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

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INVESTIGATORS

Whitney Watson (Report Author), Graduate Research Assistant, Department of Fish, Wildlife, and Conservation Ecology, New Mexico State University

Abby Lawson, Principal Investigator, USGS New Mexico Cooperative Fish and Wildlife Research Unit, Department of Fish, Wildlife, and Conservation Ecology, New Mexico State University

Corrie Borgman, Co-Principal Investigator, USFWS Division of Migratory Bird Management, Southwest Region

Steve Cox, Co-Principal Investigator, Rio Grande Bird Research, Inc.

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 due to the high elevation and remoteness of their breeding grounds; 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 June 2024, analyses of data from RFID feeder visits, mark-recapture activities, and feather samples are underway.

INTRODUCTION

Rosy-Finches are among the most climate-threatened taxa in the United States. Three species are 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 will be referred to collectively as Rosy-Finches. Rosy-Finches breed exclusively in tundra or alpine tundra ecosystems and 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 insect 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 BCRF and BLRF 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.

Although the three North American Rosy-Finch species have distinct breeding ranges (Fig. 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 types and degrees of 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 Crest 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 Crest in the Sandia Mountains of northern New Mexico is the southernmost wintering locale in which all three Rosy-Finch species co-occur and is the southernmost locale in which any of the three species ever occur (Fig. 1). It is thus a uniquely interesting site at which to study wintering Rosy-Finch populations, and document potential impacts of climate change.

We are using this long-term mark-recapture dataset to evaluate trends in Rosy-Finch winter abundance and survival probability. In addition, we are conducting hydrogen stable isotope analysis of collected feathers to infer breeding origin patterns. Using stable isotope analysis results, we can investigate the influence of climate covariates at inferred locations of breeding origin or local site conditions that may explain variance in abundance, survival, or breeding origin. Among Rosy-Finch studies, this mark-recapture dataset is unique in its longevity, sample size, and location at the southern winter range periphery. Studying peripheral species or populations at or near distributional extents is essential for efficient, long-term conservation planning at landscape scales (Steen and Barrett 2015). Peripheral populations can offer insight into a species physiological tolerances and capacity to adapt to climate change (behavior, physiology, dispersal, etc.), which is useful for evaluating effectiveness of potential management actions to curb or offset predicted changes. 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 (representing 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 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, generating thousands of annual detections to help infer overwinter survival and movement patterns. 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 REPORTING PERIOD ACTIVITIES

Administrative and Project Management

- Whitney successfully completed her third semester of coursework at NMSU
- Abby and Whitney have worked to establish a project data management system that is backed up at regular frequencies and accessible to project cooperators

Task 1

- Wrap-up of the 2023-2024 winter field season, including installation of an RFID-equipped feeder and initiation of banding site at Taos Ski Valley (Task 1)

Task 2

- Whitney completed preliminary survival analyses of mark-recapture data, and begun analysis in a robust design framework (Task 2)

Task 3

- Whitney has received additional funds ($4,000) from the Tracy Aviary Conservation Fund to support stable hydrogen isotope analysis
- Whitney has received results from 275 BCRF, 23 BLRF, and 21 GCRF feather samples (total 319 feathers) analyzed for stable hydrogen isotope composition by UNM CSI
- An additional 1,065 feathers (219 BCRF, 446 BLRF, 400 GCRF) have been cleaned and are ready for subsampling and laboratory analysis by UNM CSI
- Whitney has identified multiple sources of known-origin Rosy-Finch feathers which will increase precision of breeding origin assignment via stable hydrogen isotope analysis once obtained and analyzed
- Undergraduate researcher Kadence Presser (funded via a separate USDA grant in affiliation with NMSU's Avian Migration Program), has joined project and continued independent research project initiated by Cynthia Dunkleberger evaluating intra-feather variation in hydrogen isotopic ratios

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 Electronic Transponder Analysis Gateway (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. Antennae were frequently damaged from squirrels chewing on the apparatus, and card performance was improved by updating the card housing to include a more robust weatherproof design with less need to move componentry. The final feeder design for 2023–2024 involved "sandwiching" antenna between two sheets of plastic, which minimized the ability of squirrels to access sensitive antennas, but still allowed for detection of tags. This was a successful strategy, and feeders received minimal squirrel damage over the season.

During the 2023–2024 winter season, an RFID-equipped feeder was re-deployed at the Sandia Crest from 29 November 2023 to 19 April 2024. Poor weather and a lack of snow maintenance caused multiple delays to the start of weekly bird banding, which spanned from 31 December 2023 to 31 March 2024; 12 BCRF, 43 BLRF were marked with RFID tags (no GCRF were captured). Fifty-two unique birds were detected by the RFID feeder during the period of deployment, including 6 tags deployed in the previous winter season. All 6 individuals which were tagged in the 2022-2023 winter season and subsequently detected by the RFID reader during the 2023-2024 winter season were BLRF. Detections occurred at the highest rates at 07:00 and 15:00, and in the month of February (Fig. 2).

