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SHORT COMMUNICATION

Dispersal of fern spores by Galápagos finches

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Abstract

Fern sporangia may provide an important source of energy for bird species, which in turn can act as potential dispersers of viable spores. This study reports the first case of fern spore dispersal by land birds. We document the consumption of fern sporangia and evaluate the potential spore dispersal by Galápagos finches on Santa Cruz Island. Overall, 18% of the 34 sampled individuals of three finch species, the Vegetarian Finch (*Platyspiza crassirostris*), the Small Ground Finch (*Geospiza fuliginosa*) and the Medium Ground Finch (*Geospiza fortis*), were found to disperse viable spores of two native ferns, *Asplenium auritum* and *Asplenium feei*.

Keywords *Asplenium* · Fern-bird mutualism · *Geospiza fuliginosa* · *Geospiza fortis* · *Platyspiza crassirostris* · Sporangia consumption

Zusammenfassung

Verbreitung von Farnsporen durch Galápagosfinken

Die Sporenbehälter von Farnen können eine wichtige Energiequelle für Vogelarten darstellen, welche wiederum als potenzielle Verbreiter entwicklungsfähiger Sporen auftreten können. Diese Studie berichtet erstmalig über die Verbreitung von Farnsporen durch Landvögel. Wir dokumentieren den Verzehr von Farn-Sporenbehältern und evaluieren die mögliche Sporenverbreitung durch Galápagosfinken auf Santa Cruz. Insgesamt fanden wir, dass 18% der beprobten 34 Individuen dreier Finkenarten, Dickschnabel-Darwinfink (*Platyspiza crassirostris*), Kleingrundfink (*Geospiza fuliginosa*) und Mittelgrundfink (*G. fortis*), entwicklungsfähige Sporen von zwei auf den Galápagosinseln heimischen Farnarten, *Asplenium auritum* und *A. feei*, verbreiten.

Introduction

Islands generally have lower species richness and populations densities are usually higher than those found on the mainland. Many animals on islands are constrained to have a broader food niche than on the mainland, and thus to consume more kinds of suboptimal food (Blanco et al. 2014). This interaction release, i.e. leading to an increased diversity of biotic interactions (Traveset et al. 2015), is quite commonly reported for islands. The ecological importance of these interactions is often surprising, and successful island colonisers may demonstrate an astonishing behavioural plasticity, e.g. on the Revillagigedo Islands in the Pacific Ocean, the Burrowing Owl (*Athene cunicularia*) may consume cactus pads, fruits and flowers when food is in short supply (Brattstrom 2015).

Ferns (Pteridophyta) are often abundant in a wide range of ecosystems and may provide an important source of

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Table 1 Number of individuals of Galápagos finch species captured on Santa Cruz Island (Galápagos archipelago) in September 2016

Species	Sex			Age		Brood patch		Faecal samples analysed (*n*)	Samples containing fern spores (*n*)	Fern emergence (%)	Young sporophytes (*n*)
	Female	Male	Ind.	Juvenile	Adult	Yes	No				
Camarhynchus pallidus			1		1	1		1	0		
Camarhynchus parvulus	2	1		2	1	3		3	0		
Certhidea olivacea			2	1	1	2		2	0		
Dendroica petechia		1		1		1		1	0		
Geospiza fortis	3	8			11	6	5	11	1	100%	2
Geospiza fuliginosa	7	4		9	2	11		11	1	100%	3
Myiarchus magnirostris			1		1		1	1	0		
Platyspiza crassirostris	4				4		4	4	4	100%	19
Control 1											2
Control 2											2

Ind. Indeterminate sex

energy for animals, particularly when more commonly consumed food is scarce (Ramos 1994, 1995; Arosa et al. 2009). By feeding on fern sporangia, animals can act as potential mutualistic dispersers of fern spores (Boch et al. 2016). However, the dispersal of viable spores by endozoochory, i.e. dispersal after ingestion by animals, has been rarely reported. To our knowledge, it has only been documented for two mammal species, the Wood Mouse (*Apodemus sylvaticus*), in Northwest Spain (Arosa et al. 2010) and the Reindeer (*Rangifer tarandus tarandus*), in Norway (Bråthen et al. 2007), and for one aquatic bird, the Mallard (*Anas platyrhynchos*), in Hungary (Lovas-Kiss et al. 2018).

