Inferring Brown-Capped Rosy-Finch demography and breeding distribution trends from long-term wintering data in New Mexico

New Mexico Department of Game and Fish, Share with Wildlife Program

Semi-Annual Report

December 2023

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Funding for this project was provided by

the Share with Wildlife program of the New Mexico Department of Game and Fish,

State Wildlife Grant #T-79-R-1

ABSTRACT

The three North American Rosy-finch species, Brown-capped (*Leucosticte australis*), Black (*L. atrata*), and Gray-crowned (*L. tephrocotis*), are among the most climate-threatened species in the United States. New Mexico is an important location for understanding the effects of climate change as it is the southernmost location in which Brown-capped Rosy-finches breed, and where all three species co-occur during winter. Rosy-finches are difficult to study during the breeding season, and therefore, winter studies may lend insight into population trends, and provide direction for conservation actions based on knowledge of the breeding origins of wintering birds. Our study aims to investigate long-term term demographic and migration trends from wintering Brown-capped Rosy-finches in New Mexico and to evaluate the efficacy of radio frequency identification (RFID)-equipped artificial feeders to monitor population trends. As of December 2023, analyses of RFID, mark-recapture, and feather sample data are underway.

INTRODUCTION

Rosy-finches are among the most climate-threatened taxa in the United States. The three species found in North America—Brown-capped (*Leucosticte australis*; BCRF), Black (*L. atrata*; BLRF), and Gray-crowned Rosy-finches (*L. tephrocotis*; GCRF; all three species hereafter referred to collectively as Rosy-finches), breed exclusively in tundra or alpine tundra ecosystems. Because high elevation regions are predicted to be disproportionately impacted by climate change (Pepin et al. 2015), Rosy-finches face high risk of habitat loss as a result of tree and shrub encroachment (Grace et al. 2002). Furthermore, changes in phenology resulting from climate change may negatively impact food availability and quality. All three species of Rosy-finch are protected by the Migratory Bird Treaty Act, and both BCRF and BLRF species are listed as Birds of Conservation Concern by the U.S. Fish and Wildlife Service (USFWS 2021). BCRF and BLRF are also included in the Partners in Flight Red Watch list (Rosenberg et al. 2019) and in seven of eight State Wildlife Action Plans throughout their range, including New Mexico. Despite concern for these species, little knowledge exists regarding Rosy-finch life histories, vital rates, and migration patterns.

While the three North American Rosy-finch species have distinct breeding ranges (Figure 1), they occupy a broader range of habitats and may occur in flocks together outside of the breeding season. During winter Rosy-finches use a combination of high and low elevation areas with varying anthropogenic development, and readily approach artificial feeders. Thus, winter field studies offer a valuable opportunity to efficiently acquire demographic data and biological samples for all three Rosy-finch species with a potentially reduced logistical overhead. Our study leverages an existing long-term (20-year) mark-recapture dataset with accompanying feather samples from the Sandia Mountains of New Mexico (Fig. 1) and adds a novel component evaluating the efficacy of RFID-equipped artificial feeders to monitor wintering

Rosy-finches. The Sandia Mountains of northern New Mexico is the southernmost wintering locale in which all three Rosy-finch species co-occur, and the southernmost locale in which any of the three species occurs at all (Fig. 1). It is thus a uniquely interesting site at which to study wintering Rosy-finch populations.

We are using this long-term dataset to evaluate trends in Rosy-finch winter abundance, survival probability, and breeding origin patterns inferred from hydrogen stable isotope analysis of feather samples. Using stable isotope analysis results, we will also investigate the influence of climate covariates at locations of breeding origin or local site conditions that explain variance in abundance, survival, or breeding origin. Among Rosy-finch studies, this dataset is unique in its longevity, sample size, and location at the southern winter range periphery, in which the effects of climate change are predicted to be more acute compared to other locales.

In addition to analyzing existing datasets, we have initiated a pilot study to evaluate the efficacy of radio frequency identification (RFID) equipped feeders to improve vital rate estimates and evaluate connectivity among wintering sites. Rosy-finches are known for nomadic behavior during winter, in which they may make long-range movements within their winter range for reasons that are not well understood. Such movements (temporary emigration) violate the assumptions of many traditional modeling frameworks, meaning that relatively complex frameworks that tend to require intensive data are needed to provide unbiased vital rate estimates. In recent years, multiple avian studies have demonstrated that fitting grain feeders with radiofrequency identification (RFID)-enabled 'smart' devices is an effective way to acquire visit and movement data from wintering birds marked with tags that the RFID reader can detect at close ranges. This approach was recently used by Latimer and Gardner (2022) for Black and Gray-crowned Rosy-Finches in northern Utah, and generated thousands of annual detections, to help infer overwinter survival and movement patterns. Rosy-finches. The RFID-component of this study provides a synergistic opportunity to evaluate Rosy-Finch winter movements at small (within New Mexico) and broad ranges (across states), given the growing network of RFID-equipped feeders in their wintering range.