A second RFID-equipped feeder was deployed at a private condominium in Taos Ski Valley (TSV), New Mexico on 9 January 2024 and removed on 3 May 2024. Banding occurred at the TSV site on 3 April 2024 and a total of 13 BCRF, 8 BLRF, and 2 GCRF were banded with RFID tags. Seventeen unique individuals were detected via the RFID feeder during the period of deployment. All individuals detected at TSV were initially banded at TSV as well. Detections at TSV occurred at the highest rate at 10 am (Fig.2).

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-year) 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 21 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. 3). 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. 4) for GCRF adults.

The CJS survival model is limited in that it only estimates apparent survival, which is a measure of both true survival and site fidelity because mortality cannot be differentiated from emigration. To estimate true survival, we have shifted to an open robust design analysis framework which takes into account secondary sampling occasions to generate more precise survival estimates (Kendall et al. 1997). The open robust design structure considers the population to be closed (no immigration or emigration) between secondary sampling occasions (months within the same winter season) but allows it to be open between primary sampling occasions (winter seasons). We have used the robust design framework to model survival for the Black Rosy-Finch, the most data-rich of the three species in this study. In the Black Rosy-Finch analysis, we incorporated time variation as a covariate, and found that survival ranged across winter seasons from 0.103 and 0.999 with a mean of 0.444 (Fig. 5). We intend to run analyses in this framework for the remaining two Rosy-Finch species and to incorporate covariates of age and sex. Eventually, we intend to expand the robust design model to a multistate framework (Kendall et al. 2019), which will allow us to estimate population abundance in addition to survival. We also plan to include additional 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.

<u>Percent completion:</u> 60%

Task 3: Stable isotope analysis of feather samples

Analysis of hydrogen stable isotopes in feather samples are a widely-used tool to inferring an individual bird's breeding origin (location) to evaluate migratory connectivity patterns. 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) 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 wintering population-level breeding origin or local site conditions that explain variance in abundance or survival (Task 2).

Whitney, with help from lab technicians, has cleaned 494 BCRF feather samples, and has received results from UNM CSI from 275 of these. δ^2H values of feathers analyzed thus far range from -103.1‰ to -25.8‰, with a median value of -71.9‰ (Fig. 6). Feathers from five individuals which were captured and sampled on multiple occasions (during different years) have been analyzed. An additional 481 BLRF and 421 GCRF feathers have been cleaned to date, for a total of 1,396 feathers cleaned across the three species, and 23 BLRF and 21 GCRF samples were sent to UNM CSI for laboratory analysis in May 2024. We applied for and received additional funding ($4,000) for analyzing feather stable hydrogen isotope composition through the Tracy Aviary Conservation Fund. This money will support analysis of additional BLRF and GCRF feather samples as well as known-origin feather samples, which will improve our ability to assign breeding origins to individuals of all species sampled at the Sandia Crest during the winter. We have identified multiple avenues of obtaining known-origin Rosy-Finch feather samples to analyze in our study.

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. 7b) 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. 8A–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. 8C–F). Note that samples for general breeding origin analysis are taken from distal-most tip of feather and include rachis (Fig. 7a). 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 funded by this grant. Undergraduate Kadence Presser has joined this project and will be conducting a similar analysis to Cynthia on GCRF, which migrate longer distances than BCRF. Kadence will present a poster at the annual American Ornithological Society conference in Estes Park, Colorado in October 2024.

During the 2023–2024 winter season, we also began collecting multiple feathers from certain individual Rosy-Finches at the Sandia Crest to examine within-individual stable hydrogen isotope variation. Analysis of these feathers will allow us to determine whether the exact feather sampled from an individual bird (i.e., the 1st or 5th rectrix of the tail) affects the resulting isotope value. This component of the study will likely be carried out by an undergraduate researcher.

<u>Percent completion:</u> 50%

PROJECT TIMELINE FOR JULY–DECEMBER 2024

Quarter 3: July 1, 2024 – September 30, 2024:

- Whitney will begin her 4th semester (Fall 2024) of coursework at NMSU
- We will obtain known-origin Rosy-Finch feather samples from collaborators and analyze to increase precision of breeding origin assignment of feathers collected on wintering grounds (Task 3)
- Whitney and Kadence will analyze results from BLRF and GCRF laboratory stable isotope analysis once received from UNM CSI (Task 3)
- Whitney and lab technicians will continue to process feather samples and send to UNM CSI for isotope analysis (Task 3)
- Whitney will continue work on survival and breeding origin analyses (Tasks 2 and 3)

Quarter 4: October 1, 2024 – December 31, 2024:

- Whitney will complete her Fall 2024 semester, completing all coursework required for her Biology PhD degree, and take her Comprehensive Exam in December 2024 to advance to PhD candidacy
- Whitney will begin compiling, visualizing, and analyzing RFID data (Task 1)
- Whitney will present her stable hydrogen isotope Rosy-Finch breeding origin findings at the American Ornithological Society annual conference in Estes Park, Colorado (Task 3)

