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A feather hydrogen isoscape for Mexico

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ABSTRACT

Developing useful biological isoscapes for areas of the world is a priority. This is the case for Mexico that hosts a large percentage of North America's Neotropical migrant birds. Here we investigated the use of House Sparrow (*Passer domesticus*) feathers to create a spatially explicit feather deuterium isoscape for that country using samples ($n = 461$) that were collected across Mexico. Considerable and useful spatial hydrogen isotopic structure was observed, suggesting that isotopes may be a potential forensic tool for evaluating origins of Mexican derived fauna and flora. The most positive feather δD values occurred in the northeast and most negative in the south-central part of the country, roughly matching δD patterns observed in groundwater. A weak negative isotopic relationship was found with altitude in both the Pacific and Atlantic drainage systems. The most parsimonious model describing isotopic spatial variation in feathers between 300 and 3000 m a.s.l. included groundwater δD (δD_{gw}; precipitation proxy), sex, amount of precipitation, and the coefficient of variation in amount of precipitation. Overall, δD_{gw} was a poor predictor of sparrow δD_f values for all of Mexico. However, this relationship was considerably strengthened when we considered sex separately, removed the Baja peninsula from our sample, and considered the Atlantic and Pacific drainage basins separately. The strongest relationship between δD_{gw} and δD_f was found for female sparrows in the Atlantic drainage basin ($r^2 = 0.464$). We recommend that researchers interested in inferring origins of migratory birds and other animals in Mexico create species specific isotopic basemaps that may be guided by the isotopic patterns we have observed for House Sparrows and groundwater.

1. Introduction

Fundamental to the practical application of "isoscapes" for tracking migrant organisms over large geospatial scales is that fixed tissue stable isotope values can be directly linked to geographical regions of known origin (Hobson and Wassenaar, 2008). For Neotropical migrant birds, these tissues are often feathers formed in the northern summer breeding or southern wintering sites. The isotopic composition (e.g. ^{13}C, ^{15}N, ^{2}H) of tissue is linked to discrete and continuous underlying spatial geological or hydrological isotopic patterns through local diet and foodwebs. To date, the long-term growing-season average patterns in the hydrogen isotopic composition of rainfall (δD_p) at continental scales have proven to provide the most useful predictable spatial foundation for biological samples (Bowen et al., 2005; Hobson 2008). For example, in North America the strong latitudinal gradient in δD_p across much of the USA and Canada is directly reflected in feathers (δD_f) grown by birds prior to migration. This hydrosphere–biosphere isotopic linkage provides a powerful means of inferring origins of individuals captured elsewhere (Kelly et al. 2002; Rubenstein et al. 2002; Hobson et al. 2006, 2007).

Currently, the strength of the relationship between δD_p and δD_f has defined the utility of the isotope approach for tracking migrant birds. It is clear that such relationships will be influenced initially by our ability to accurately predict δD_p for a given year and region, by the degree to which δD_p reflects the δD value of local waters most relevant during the time of feather or tissue growth, and by ecological and physiological processes that may alter the relationship between these two parameters for the focal species. Despite several examples showing excellent and robust correlations between δD_p and δD_f in temperate regions of North America, much more research is required to elucidate the nature of the variance associated with such regressions (Hobson 2008; Wunder and Norris 2008). In addition, while some regions (e.g. central Europe) have reasonably good isotopic coverage of rainfall, other areas (Africa, Asia, high-latitude regions) have relatively poor data coverage.

In North America, Mexico is represented by only two IAEA Global Network for Isotopes in Precipitation (GNIP) stations, and the complex terrain of that country makes an interpolated δD_p basemap as a starting point problematic. This is unfortunate because Mexico hosts one of the greatest proportions of all Neotropical migrant songbirds that annually migrate there from temperate areas in the USA and Canada to winter (Petit et al. 1995). Knowledge of the patterns of $\delta D/\delta^{18}O$ in rain and

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surface waters of Mexico and how those ultimately relate to tissue values in fauna would greatly assist inferring origins of animals wintering there or for resident species moving within Mexico.

In this paper, we present the first avian feather-based deuterium isoscape for Mexico created from spatially extensive collections of sparrow feathers. We further explored the utility of using isotope proxies as an alternative to the long-term GNIP database to create a usable isoscape for inferring origins of birds growing tissues in Mexico. We chose the groundwater δD patterns (δD_{gw}) described in a companion paper (Wassenaar et al., this volume) since groundwater was demonstrated to be a good proxy for annual precipitation in Mexico (Clark and Fritz 1997). At many of the same locations where groundwater samples were collected in Wassenaar et al. (this volume), we also captured House Sparrows (*Passer domesticus*) and sampled their feathers. Since House Sparrows are non-migratory, experience limited dispersal, and are extensively distributed throughout Mexico below 3000 m elevation, we reasoned that their feathers would reflect local baseline foodweb water δD values during growth. If precipitation and/or shallow groundwater drives the foundation of local foodweb δD values, then we would expect a strong relationship between House Sparrow δD_f and δD_{gw}. Besides the pattern observed in the feather basemaps, we hoped to ascertain a useable relationship between shallow ground water and feathers since a good relationship with ground water would provide a spatially explicit proxy for a GNIP-like database for Mexico, which could be used to aid in inferring the origins of birds and other wildlife.