The SwW funds are being used to support three tasks related to BCRF (below), as part of the larger study focused on all three Rosy-finch species that is the focus of Whitney Watson's PhD dissertation. As such, we report results for all three species, for ease of presentation. The three tasks are as follows:

Task 1: Establish new RFID feeders for the winter (2022-2023 field season)

Task 2: Demographic analysis of mark-recapture data

Task 3: Stable isotope analysis of feather samples

SUMMARY OF ACTIVITIES TO DATE

During the reporting period (July–December) for calendar year 2023, we have made progress in the following areas:

- Initiation of the 2023-2024 field season, including reinstallation of an RFID-equipped feeder at the Sandia Mountains banding site by Corrie (Task 1)
- Whitney Watson successfully completed her second semester of coursework at NMSU, assembled her four-person PhD committee, and completed her Qualifying Exam
- Whitney completed preliminary survival analyses of mark-recapture data (Task 2)
- Whitney attended the IsoCamp 2023 short course held in June at the Center for Stable Isotopes at the University of New Mexico (UNM CSI) to receive specialized training in stable isotope research (Task 3)
- Whitney has received results from two batches of BCRF feather samples (total 255 feathers) analyzed for stable hydrogen isotope composition by UNM CSI (Task 3)
- An additional 700 feathers (250 BCRF, 300 BLRF, 150 GCRF) have been cleaned and are ready for subsampling and laboratory analysis by UNM CSI (Task 3)
- Undergraduate researcher Cynthia Dunkleberger (funded via a separate USDA grant in affiliation with NMSU's Avian Migration Program), has completed an independent research project evaluating intra-feather variation in hydrogen isotopic ratios (Task 3)
- Undergraduate lab technicians (funded via a separate grant) have been hired to assist with stable isotope sample preparation in 2024 (Task 3)

Next, we detail progress on project-specific tasks identified in the original scope of work and provide an estimate of percent completion.

Task 1: Establish new RFID feeders for winter monitoring

An RFID reader apparatus consists of ETAG readers powered by 6,400mAh USB battery packs and 3.5 Watt 6 V solar panel arrays (voltaicsystems.com). These readers detect low-frequency (125 kHz) RFID tags affixed to the legs of tagged Rosy-finches. Birds equipped with RFID tags are detected when they land on or within antenna coils designed to match tag frequencies. Largely based on trial and error, we utilized numerous iterations of feeder and antenna design to reach an optimal design. Antenna were frequently damaged from squirrels chewing on the apparatus, and card performance was improved through exchanging card housing to include a more robust weatherproof design with less need to move componentry.

For the 2022–2023 winter field season, we deployed 2 arrays of RFID antennae on a platform feeder at the Sandia Mountains site on 20 January 2023. We had planned to deploy one RFID reader at Taos Ski Valley, but after numerous performance and design issues as discussed previously, we decided to focus efforts on improving reader and antenna design at the Sandia Mountains site before deploying at a site with significantly greater investment of time and travel. Antennae were checked and repaired as necessary through 8 February, when the entire apparatus was removed for a design overhaul. The apparatus was re-deployed on 10 February. After re-deployment, fewer antennae were damaged, and there were no card performance issues. However, following a severe storm, an entire side of the array was missing, and was relocated later but was not salvageable. Data from bird detections was saved onboard ETAG readers, and a copy was downloaded onto a SD card approximately weekly from the date of deployment through the middle of April.

Between 20 January and 10 April 2023, we recorded 2,810 detections of 51 unique tags at the RFID readers. In winter 2023, 54 birds were banded and fitted with RFID tags (94% of tagged birds were detected at least once at the RFID readers). Ranges of detections for individual birds were from 1–255 detections (mean = 55.1). The RFID apparatus was removed on 16 April after no new detections had been recorded for 6 days.