- All project PIs will prepare for and initiate the 2024–2025 field season on the Sandia Crest and Taos Ski Valley

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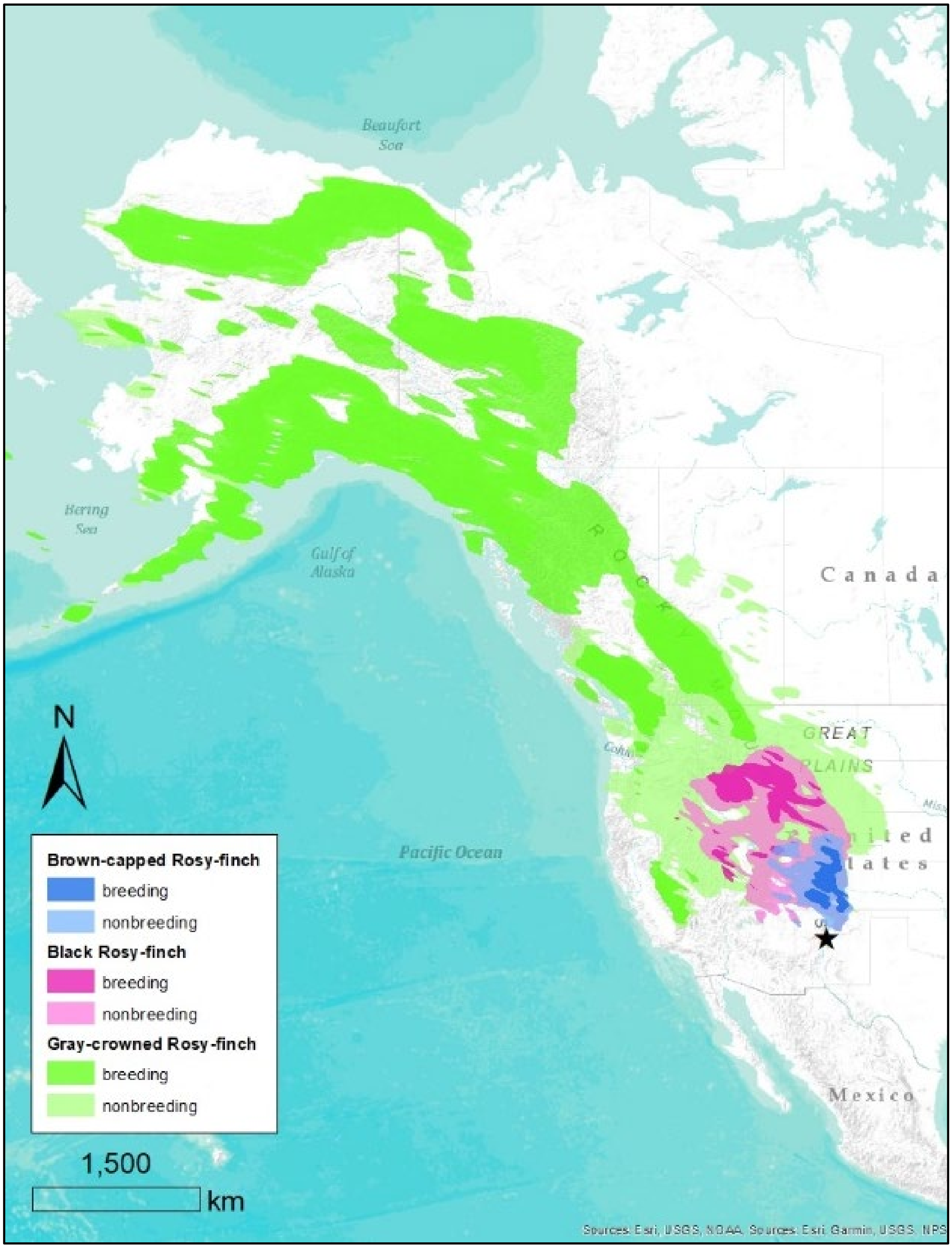

Figure 1. Distributions of each of the three North American Rosy-Finch species. Darker colors represent breeding ranges, and the black star indicates the study site at the Sandia Crest in northern New Mexico. Data layers from Fink et al. 2022.

