth. Knowledge of breeding location would enable future research to connect ecological variables on breeding grounds to population changes observed at Hawk Ridge and allow our long-term monitoring data to be interpreted within a geographical framework. For this initial pilot project, we selected three species to assess: Northern Saw-whet Owl (*Aegolius acadius*), Sharp-shinned Hawk (*Accipiter striatus*), and Red-tailed Hawk (*Buteo jamaicensis*).

Researchers have successfully used stable hydrogen isotope analysis to estimate geographic origin by comparing δ^2H_f values to an "isoscape" of feathers of known origin (Wassenaar and Hobson 2006). δ^2H of precipitation varies predictably in a latitudinal pattern and because organisms rely on precipitation as their main source of hydrogen, these same patterns can be found in the tissues of organisms living in different geographic locations. Growing feathers incorporate hydrogen isotopes in proportion to isotope amounts in the environment in which the feathers are grown. After growth, feathers remain inert. Therefore, if a bird is known to molt on its breeding ground, birds of unknown breeding location can be assigned a geographic origin based on δ^2H. This developing technique is promising as a non-invasive way to determine migratory connectivity. However, recent research suggests this technique may not currently be useful for adult raptors due to unknown physiological and behavioral mechanisms affecting δ^2H_f. Studies analyzing adult feathers show unexpected results and varied ^2H enrichment (Greenwood and Dawson 2011, Ruyck et al. 2013). Therefore, this study will be restricted to the analysis of hatch-year migrants.

Objectives:

1. Estimate natal/breeding origins for juvenile raptors banded in the fall at Hawk Ridge.
2. Determine temporal migration patterns in relation to natal origins.

Methods:

Sample collection

Feather samples were collected from juvenile Sharp-shinned Hawks (*Accipiter striatus*), Red-tailed Hawks (*Buteo jamaicensis*), and Northern Saw-whet Owls (*Aegolius acadicus*) caught during fall migration 2020 at Hawk Ridge in Duluth, MN (Table 1). The fall diurnal raptor banding season took place daily from 15 August until mid-December. All raptors were fit with an aluminum band, aged, and sexed, when possible. Morphological measurements were recorded per standard banding protocol (weight, wing chord, and tail length). The fall owl banding season took place over 67 nights between 15 September and 20 November. All required federal and state permits were granted for trapping, banding, and feather collection. Feather sampling techniques were approved under the University of Minnesota IACUC protocol (1904-36977A to M. Etterson).

Table 1. Number of individuals sampled during migration and number sent for stable isotope analysis.

Species	Number of Individuals Sampled	Number of Individuals Analyzed for Stable Isotopes
Northern Saw-whet Owl	424	100
Sharp-shinned Hawk	440	100
Red-tailed Hawk	70	40

A subset of the samples collected were sent to the Central Appalachian Stable Isotope Facility for hydrogen stable isotope analysis. These samples were randomly selected across the banding season.

Data analysis: natal origins

We utilized the package assignR in R to assign probability density of natal origin for each species (Ma et al., 2020; R Core Team, 2013). We first created probability density maps for each individual and then summed these probabilities to create probability density maps for each species. Maps were constrained with known breeding ranges for each species as well as knowledge compiled from banding return data.

Data analysis: migration patterns

Migration patterns were assessed by regressing δ^2H_f against Julian date of banding. Since δ^2H of precipitation in North America follows a mostly latitudinal gradient, δ^2H_f can be used as an estimate of latitudinal origin. For Sharp-shinned Hawks and Northern Saw-whet Owls, regressions were run separately for male and female individuals. Red-tailed hawks are not easily sexed morphometrically and therefore the sexes of the individuals analyzed were unknown.

Results:

Figures 1 and 2 show the main results from this project.