For the 2023–2024 winter season, an RFID-equipped feeder was re-deployed at the Sandia Mountains site on 29 November 2023. A private condominium in Taos Ski Valley, New Mexico has agreed to house a second RFID-equipped feeder; deployment will occur in early January 2024. Banding attempts began on 3 December 2023 at the Sandia Mountains site, but high winds have prevented successful trapping attempts to date.

Percent completion: 75%

Task 2: Demographic analysis of mark-recapture data

We are leveraging existing mark-recapture data and feather samples from a long-term (20 years) study to evaluate trends in winter abundance and survival probability for all three North American Rosy-finch species. Whitney has begun analysis of the Rosy-finch mark-recapture data to estimate Rosy-finch annual apparent survival. Across the first 19 years of this study, the rate of new individuals captured and banded per day of trapping effort varied between 0.3 and 48.1 for BCRF, between 2.0 and 74.1 for BLRF, and between 0.3 and 18.7 for GCRF (Fig. 2). In Bayesian Cormack-Jolly-Seber (CJS) survival analyses including time (winter season), sex, and age as covariates in separate models for each of the three species, the top model for all three species was the model with age as a covariate. These age-dependent models allowed survival estimates to differ between adults and juveniles and accounted for juveniles becoming adults after their first winter season captured as juveniles. In these analyses, apparent survival probability was 0.43 (95% credible interval [CRI]: 0.31–0.59) for BCRF juveniles, 0.38 (95% CRI: 0.32–0.44) for BCRF adults, 0.27 (95% CRI: 0.20–0.35) for BLRF juveniles, 0.40 (95% CRI: 0.34–0.45) for BLRF adults, 0.48 (95% CRI: 0.21–0.87) for GCRF juveniles, and 0.37 (95% CRI: 0.24–0.50; Fig. 3).

The CJS survival model is limited in that it only allows us to estimate apparent survival, which is a measure of both true survival and site fidelity because mortality cannot be differentiated from emigration. In order to estimate true survival, we have plans to shift to a multistate open robust design analysis framework in which we will take into account secondary sampling occasions to generate more precise survival estimates. The open robust design structure considers the population to be closed (no immigration or emigration) between secondary sampling occasions (trapping days within the same winter season) but allows it to be open between primary sampling occasions (winter seasons). The multistate framework will allow us to estimate populations abundance in addition to survival. We will include covariates in these models (in addition to time, age, and sex) including time varying individual covariates like body condition and breeding origins (deduced from stable isotope analyses) and time-varying environmental covariates such as precipitation and temperature.

Percent completion: 40%

Task 3: Stable isotope analysis of feather samples

We can infer breeding origin patterns from hydrogen stable isotope analysis of feather samples. The ratio of deuterium [^{2}H] to protium [^{1}H] (δ^2H) in precipitation varies geographically and with elevation (Hobson and Wassenaar 1997, Meehan et al. 2004), and the δ^2H signature of a particular location is reflected in tissues (such as feathers) grown in that location as a result of nutrient uptake (Bowen et al. 2005, Wunder 2012). Because Rosy-finches undergo complete molts each breeding season (Pyle 1997), a feather collected during the winter is assumed to have been grown on the breeding grounds during the preceding breeding season. We can thus infer breeding locations of individuals by generating probability-of-origin maps (Campbell et al. 2020; Fig. 4) from feathers sampled during winter when Rosy-finches can be much more readily located and captured. Using stable isotope analysis results, we will also investigate the influence of climate covariates at locations of breeding origin or local site conditions that explain variance in abundance or survival (Task 2).

Whitney, with help from lab technicians, has cleaned 460 BCRF feather samples, and has received results from UNM CSI from 255 of these. An additional 300 BLRF and 150 GCRF feathers have been cleaned to date. δ^2H values of feathers analyzed thus far range from -103.1‰ to -25.8‰, with a median value of -71.9‰ (Fig. 4). Feathers from five individuals which were captured and sampled on multiple occasions (during different years) have been analyzed. We applied for additional funding for analyzing hydrogen stable isotope composition of BLRF and GCRF feather samples through Tracy Aviary Conservation Fund grant.

