Spring 2020

Ecologically Distinct Populations of Hawaiian Petrel (Pterodroma sandwichensis): Quantitative Isotopic Analysis to Explore the Uniqueness of Foraging Habits in Kauai and Hawaii Populations

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Honors Research Project

Submitted to

The Williams Honors College
The University of Akron

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Introduction

Due to its isolation, Hawaii harbors many endemic species, but is also considered the extinction capital of the world (Warner 1968). Hawaiian organisms in general, and seabirds specifically are highly affected by anthropogenic disturbances (Wiley et al 2019, Olson and James 1991, Warner 1968). The Hawaiian petrel (*Pterodroma sandwichensis*) is no different. In the past 20 years, the Kauai population of Hawaiian petrels has been reduced by 78% (Raine et al. 2017). There are currently four known colonies on the islands of Kauai, Lanai, Maui, and Hawaii. About 1,500 years ago, petrels also inhabited Oahu, but that colony was extirpated as Polynesians arrived (Wiley et al. 2013). The decline in Hawaiian petrel population size is mainly attributed to predation and human contact (Simons 1985). Predators include rats, pigs, owls, and perhaps most deadly, cats. Cats were brought to the Hawaiian Islands by humans and kill for both need and sport. Video evidence suggests that once they find a seabird nesting burrow, they will repeatedly return and kill birds. They often rip off a seabird's wings, then carry off and eat the body. Wings are later found and used as evidence of cat predation (Raine et al. 2017; Simons 1985). An additional anthropogenic disturbance is that of powerlines. Powerlines are located in seabird flight paths and on the island of Kauai, they cause about 10,000 collisions each year (Raine et al. 2017). Although threats to seabirds are well-documented on land, there are also concerns about marine-based threats, such as competition with fisheries and seabird bycatch (death in fishing lines, etc.). Unfortunately, these threats are not as well understood, and thus land-based threats are the focal point of conservation efforts (Wiley et al. 2013; Cury et al. 2011).

Seabirds follow what is known as the seabird paradox: despite their ability to cover hundreds to thousands of kilometers in a single journey, they breed extremely close to their hatch site (Milot et al. 2008). To avoid Hawaiian seabirds going extinct, conservation managers have implemented translocation projects. Birds are moved to artificial burrows or nest sites in hopes of saving a population and regenerating breeders (e.g. Raine et al. 2017). Recently, petrel calls have been heard on Oahu, where Hawaiian petrels were assumed to be extirpated. It is unknown if the Oahu birds started reappearing (violating the seabird paradox by flying from a different island) or if petrels have been there all along, undetected (Young et al. 2019). Hawaiian petrels have also been found breeding for the first time on West Maui (Wiley et al. 2019).

To provide context on the biology of the Hawaiian petrels from Oahu and West Maui, I analyzed the stable carbon and nitrogen isotope ratios of Hawaiian petrel feathers. Carbon isotope ratios (reported as $\delta^{13}C$ values) have an inverse relationship with latitude: the closer to the equator foraging takes place, the higher the $\delta^{13}C$ values would be (Welch et al. 2012, Wiley et al. 2013, Wiley et al. 2019). Nitrogen isotope ratios (reported as $\delta^{15}N$ values) vary based on trophic level and foraging location. Different foraging locations leads to differences in nitrogen isotope data, and previous evidence shows that among Hawaiian petrel feathers, foraging location is the main source of variation in $\delta^{15}N$. By analyzing stable carbon and nitrogen isotopes of four feathers grown in a sequence, I aimed to characterize the foraging habits of Hawaiian petrels throughout the period of molt. Specifically, I generated isotope data from the Hawaii and Kauai colonies and compared them to similar, previously-published data from the colonies on Lanai and Haleakala, Maui so that Oahu and West Maui birds could be classified to their parent population (i.e. one of the four major colonies) using discriminant analyses. In this context, a parent population is not necessarily the original colony of a bird, but rather a population that has similar foraging habits. More broadly, I hope this research will provide insight into the movement patterns of procellariiforms, which exhibit an unusual trait: they are often endangered, but rarely go extinct.

Materials and Methods

Stable isotope data was acquired from salvaged Hawaiian petrel carcasses from Hawaii Volcanoes National Park (HVNP) and the Island of Kauai. These data were compared to previously published data from Hawaiian petrels from Haleakala, Maui and Lanai to figure out how distinct the four major populations are in $\delta^{13}C$ and $\delta^{15}N$. Most carcasses (from this and previous studies) were presumed to be killed by cats and to be of breeding age. I chose 4 primary feathers for isotope analysis, which represent about 3 months of growth while Hawaiian petrels forage during the non-breeding season. Petrels have 10 primary feathers that are grown in succession starting with P1 (proximal) and ending with P10 (distal).To obtain a foraging timeline the P1, P4, P6, and P9 feathers were sampled from 24 individuals: 15 from HVNP and 9 from Kauai. This sampling approach allowed me to obtain 3 months of foraging data from each individual. In seven instances, the P1 feather was missing so the P2 feather was sampled instead. Barbs from base of each of the feathers were extracted and washed in Chloroform:Methanol 87:13 and dried in a vacuum oven for 24 hours. Samples weighing 0.8-1.0 mg were packaged into a tin cups and analyzed with an elemental analyzer (Vario PYRO Cube) interfaced to a stable isotope mass spectrometer (Isoprime 100) at the University of Akron. Isotope values were reported in δ-notation, expressed in per mil (‰) according to the following equation: $\delta X=([R_{sample}/R_{standard}]-1) \times 1000$, where X is ^{13}C or ^{15}N, and R is the corresponding ratio $^{13}C/^{12}C$ or $^{15}N/^{15}N$. Rstandard is V-PDB and Air for $\delta^{13}C$ and $\delta^{15}N$, respectively. Lab standards were ran between every 10 unknowns; precision was 0.2 per mil or less for both $\delta^{13}C$ and $\delta^{15}N$.

Jackknife multivariate analysis was utilized to identify outliers. The jackknife distance is calculated by comparing each observation to standard deviations to create a correction matrix. This allows a line of normality to be created and observations reported above the line of normality are considered outliers. 90% ellipses were used to visually compare isotope data from the four major Hawaiian petrel colonies.

Results

Results have been removed from this report; they will be published in a scientific journal article at a later date.

Discussion

My isotope data provide information on the similarity of foraging habits between Hawaiian petrels during the non-breeding season when Hawaiian petrels are growing their primary feathers. Specifically, these data give you information on foraging latitude ($\delta^{13}C$) and nutrient regime/location ($\delta^{15}N$).

Previous research shows that genetically, Hawaiian petrels of Oahu, Molokai, and Lanai have an unusual degree of similarity (Welch et al. 2012). The proposed hypothesis is that Hawaiian petrels moved from Oahu and Molokai to Lanai around 100-200 years ago as their breeding sites on Oahu and Molokai became threatened, violating the seabird paradox (Welch al. 2012).

My project highlights the importance of understanding how and when seabirds colonize new breeding sites. Potentially, new breeding populations are created by procellariiforms as a last resort to avoid predators.

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