

Research note

Efficient avian pollination of *Strelitzia reginae* outside of South Africa

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Abstract

In its native South Africa, endemic birds pollinate the complex flowers of *Strelitzia reginae* (bird of paradise) through a highly complex method of pollination. The plant is cultivated worldwide in warm-temperated regions but systematic pollination of the ornithophilous species by local birds has not been reported, and, consequently, seed production is rare outside of South Africa. We found that a member of the New World warblers, *Geothlypis trichas*, efficiently carried out pollination of *S. reginae* in southern California, thereby supplementing its typical diet of insects with the energy-rich nectar of *S. reginae*. Only occasionally, seeds were found in plantings not visited by these birds. The pollinator service provided by the warbler increases seed production in an area outside of South Africa. This could lead to adaptive changes in the exotic species, advance species establishment and persistence and possibly promote invasive behavior in a non-native environment.

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1. Introduction

The bird of paradise flower or crane flower (*Strelitzia reginae*), a native of South Africa, is a common sight in parks and gardens in southern California, Florida and many other warm-temperated regions. The plant is also often used in sophisticated landscaping arrangements. The city of Los Angeles even named the bird of paradise the official city flower.

In its native South Africa, *S. reginae* is primarily pollinated by the Cape Weaver (*Ploceus capensis*), an endemic bird species (Coombs et al., 2007; Frost and Frost, 1981; Skead, 1975). Ornithophily in *S. reginae* occurs via a highly adaptive mutualistic mechanism (Kronstedt and Walles, 1986; Scott-Elliott, 1890). Landing of the bird on the blue sheath-forming petals exposes the hidden pollen to the feet of the bird, while the bird probes the corolla tube with its beak and extends its tongue to reach the nectar (Frost and Frost, 1981; Pauw, 1998). Once landed and feeding, these birds have been observed to seldom move their feet, thus keeping self-pollination low (Johnson and

Brown, 2004). As a consequence, the best place for the bird to feed is also the best position for pollination (Frost and Frost, 1981). In spite of a long history of worldwide cultivation of *S. reginae*, no bird pollination has been described in this species outside of South Africa.

Typically, propagation of *S. reginae* is achieved by growing mature plants from seed (Van de Pol and Van Hell, 1988). *S. reginae* plants cultivated in the area of southern California covered in this investigation (Table 1) are mostly derived from seeds ordered from South African suppliers. Because of the lack of a natural pollinator, seed production is rare in southern California and probably generally outside of South Africa (Wang et al., 2001). As a result of "accidental pollination" by different animals, filled seed capsules can only rarely be found. We here report our observation of efficient pollination of *S. reginae* by a Californian warbler species and an assessment of the seed production.

2. Materials and methods

We examined systematically patches of *S. reginae* Banks (bird of paradise flower) throughout the Orange County region of California and sporadically from San Diego (32.44 N, 117.10 W) to San Luis Obispo (35.20 N, 120.43 W) for seed-producing

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Table 1
Seed production in *Strelitzia reginae* at selected sites in southern California.

Site	Irvine Civic Center	UC Irvine Research Park	UC Irvine Arboretum	Valley Center Farm
Latitude	N 33°41'11.1293"	N 33°38'43.7722"	N 33°39'50.7731"	N 33°13'6.1324"
Longitude	W 117°49'35.9491"	W 117°51'24.0958"	W 117°51'15.5985"	W 117°51'15.5985"
Pollinator observed	Yes	Yes	No (hand-pollinated)**	No**
Total inflorescences	~14,400	2376	25	>30,000
Seed producing inflorescences	~12,700 (88%)	872 (36.7%)*	19 (76%)	<100 (<0.4%)
Seed pods per inflorescence	4.83 ^a	4.60 ^a	4.68 ^a	Not counted
Seeds per seed pod	51.2 ^a	48.9 ^a	46.8 ^a	Not counted
Pollen germination rate <i>in vitro</i>	68.3% ^a	not tested	65.9% ^a	Not tested

*Landscaped (withered inflorescences occasionally removed).