In addition to this work, undergraduate researcher Cynthia has completed her own study relating to the hydrogen isotope composition of Rosy-finch feathers. She investigated the variation in δ^2H ratios within individual feathers, to determine whether the section of the feather analyzed impacts the resulting δ^2H value for that feather, as has been evidenced in other studies (e.g. Wassenaar and Hobson 2006, Gordo 2020). To do this, she subdivided 21 Brown-capped Rosy-finch feather samples from adults into 5 sections (Fig. 5b) and compared δ^2H values across these different sections. She found that sections excluding feather rachis subsampled longitudinally (A1, B1, and C) did not result in significantly different δ^2H values (Fig. 6A–B), while lateral comparisons of sections with rachis and without rachis *did* result in significantly different δ^2H values (A1 vs. A2 and B1 vs. B2; Fig. 6C–F). Note that samples for general breeding origin analysis are taken from distal-most tip of feather and include rachis (Fig. 5a). This work suggests the inclusion or exclusion of the rachis may influence hydrogen stable isotope ratios, which will help with standardizing duplicate feather samples for the breeding origin study.

Percent completion: 30%

PROJECT TIMELINE FOR JANUARY–JUNE 2024

Quarter 1: January 1, 2024 – March 31, 2024:

- Whitney will enroll in the Spring 2024 semester at NMSU
- Construct and deploy RFID reader-equipped birdfeeder in Taos, begin banding Rosy-finches at Taos Ski Valley, continue 2023-2024 Rosy-finch field season at Sandia Mountains site (Task 1)
- Whitney will incorporate additional covariates into existing survival analyses and transition to a multistate open robust design modeling framework (Task 2)
- Whitney and lab technicians will continue to process feather samples and send to UNM CSI for isotope analysis (Task 3)
- Whitney will begin modeling hydrogen isotope data and creating breeding origin assignment maps (Task 3)
- Whitney will look into obtaining known-origin Rosy-finch feather samples from collaborators or field work to increase precision of breeding origin assignment of feathers collected on wintering grounds (Task 3)

Quarter 2: April 1, 2024 – June 30, 2024:

- Whitney will complete her Spring 2024 semester of coursework at NMSU
- Wrap-up of 2023-2024 Sandia Mountains and Taos Ski Valley Rosy-finch banding seasons (Tasks 1 and 2)
- Whitney will begin compiling, visualizing, and analyzing RFID data (Task 1)
- Whitney will continue work on survival and breeding origin analyses (Tasks 2 and 3)

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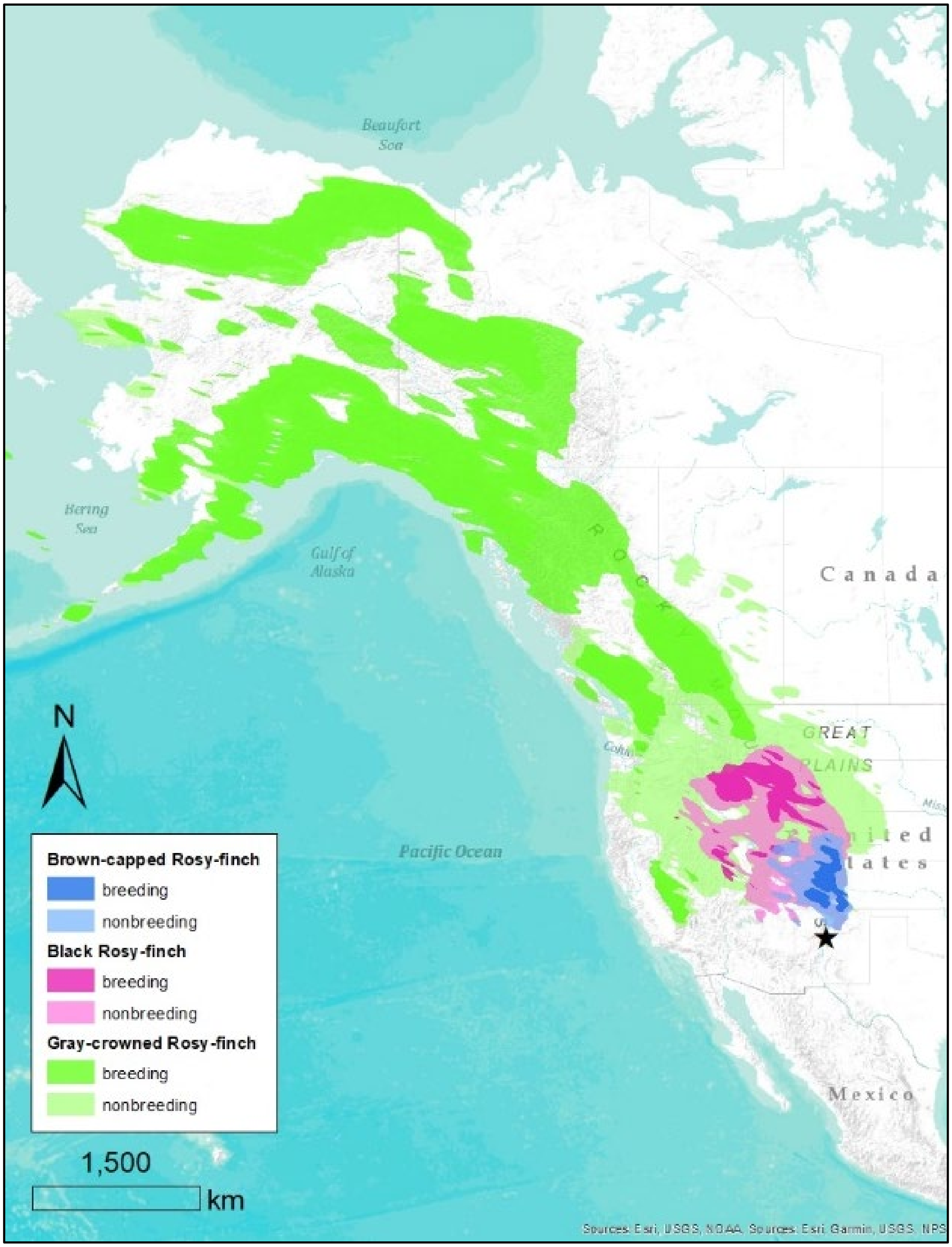