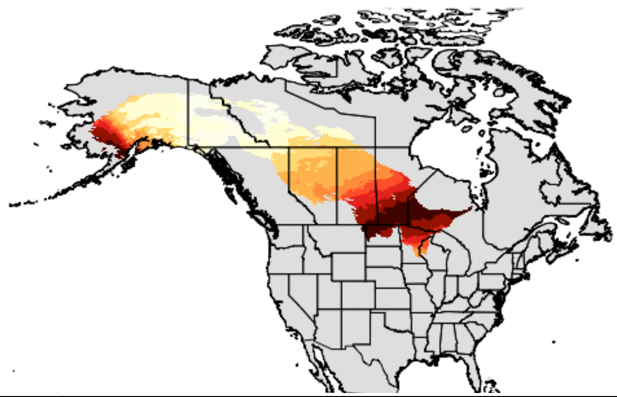
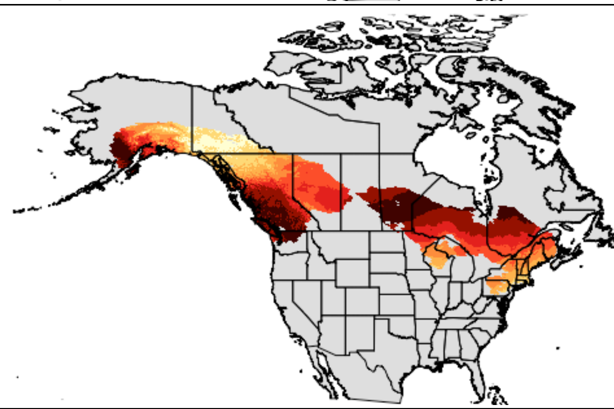
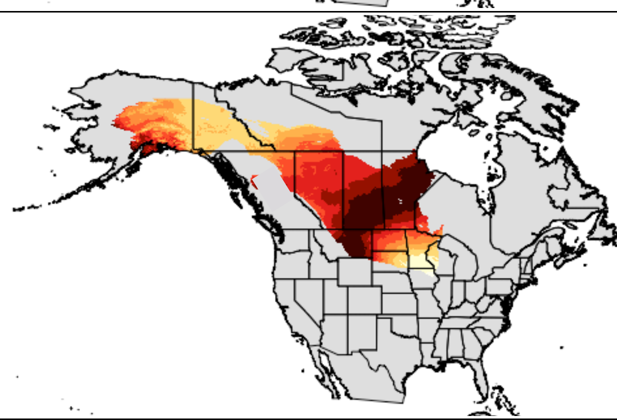
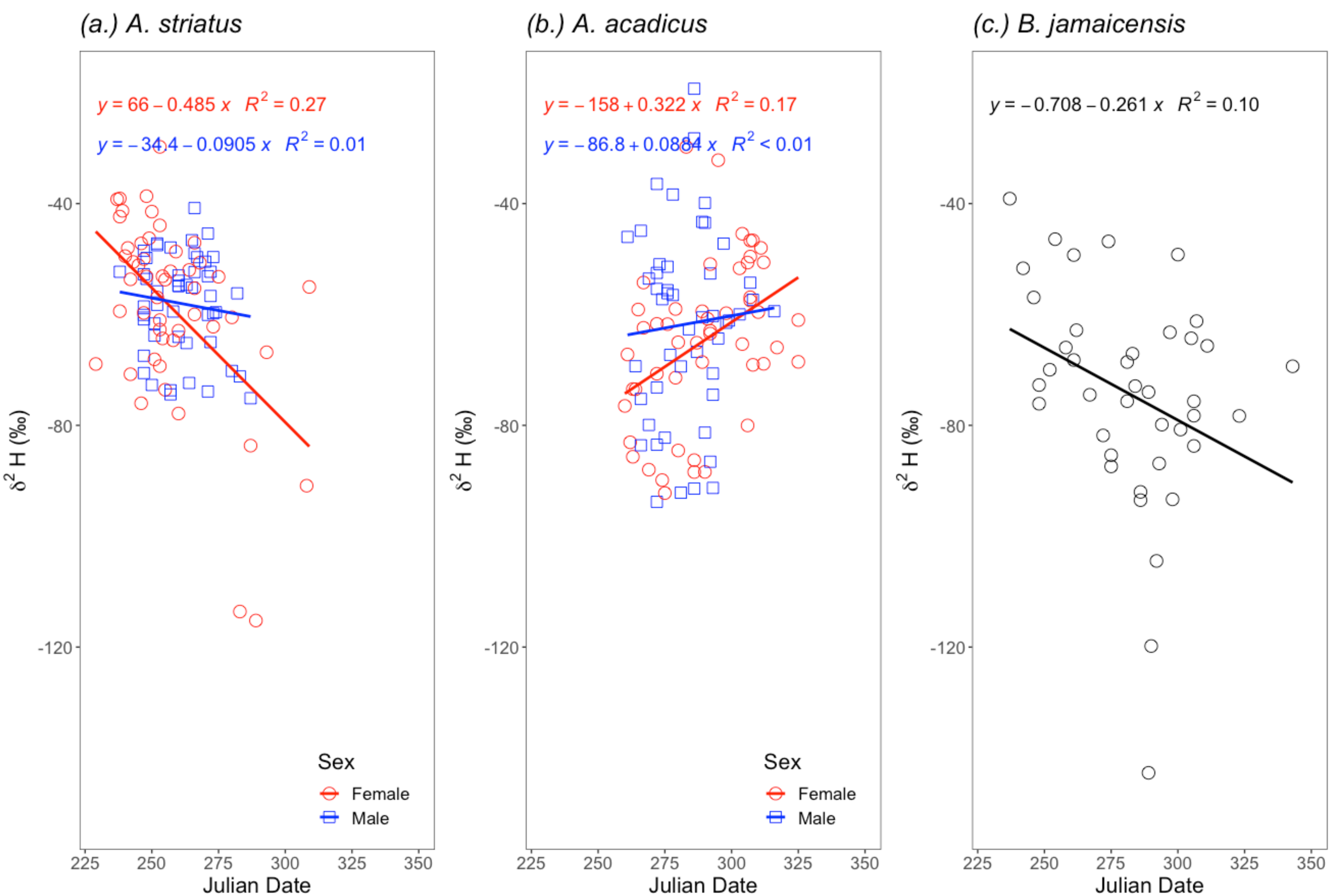
Sharp-shinned Hawk	
Northern Saw-whet Owl	
Red-tailed Hawk	