On 25 August 2016, we observed consumption of fertile fronds (i.e. with spores) of *Asplenium feei* by the Galápagos Vegetarian Finch (*Platyspiza crassirostris*) in the humid zone of Santa Cruz Island. Although clearly understudied, the dispersal of fern spores is very important, as many ferns cannot self-fertilise (i.e. the genetic material of two parent ferns is required for reproduction) (Soltis and Soltis 1992). Here we evaluate the role of granivorous finches as fern dispersers by quantifying their ingestion of ferns in the field and testing spore germinability after gut passage.

Methods

Faecal samples were collected on 22 and 23 September 2016 from mist-netted birds in Media Luna (0°39′30.43″S, 90°19′39.48″W; ca. 700 m a.s.l.), within the humid zone of Santa Cruz Island where ferns are abundant. A total length of 21 m of mist nest was used between 0600 and 1800 hours (12 h in total). During the same period, one observer tracked bird foraging activity from a distance with binoculars to determine potential fern consumption. Captured birds were left for up to 20 min in ringing bags to defecate. For each captured bird, we recorded species, sex, age and the presence of a brood patch. Faecal samples were later examined under a stereomicroscope (×60) and those containing fern reproductive tissues (presumably a prothallus with an embryo or young sporophyte) were individually placed in Petri dishes filled with soil and subsequently covered with plastic wrap. In addition, control spores from two *Asplenium feei* were directly sown in soil under similar conditions. Soil was kept moist for 9 months and fern emergence (prothallus with embryo or young sporophyte) was recorded weekly.

Results and discussion

Thirty-four faecal samples from eight finch species, all endemic to the Galápagos, were collected on 22 and 23 September 2016. One-fifth of the samples ($n = 6$; 18%) contained viable spores of the native fern *A. auritum* (Table 1). Samples containing spores originated from three finch species: the Vegetarian Finch, the Small Ground Finch (*Geospiza fuliginosa*) and the Medium Ground Finch (*Geospiza fortis*). A total of 24 young sporophytes of *A. auritum* ($\bar{X} = 4$, range = 2–7) grew from the bird faeces within 91 days ($\bar{X} \pm 22.5$ SD), while four young sporophytes that grew from control spores took 135 ($\bar{X} \pm 17.8$) days to germinate.

Granivorous Galápagos finches fed on fern sporangia and acted as fern dispersers. It is still unclear whether ferns are a preferred food resource of finches or if ferns are ingested only as sub-optimal food when other alternatives (e.g. seeds, fruits and insects) are scarce. Of the six faecal samples containing fern tissues, five were from females with a brood patch, suggesting that fern sporangia might satisfy the energy requirements for egg formation (Meijer and Drent 1999; Arosa et al. 2009). Further research is needed to

assess which factors explain fern consumption by Galápagos finches and how important ferns are in their diet.

This study is the first to demonstrate fern spore viability, namely those of the native fern *A. auritum*, after internal dispersal by land birds. We also observed the Vegetarian Finch feeding on *A. feei* sporangia, so they likely act as dispersal vectors for other terrestrial ferns as well. This might be particularly significant for self-incompatibility in fern sexual reproduction, as documented for *A. setoi* (Soltis and Soltis 1992; Sugita et al. 2013). Though most fern species are generally considered to be dispersed by wind or water (Sharpe et al. 2010), our results suggest that animal dispersal, particularly by birds, a group with unparalleled mobility, might also play an important role in their dispersal (Sekercioglu et al. 2016). Future research should assess the ecological role of Galápagos finches, and birds elsewhere, as fern dispersers.

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Author contributions S. H. P. and R. H. conceived the idea for the study, design and experiment; S. H. P. collected and analysed the data; S. H. P. wrote the paper with contributions from all the other authors.

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