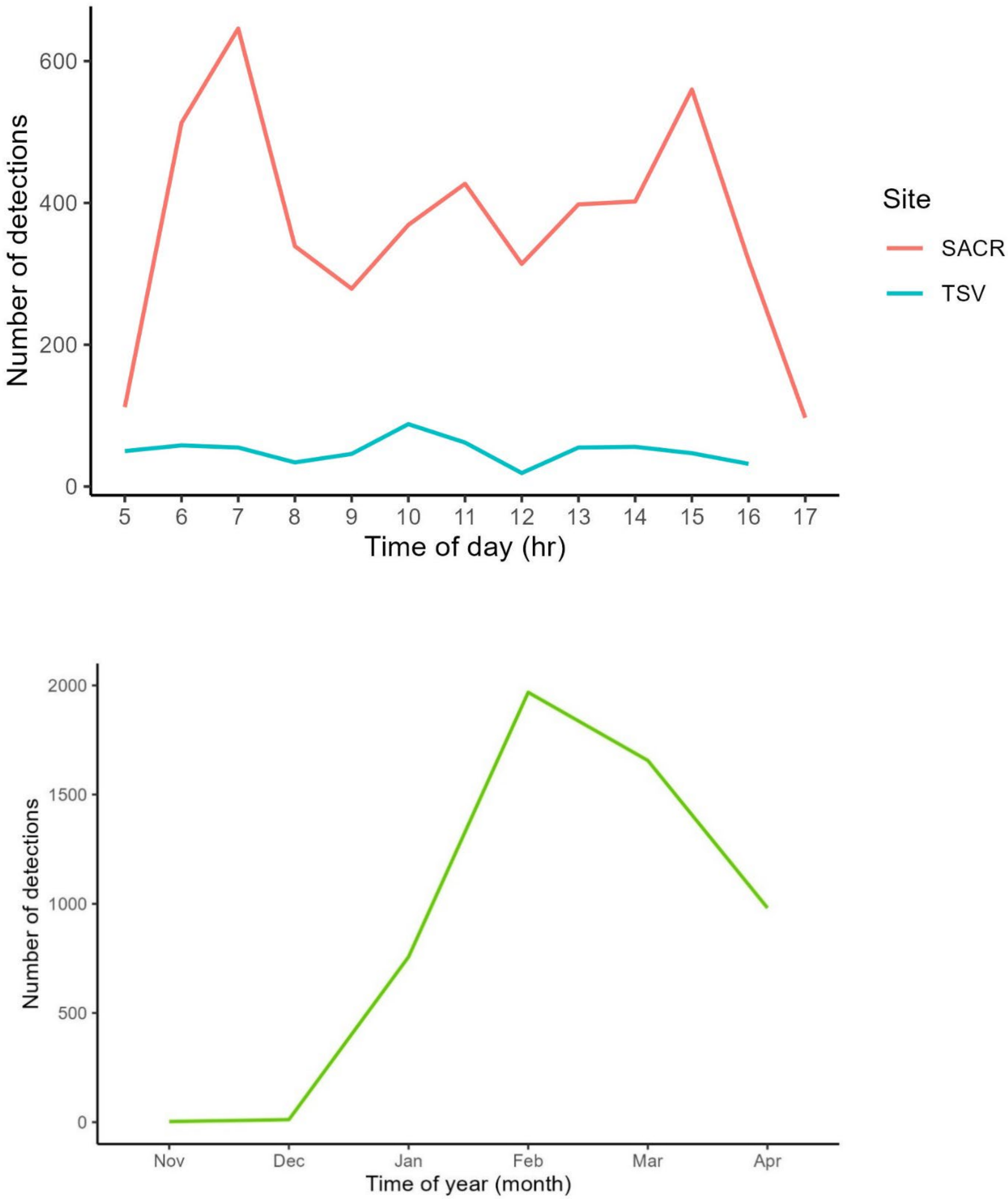

Figure 2. Detections of RFID-tagged individuals by RFID-enabled feeders (top) by time of day and (bottom) month of year. Sandia Crest (SACR) includes data from 2022–2023 and 2023–2024 winter season; whereas Taos Ski Valley (TSV) data spans the 2023–2024 winter season only. All Taos detections occurred in April; thus the bottom panel only includes detections from Sandia Crest.