Figure 1. Distributions of each of the three North American Rosy-finch species. Darker colors represent breeding ranges, and the black star indicates the study site at the Sandia Mountains in northern New Mexico. Data layers from Fink et al. 2022.

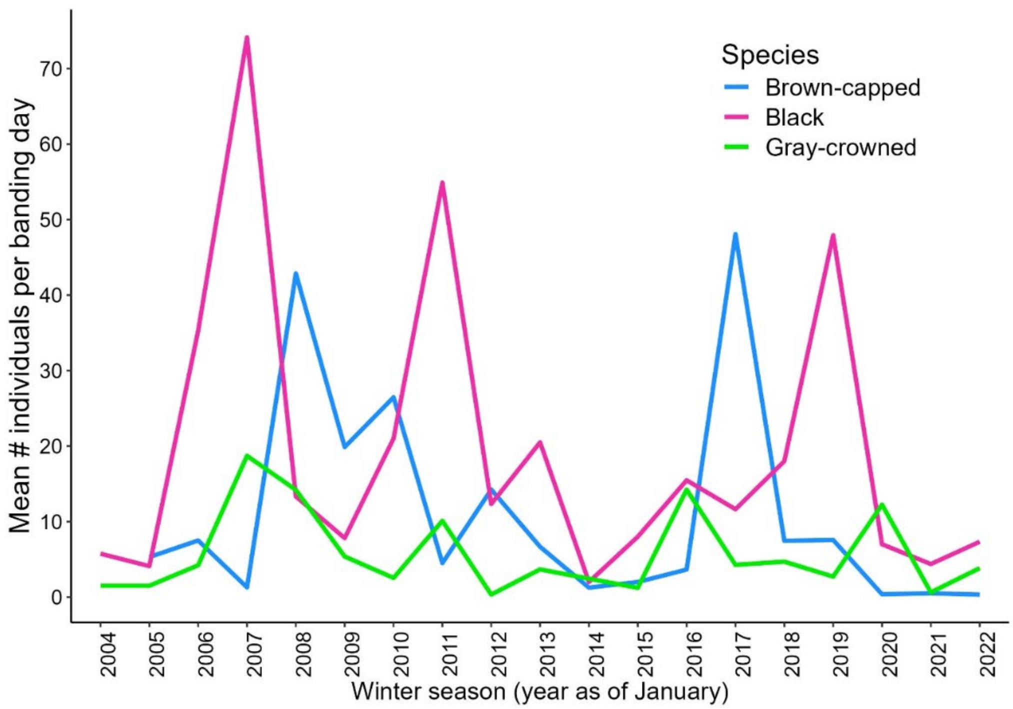

Figure 2. Mean number of unique Rosy-finches captured by species per banding day during each winter banding season at the Sandia Mountains site, NM 2004–2022. Year denotes latter year of winter season (i.e., "2004" refers to November 2003–April 2004 winter season).