**Confirmed through long-term observations by nursery staff (personal communication).

^a Means within a row that are not significantly different (t-test, $p=0.1$).

inflorescences. In order to study pollinator activity, we established vantage points in proximity to a patch that allowed adequate observation as well as limited disturbance to the wildlife. The observations were carried out from 2007 to 2010 during peak flowering time (November to March) and thereafter during harvests. Interactions with the flowers by potential pollinators were documented photographically using a digital SLR camera with a 200 mm lens. Analysis of these photos in conjunction with visual observation and counting of seedpods allowed us to identify activities that resembled the pollination mechanism reported for the natural pollinators in South Africa. Seedpods were scored when visible outside of the spathe and seeds were collected from opening pods. *S. reginae* pollen was germinated after vortexing as described previously (Hoffmann et al., 1988).

3. Results and discussion

In 2007, we discovered a *S. reginae* planting, surrounding the Irvine (Orange County) civic center, with approximately 14,400 inflorescences at peak flowering time, of which 88% produced viable seeds (Table 1). The planting area was an estimated 0.5 ha, densely covered and largely impassable (which prevented the gardeners from cutting dried-up inflorescences). The patch provided us with sufficient and conveniently available material for studying *S. reginae* embryogenesis and embryo culture (data not shown). Thousands of seeds were given to a local nursery and germinated under standard conditions at a rate (78%) comparable to seeds purchased in South Africa (personal communication). The number of seed pods per inflorescence, of seeds per pod and pollen viability for these plants did not differ from hand-pollinated control plants (Table 1).

Because of the exceptional seed production of this patch, we paid particular attention to the avian activity at this location. We noticed an unusual high number of birds of the species *Geothlypis trichas* (Common Yellowthroat) and observed these birds, males as well as females, flying from flower to flower, where they specifically elected to perch on the fused petals (sheath) that harbor the anthers, thus pulling these petals apart and collecting pollen on their feet. From this position, they could easily lower their beaks into the corolla tube to reach the nectar (Fig. 1). The bird weighs 9–10 g and is safely supported by the mechanically reinforced sheath (Kronstedt and Walles,

1986; Wagner, 1894). The behavior was consistent for *G. trichas*. We also observed other bird species, like sparrows, that occasionally perched on random parts of the plants without systematically interacting with the flowers or attempting to steal nectar, as was reported by Coombs and Peter (2009) for sunbirds in South Africa.

We found in the area also 2 smaller patches, less densely covered and probably occasionally pruned, with lower but still significant seed production, 18% and 37% (Table 1). In both places, *G. trichas* was observed to visit the flowers of *S. reginae*. We spot-checked further plantings in California ranging 250 km from San Diego in the South to Camarillo in the North without finding significant seed production. We also investigated a commercial plantation of *S. reginae* in San Diego County with more than 30,000 inflorescences. The habitat was very different from the marshlands and riparian areas preferred by *G. trichas*. No specimen of the species could be spotted at the plantation, and seed production was negligible (Table 1).

Behaviorally, the warblers collect insects from the ground, meaning that these birds typically snatch up stationary prey as opposed to catching it in mid-flight. This method of predation requires constant quick movements (Griscom and Sprunt, 1979) from perch to perch, similar to the behavior of nectarivorous species (such as the sunbirds or hummingbirds) that fly from



Fig. 1. *Geothlypis trichas* (common yellowthroat), a warbler family member, weighs 9–10 g, which is supported by the landing site, a mechanically reinforced anther sheath formed by fused petals of *Strelitzia reginae* (Wagner, 1894). The male bird reaches for the nectar, the feet pick up the pollen.

flower to flower to feed (Coombs et al., 2007). Since *G. trichas* is typically an insectivore, it is highly possible, that the bird was drawn to prey on the large amount of ants that inhabit the sticky inflorescences of *S. reginae*. The energy available in the sugar-containing nectar probably attracted the birds into supplementing their typical diet of insects with the additional sugars. This behavior is not uncommon in warblers that are considered to be opportunistic eaters.