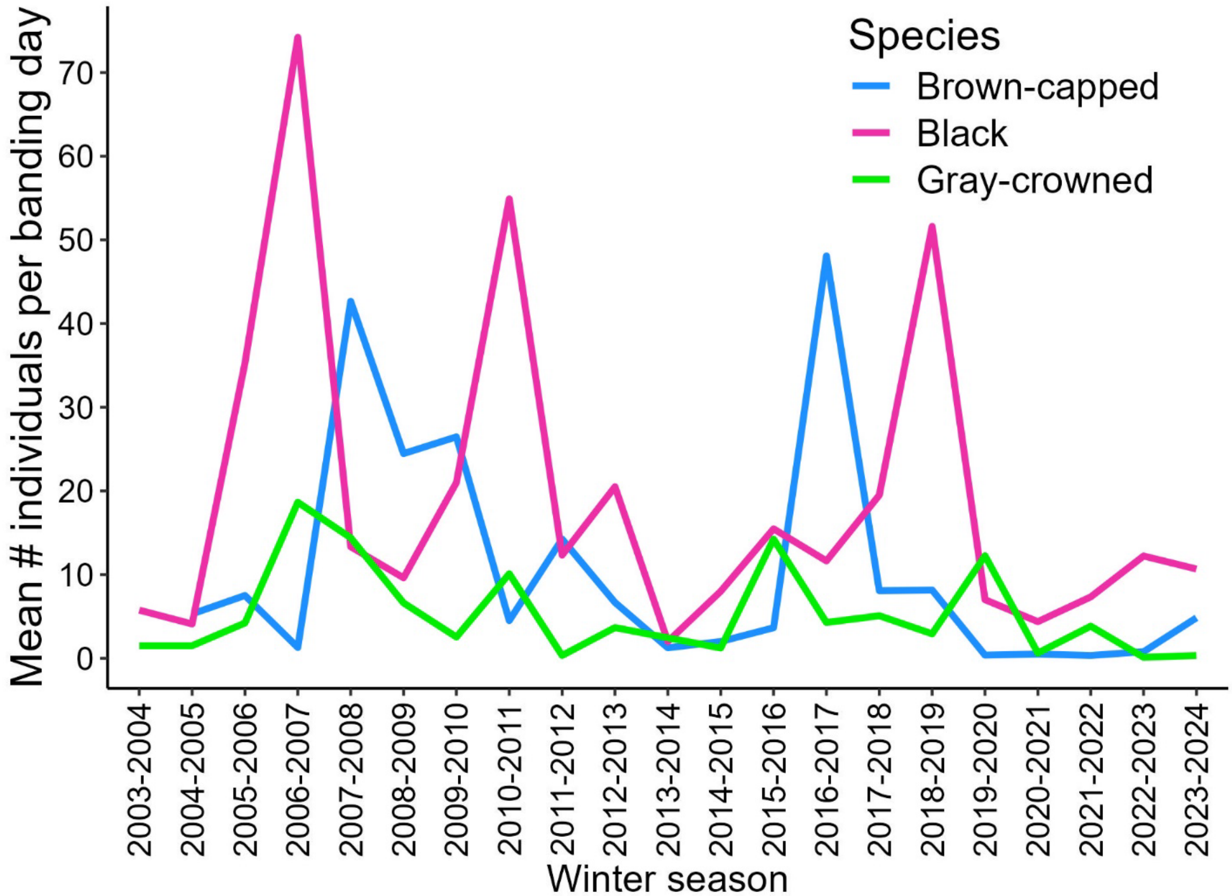

Figure 3. Mean number of unique Rosy-Finches captured by species per successful banding day during each winter banding season at the Sandia Crest, NM 2003–2024.

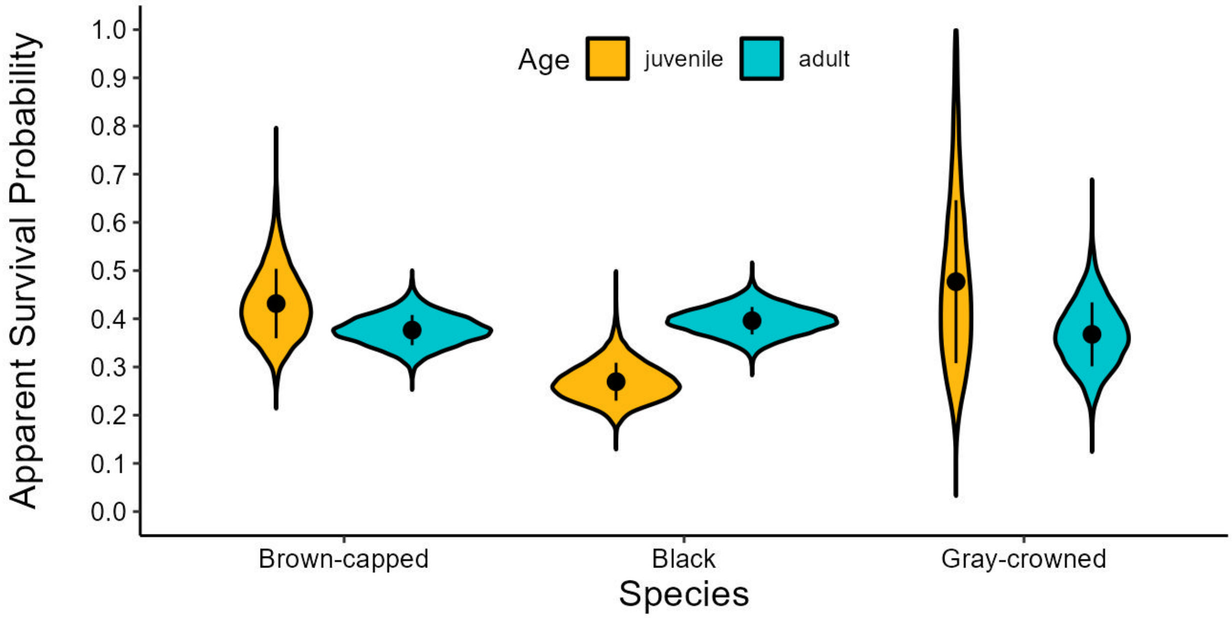

Figure 4. Apparent survival estimates for Rosy-Finches overwintering at the Sandia Crest from 2004 to 2022 by species and age class. The error bars for each estimate reflect the 95% Bayesian credible interval.