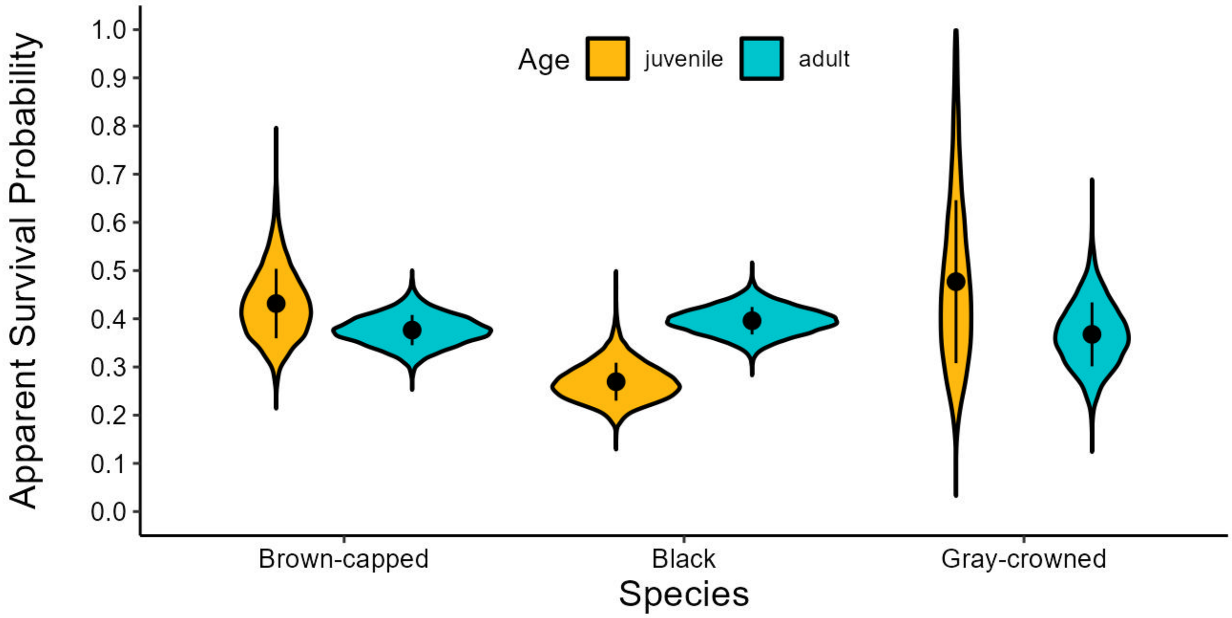

Figure 3. Apparent survival estimates for Rosy-finches overwintering at the Sandia Mountains site from 2004 to 2022 by species and age class. The error bars for each estimate reflect the 95% Bayesian credible interval.

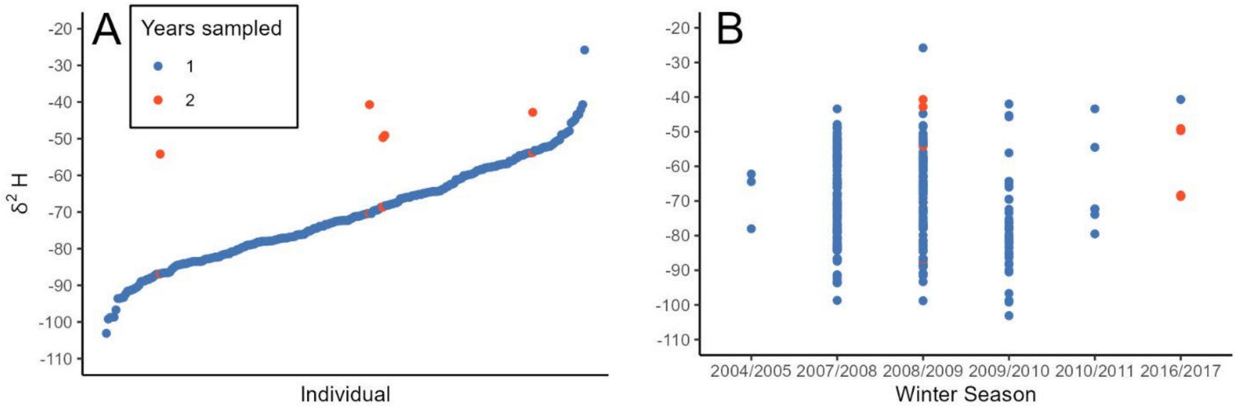

Figure 4. Hydrogen stable isotope values ratio (‰ ^2H:^1H; δ^2H) of brown-capped rosy-finch (*Leucosticte australis*) feathers sampled to date arranged by (A) individual and (B) winter season in which feather was collected. Values for individuals with multiple samples analyzed from different years are shown in orange; values for individuals with sample from only one year are in blue.