Ornithophily is an energy-costly strategy for plants and must be efficient to be useful (Stiles, 1978). The pollination syndrome must be inviting and guiding but also protect from nectar theft by birds and insects (Coombs and Peter, 2009). We have shown that *S. reginae* co-opted a non-native pollinator in a part of the world where it has been introduced. It is unclear if this and/or a similar mutual relationship has always existed in California without developing into a regular association or if we have observed the beginning of a new ornithophilous affiliation triggered by learning or genetic changes. However, it is unknown how much learning, if any, is involved in flower-visiting birds. Much of the behavior may be innate and guided by plant signals. Since most *S. reginae* plants cultivated in southern California are derived from seeds produced in South Africa, the flowers have probably not changed under the foreign environment, i.e., it is also unlikely that adaptive floral changes have started the association. Nevertheless, the mutualistic pollinator service provided by the warbler increases seed production in an area outside of South Africa, a step towards overcoming barriers to establishment (Richardson et al., 2000). Furthermore, *G. trichas* is a widespread species, nesting from Alaska across Canada and the United States and wintering from the southern United States to northern South America and the West Indies. Together, this could lead to adaptive changes of the alien plant species, advance its distribution, establishment and persistence and possibly promote invasive behavior in a non-native environment. Non-native plant and animal species have been observed to affect the functioning of invaded ecosystems by disrupting reproductive mutualism (Aizen et al., 2008; Traveset and Richardson, 2006). Since *G. trichas* has not been a part of a

pollination web, its role as pollinator of *S. reginae* should not directly affect native species.

References

- Aizen, M.A., Morales, C.L., Morales, J.M., 2008. Invasive mutualists erode native pollination webs. *PLoS Biology* 6, 396–403.
- Coombs, G., Peter, C.I., 2009. Do floral traits of *Strelitzia reginae* limit nectar theft by sunbirds? *South African Journal of Botany* 75, 751–756.
- Coombs, G., Mitchell, S., Peter, C.I., 2007. Pollen as a reward for birds. The unique case of weaver bird pollination in *Strelitzia reginae*. *South African Journal of Botany* 73, 283.
- Frost, S.K., Frost, P.G.H., 1981. Sunbird pollination of *Strelitzia nicolai*. *Oecologia* 49, 379–384.
- Griscom, L., Sprunt, A., 1979. *The Warblers of America*. Doubleday, Garden City, N.Y., pp. 161–164.
- Hoffmann, F., Sibley, R.B., Tsay, S.-S., 1988. Transgenic antibiotic resistance may be differentially silenced in germinating pollen grains. *Plant Cell Reports* 7, 542–545.
- Johnson, S.D., Brown, M., 2004. Transfer of pollinaria on birds' feet: a new pollination system in orchids. *Plant Systematics and Evolution* 244, 181–188.
- Kronstedt, E., Walles, B., 1986. Anatomy of *Strelitzia reginae* flower (*Strelitziaceae*). *Nordic Journal of Botany* 6, 307–320.
- Pauw, A., 1998. Pollen transfer on birds' tongues. *Nature* 394, 731–732.
- Richardson, D.M., Allsopp, N., D'Antonio, C.M., Milton, S.J., Rejmanek, M., 2000. Plant invasion—the role of mutualism. *Biological Reviews of the Cambridge Philosophical Society* 75, 65–93.
- Scott-Elliot, G.F., 1890. Note on the fertilization of *Musa*, *Strelitzia reginae* and *Ravenala madagascariensis*. *Annals of Botany* 4, 258–263.
- Skead, C.J., 1975. Weaverbird pollination of *Strelitzia reginae*. *Ostrich. Journal of African Ornithology* 46, 183–185.
- Stiles, G.F., 1978. Ecological and evolutionary implications of bird pollination. *Integrative and Comparative Biology* 18, 715–727.
- Traveset, A., Richardson, D.M., 2006. Biological invasions as disruptors of plant reproductive mutualism. *Trends in Ecology and Evolution* 21, 208–216.
- Van de Pol, P.A., Van Hell, T.F., 1988. Vegetative propagation of *Strelitzia reginae*. *Acta Horticulturae* 226, 581–586.
- Wagner, A., 1894. Zur Anatomie und Biologie der Blüte von *Strelitzia reginae*. *Berichte der Deutschen Botanischen Gesellschaft* 12, 53–72.
- Wang, Z., Cai, B., Chen, D., Wang, Y., 2001. Self-pollination and cross-pollination in *Strelitzia reginae* Banks. *Journal of Beijing Forestry University* 23, 32–35.