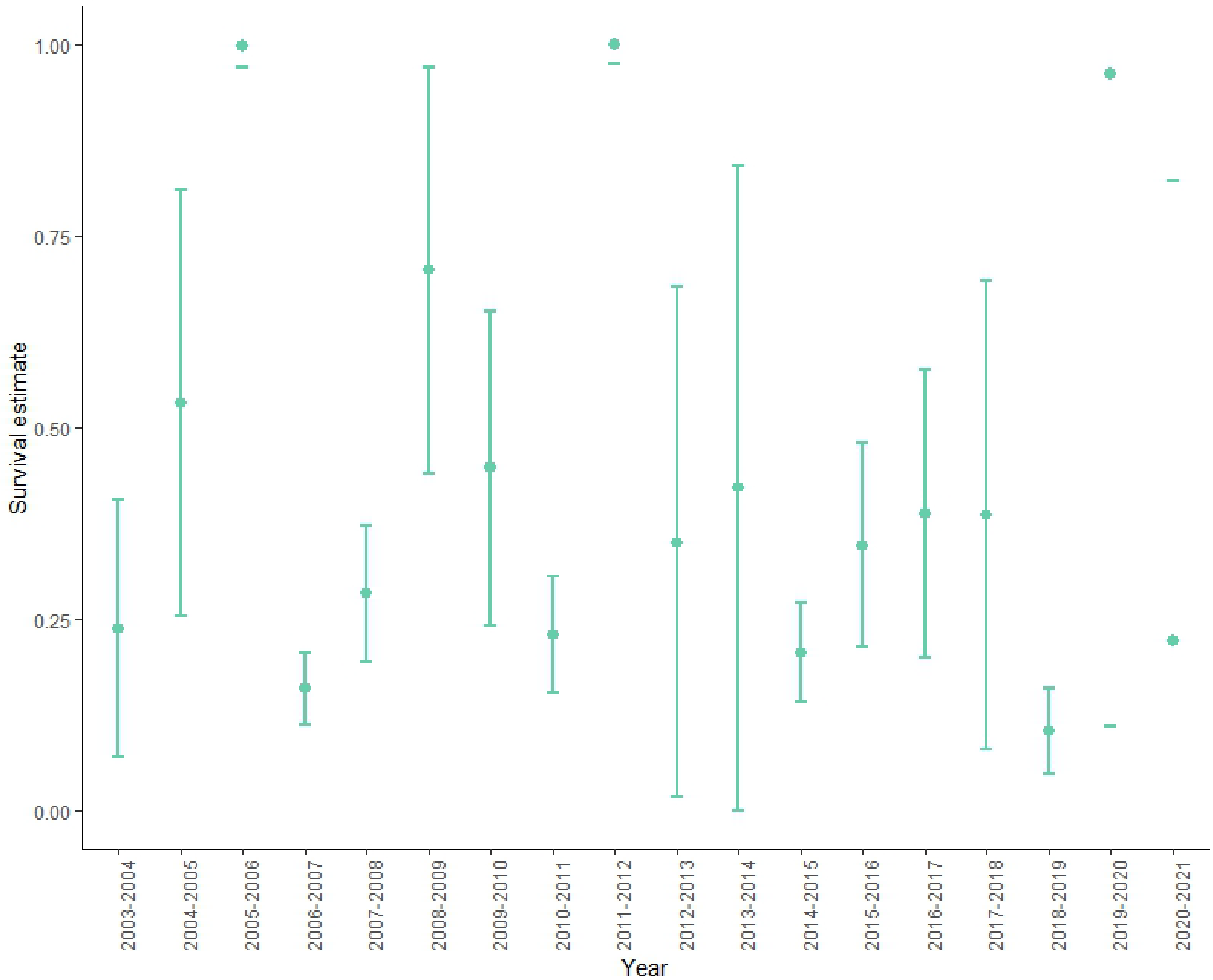

Figure 5. Mean survival estimates (± standard error) of Black Rosy-Finches by year from robust design model with time-varying survival.