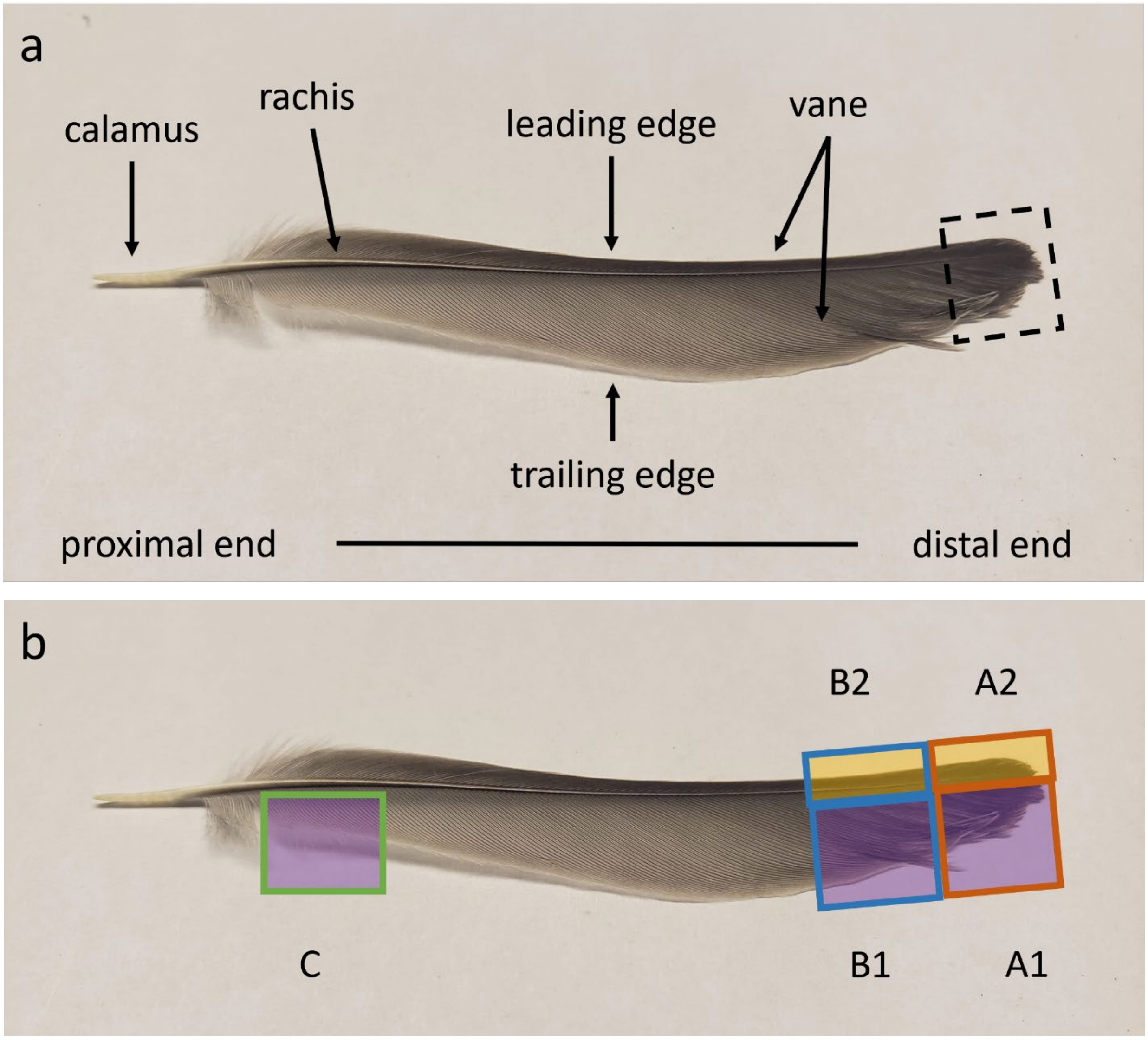

Figure 5. Feather diagrams for stable hydrogen isotope studies. Panel (a) shows general feather anatomy and sampling region for breeding origin analysis (dashed black box); panel (b) shows subsampling delineations for intra-feather variation study. Orange outlines indicate the most distal region of the feather sampled (A1 & A2) blue outlines indicate the next distal-most region (B1 & B2) and the green outline indicates the proximal-most feather section beyond downy barbs (C). Shapes with purple shading (A1, B2, C) distinguish feather sections excluding rachis, or central feather shaft, from those including rachis, which are shaded in yellow (A2, B2).