Figure 1. Maps showing the probability density surface for each species after being constrained with known breeding ranges and band recovery data. Areas that are darker (red) represent higher probability densities. For all three species, areas of highest probability density are north of Duluth.



(a.) A. striatus
y = 66 − 0.485 x   R² = 0.27
y = − 34.4 − 0.0905 x   R² = 0.01
(b.) A. acadicus
y = − 158 + 0.322 x   R² = 0.17
y = − 86.8 + 0.0884 x   R² < 0.01
(c.) B. jamaicensis
y = − 0.708 − 0.261 x   R² = 0.10
δ² H (‰)
-40
-80
-120
225
250
275
300
325
350
Julian Date
Sex
Female
Male

Figure 2. Regressions of δ^2H_f against Julian date of banding for each species. (a) Female *A. striatus* have a negative relationship between Julian date of banding and δ^2H_f ($p < 0.001$). Male *A. striatus* showed no significant relationship between Julian banding date and δ^2H_f ($p = 0.42$). (b) Female *A. acadicus* have a positive relationship between Julian date of banding and δ^2H_f ($p < 0.01$). Male *A. acadicus* showed no significant relationship between Julian banding date and δ^2H_f ($p = 0.66$). (c) *B. jamaicensis* feathers have a negative relationship between Julian date of banding and δ^2H_f ($p = 0.046$).

Discussion:

Natal origins

As in previous studies, we found that δ^2H values of juvenile raptor feathers can be used to broadly assign natal origin of birds on a broad spatial scale (Crowley et al., 2021; Ruyck et al., 2013; Smith et al., 2003; Wommack et al., 2020). Probabilistic assignments using the *assignR* package had highest probability densities of natal origin north of Duluth. However, hydrogen isotopes have broad latitudinal bands across North America which means that assignments are not constrained on an East-West direction and therefore this technique has limitations for gaining understanding of more precise natal origins. Future studies at Hawk Ridge using stable isotopes could incorporate a dual- or multi-isotope approach that has complementary gradients to hydrogen isotopes (Crowley et al., 2021; Wommack et al., 2020). In addition, the combined use of extrinsic techniques like transmitters could help to verify assignments made with isotopes. Other intrinsic techniques like genetics or trace metal analysis could also be used to further refine assignments by isotope analysis.

Migration patterns

Regression of Julian date of banding with δ^2H_f values revealed temporal migration patterns. Female Sharp-shinned Hawks and all Red-tailed Hawks had a significant negative relationship between Julian banding date and δ^2H_f indicating that southern individuals were in general migrating through Duluth earlier in the season than more northern-breeding individuals. However, Northern Saw-whet Owls had a significant positive relationship between banding date and δ^2H_f indicating that more northern populations were banded at Hawk Ridge earlier in the season. This is an interesting finding that deserves more analysis to confirm.

Neither Sharp-shinned Hawk and Northern Saw-whet Owl males had a significant relationship between banding date and δ^2H_f. The lack of significant relationship suggests that males are migrating in a broad front pattern. One explanation for the lack of migration pattern is that males may use the time post-fledging as a precursor to finding nesting habitat for the next breeding season (Ciaglo et al., 2021; Patchett et al., 2022). This phenomenon of post-fledging prospecting has been reported in a variety of species and may contribute to breeding success the following year.

Budget Report:

Complete funding for this project was supplied by grants from Minnesota Ornithologists' Union Savaloja Grants, Hawk Migration Association of North America Research Award, Sigma Xi Grants in Aid of Research. Analysis of 240 samples for hydrogen stable isotopes was a total of $6,182. MOU provided the funding for over half of the isotope analysis.

Funding Source	Funding Amount
MOU Grant	$3,716
Other Funding Sources	$2,466
TOTAL	**$6,182**

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