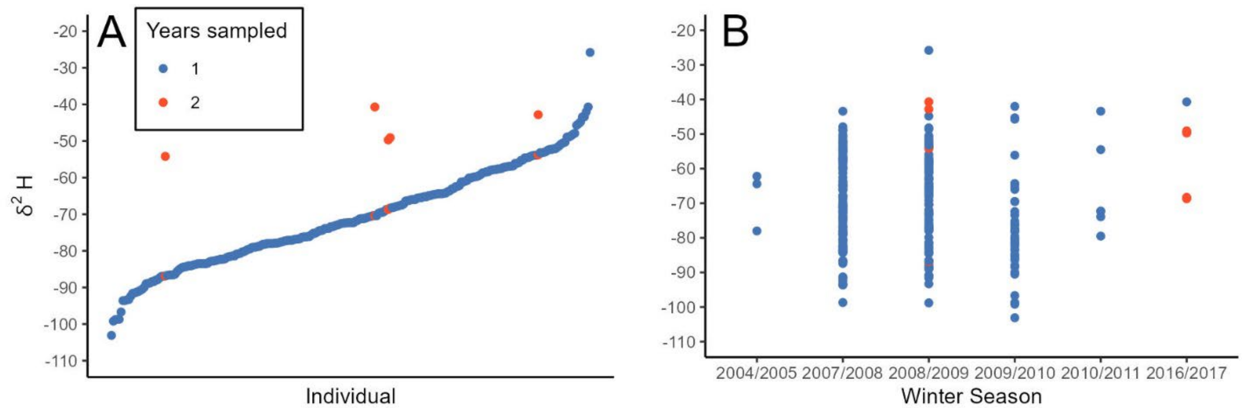

Figure 6. Hydrogen stable isotope values ratio (‰ ^2H:^1H; δ^2H) of wintering Brown-capped Rosy-Finch (*Leucosticte australis*) feathers sampled on the Sandia Crest, New Mexico (2004–2017). The samples analyzed to date arranged by (A) individual and (B) winter season in which feather was collected. Values 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.

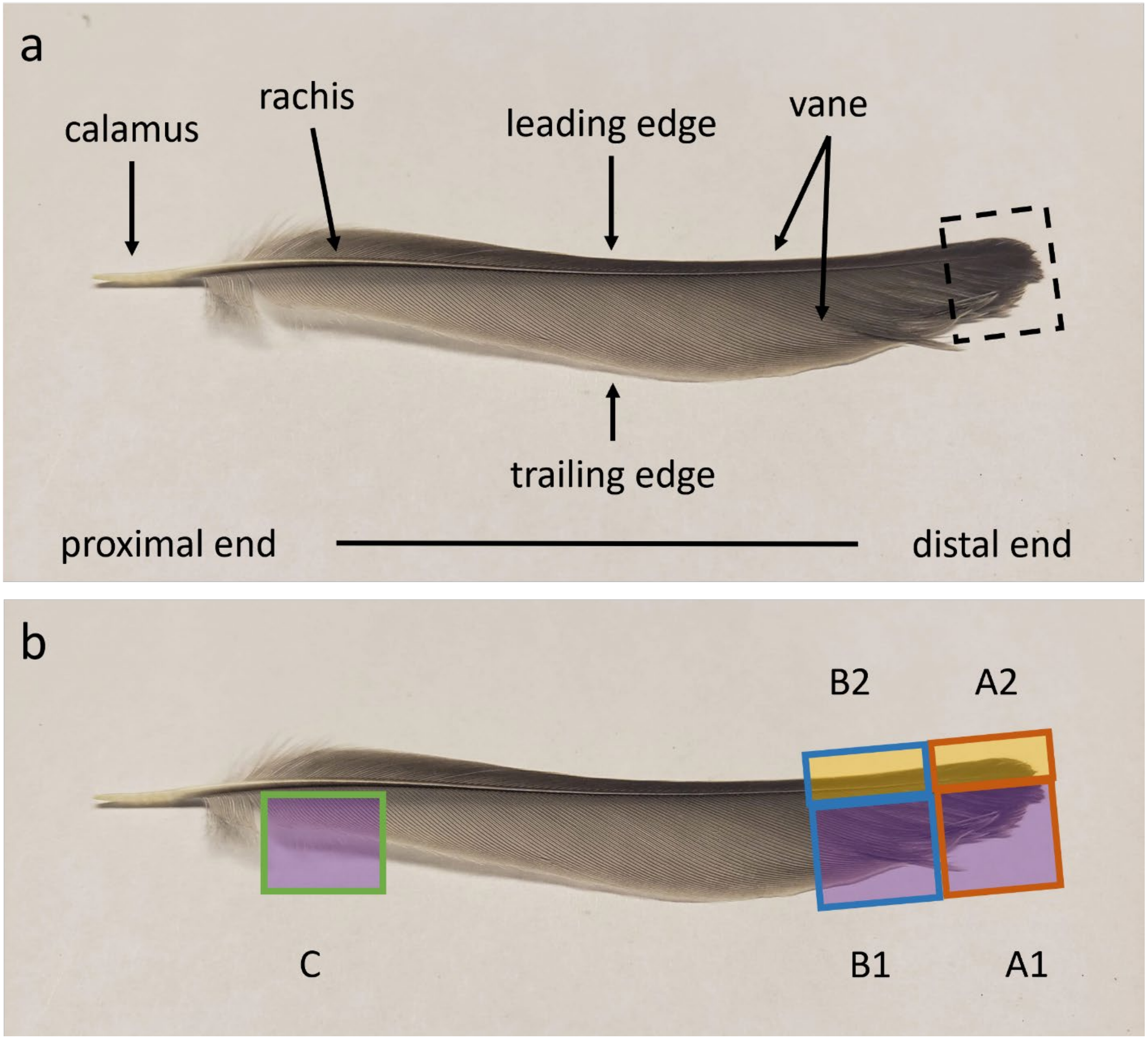

Figure 7. Feather diagrams for stable hydrogen isotope studies. Panel (a) shows general feather anatomy and sampling region for breeding origin analysis (dashed black box); panel (b) shows subsampling delineations for intra-feather variation study. Orange outlines indicate the most distal region of the 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).