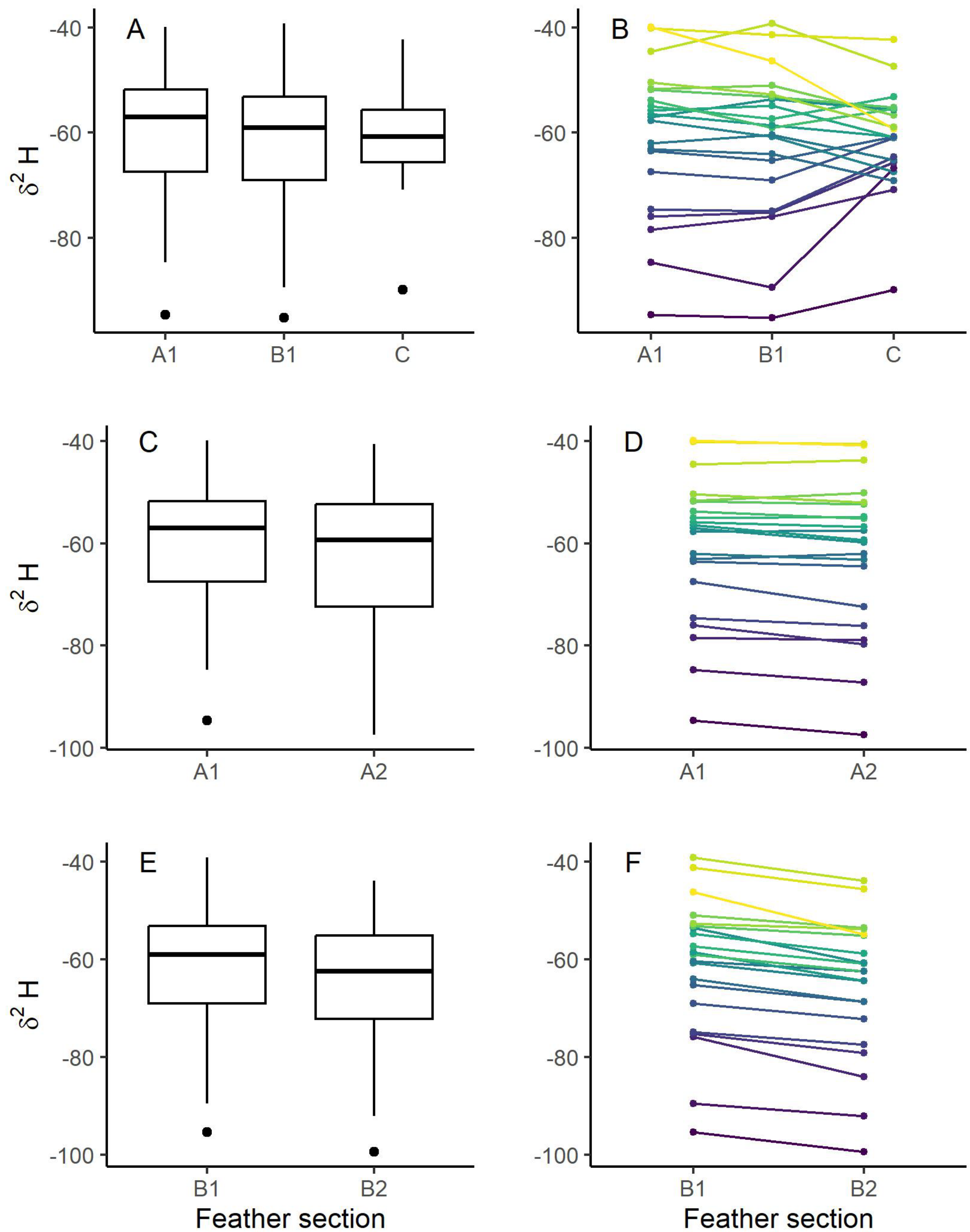

Figure 6. Boxplot and line plots for comparison of δ^2H values for different feather sections (A-B) A1, B1, and C, (C-D) A1 and A2, and (E-F) B1 and B2.