2. Methods

2.1. Field sampling

House Sparrows were selected as the target species due to their broad distribution across Mexico and their affinity to both populated and agricultural areas. Birds were captured using mist nets during February to March, 2007 primarily along roadways and conveniently accessible areas (Fig. 1). We collected several feather types from each individual but used the inner (P1) primary for isotope analysis since this is one of the first to be molted and so had the highest probability of being related to the location of capture. Field sampling locations were coordinated with groundwater sampling locations described in Wassenaar et al. (this volume).

2.2. Stable isotope methods

All feathers were cleaned of surface oils in a 2:1 chloroform: methanol solvent rinse and prepared for stable-hydrogen isotope analysis at the Stable Isotope Hydrology and Ecology Laboratory of Environment Canada in Saskatoon, Canada. Stable-hydrogen isotope analyses of feathers were conducted using the comparative equilibration method described by Wassenaar and Hobson (2003) through the use of calibrated keratin hydrogen-isotope reference materials. Stable-hydrogen isotope measurements were performed on H_2 derived from high-temperature (1400 °C) flash pyrolysis of 350 ± 10 μg feather subsamples using continuous-flow isotope-ratio mass spectrometry. All results are for non-exchangeable δD expressed in the typical delta notation, in units of per mil (‰), and normalized on the Vienna Standard Mean Ocean Water — Standard Light Antarctic Precipitation (VSMOW-SLAP) standard scale. Measurement of three keratin laboratory reference materials (CFS, CHS, BWB) (corrected for linear instrumental drift) were both accurate and precise with typical mean $\delta D \pm$ SD values of -147.4 ± 0.79 ($n = 5$), -187 ± 0.56‰ ($n = 5$) and -108 ± 0.33‰ ($n = 5$) per autorun, respectively. A control keratin reference yielded a 6-month SD of ± 3.3‰ ($n = 76$). All results are for non-exchangeable δD expressed in the typical delta notation, in units of per mil (‰), and normalized on the Vienna Standard Mean Ocean

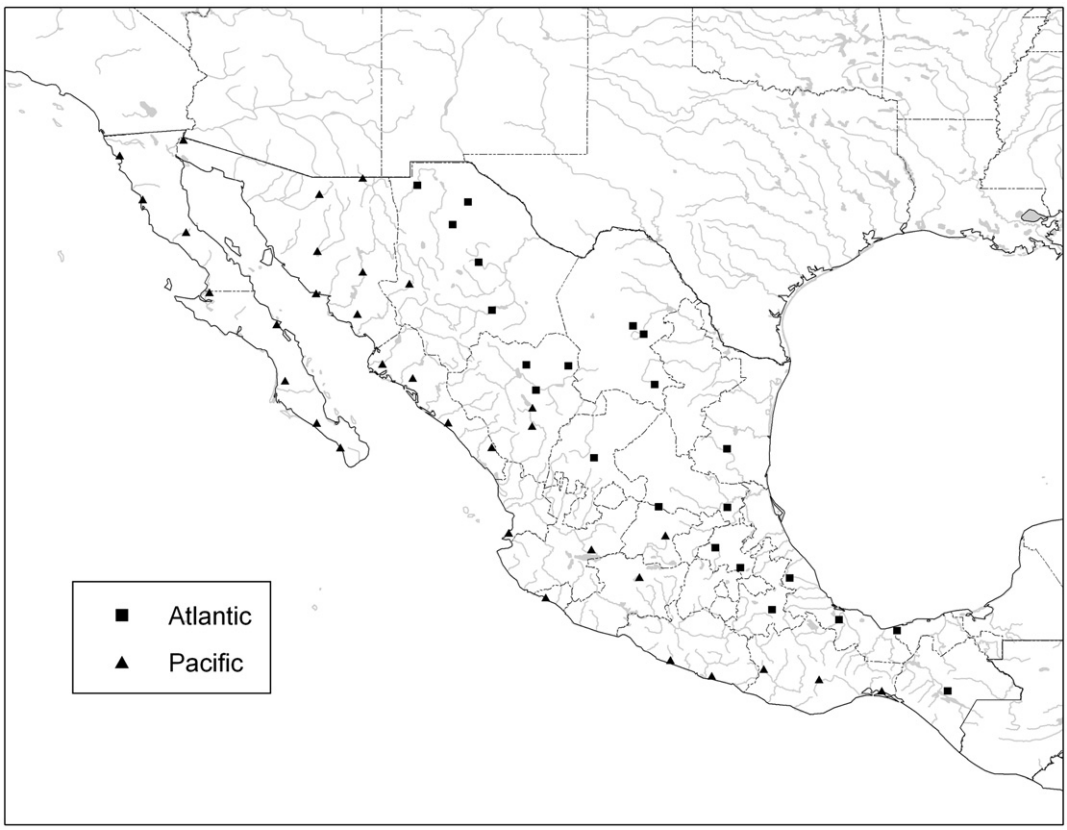

Fig. 1. Location of House Sparrow feather sampling sites in Mexico, January–March 2007, in relation to drainage basin.