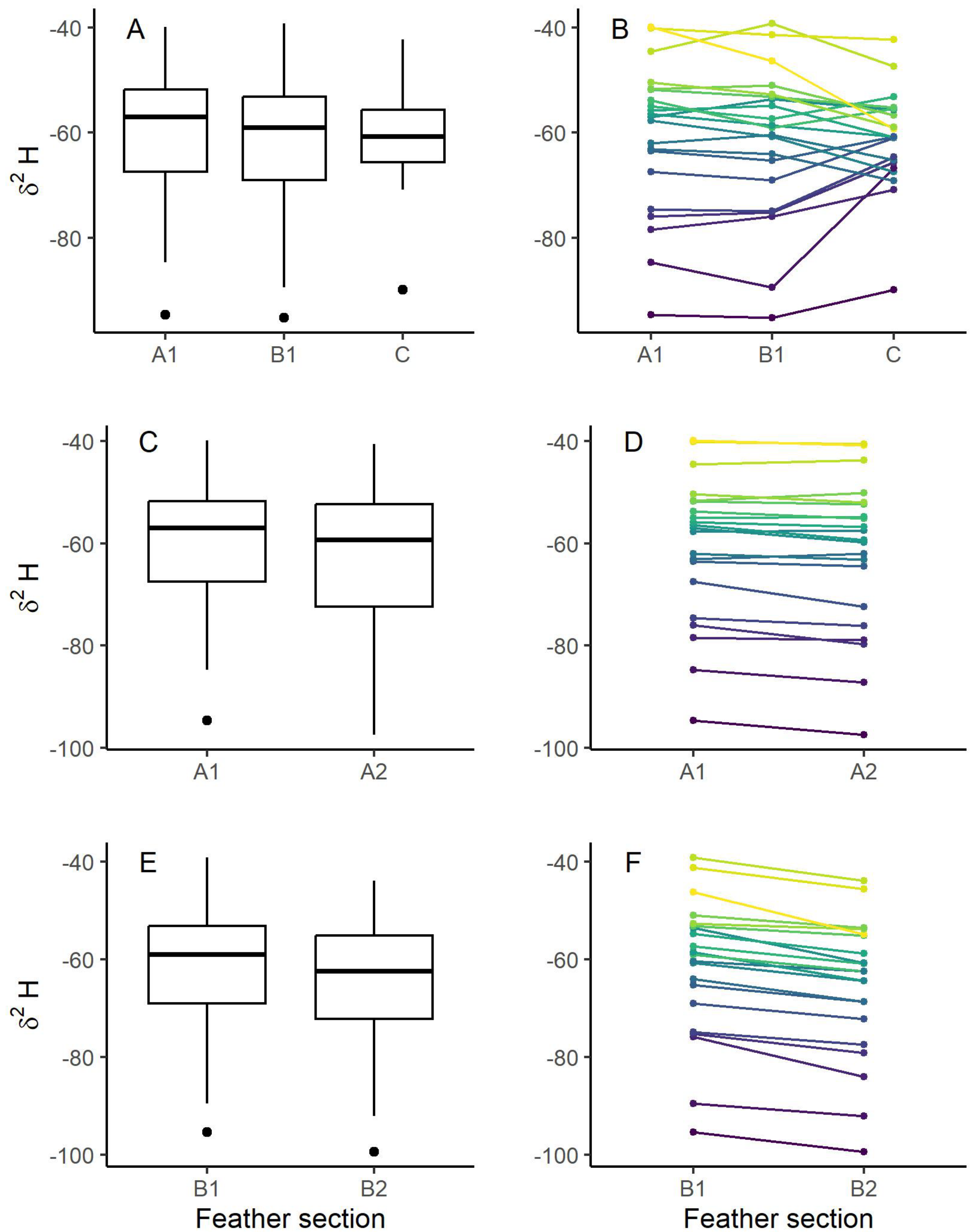

Figure 8. Boxplot and line plots for comparison of δ^2H values for different sections of wintering Brown-capped Rosy-Finch (*Leucosticte australis*) feathers collected on the Sandia Crest, New Mexico. Feather sections are shown in Figure 7. Panels A-B compare longitudinal sections of the feather's leading edge ordered from distal to proximal (A1, B1, C). Whereas panels C–D and E—F compare feather sections with (–2) and without (–1) rachis material for the most distal (A) and second most distal (B) cross sections.