Correspondence

Darwin's finches combat introduced nest parasites with fumigated cotton

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Introduced parasites are a threat to biodiversity when naïve hosts lack effective defenses against such parasites [1]. Several parasites have recently colonized the Galápagos Islands, threatening native bird populations [2]. For example, the introduced parasitic nest fly *Philornis downsi* (Diptera: Muscidae) has been implicated in the decline of endangered species of Darwin's finches, such as the mangrove finch (*Camarhynchus heliobates*) [3]. Here, we show that Darwin's finches can be encouraged to 'self-fumigate' nests with cotton fibers that have been treated with permethrin. Nests with permethrin-treated cotton had significantly fewer *P. downsi* than control nests, and nests containing at least one gram of cotton were virtually parasite-free. Nests directly fumigated with permethrin had fewer parasites and fledged more offspring than nests treated with water.

Adult *P. downsi* flies, which are not parasitic, lay their eggs in the nests of Darwin's finches and other land birds in the Galápagos. Once the eggs hatch, the fly larvae feed on the blood of nestlings and adult females when they sit on the nest. Several previous studies have shown that *P. downsi* reduces the reproductive success of Darwin's finches [4]. In some years, 100% of nests at a given location can fail due to *P. downsi* [4–6]. It is therefore critical that control measures be developed to help reduce the effect of *P. downsi* on endangered Darwin's finches and other birds [3,7].

Our study was conducted January–April, 2013 at the El Garrapatero field site on Santa Cruz island [4,5]. The study was prompted by observations of several species of Darwin's finches incorporating cotton fibers from laundry lines into their nests (Figure 1A). To determine whether finches can be encouraged to self-fumigate their nests, we placed 30 cotton dispensers (Figure 1B) at 40-meter intervals along two transects through our study site (Supplemental information). Preliminary trials showed that finches transport cotton up to 20 meters (Supplemental information).

We used two types of (interspersed) dispensers: experimental dispensers, which contained cotton treated with a 1% permethrin solution, and control dispensers, which contained cotton treated with water. Processed and unprocessed cotton were used to distinguish between the treatments. The two types of cotton were similar in appearance, but could be distinguished upon close inspection. A coin toss determined which treatment was assigned to which cotton type: processed cotton was used for the experimental treatment and unprocessed cotton for the control treatment. A preliminary experiment showed that finches do not discriminate on the basis of cotton type or fumigant (Figure 1C; Supplemental information).

Over the course of the study, we searched once a week for active nests within 20 meters of each dispenser. When a nest was found, it was checked with a camera on a long pole to confirm breeding activity. After the birds finished breeding, the nests were collected and dissected to quantify the number of *P. downsi* in each nest. Cotton and natural nest materials were separated and weighed.

We located 26 active Darwin's finch nests, 22 (85%) of which contained cotton (Figure 1D). None of the nests contained more than one type of cotton. Thirteen nests had experimental (permethrin) cotton and nine nests had control (water) cotton. Nests were constructed by four species of Darwin's finches: *Geospiza fortis*, *G. fuliginosa, Camarhynchus parvulus,* and *Platyspiza crassirostris.* Nests with experimental cotton had a mean (± SE) of 14.69 ± 9.54 parasites; control nests had a mean of 29.89 ± 7.69 parasites (Mann-Whitney test: $U = 31.00$, $P = 0.03$). The effect of the experimental cotton was dose-dependent. Of the eight nests that contained at least one gram of experimental cotton, seven had no parasites and the eighth had only four parasites (Figure 1E). There was no relationship between cotton and parasite load among control nests (Figure 1E).

Monitoring reproductive success requires climbing to nests and banding nestlings, which could interfere with self-fumigation behavior. We therefore quantified the effect of fumigation on host reproductive success using another 37 Darwin's finch nests adjacent to the self-fumigation transects. We sprayed experimental nests with a 1% permethrin solution and control nests with water. Nestlings were banded with color bands, enabling us to confirm fledging success by identifying individual birds after they left the nest [4,5]. Once all of the nestlings in a nest had fledged or died, the nest was collected and dissected to quantify the number of parasites.

The twenty experimental nests sprayed with permethrin had no parasites, while the 17 control nests sprayed with water had a mean of 17.00 ± 3.89 parasites (Mann-Whitney test, $U = 20.00$, $P < 0.0001$). Nineteen of the twenty experimental nests (95%) fledged at least one offspring, while only 11 of the 17 control nests (65%) fledged any offspring (Fisher's Exact, $P = 0.03$). Overall, 50 of 60 nestlings (83%) fledged from experimental nests, compared to just 29 of 54 nestlings (54%) from control nests (Figure 1F).

Our study shows that Darwin's finches can control *P. downsi* with permethrin-treated cotton, and that fumigation increases fledging success. There are currently no other effective methods for controlling *P. downsi*. Self-fumigation may thus be a viable approach for combatting *P. downsi* in the nests of Darwin's finches. The mangrove finch is the most critically endangered species of Darwin's finch, with a population of less than 100 individuals restricted to a home range of less than 1km^2 on Isabela Island [3]. Sixty cotton dispensers could treat this entire population. Self-fumigation may be a particularly efficient approach because mangrove finches often build their nests high in mangrove trees, where they are relatively inaccessible [3].

Our study is the first to demonstrate the effectiveness of self-fumigation against parasites. This approach has been tried previously where mice were encouraged to incorporate fumigated

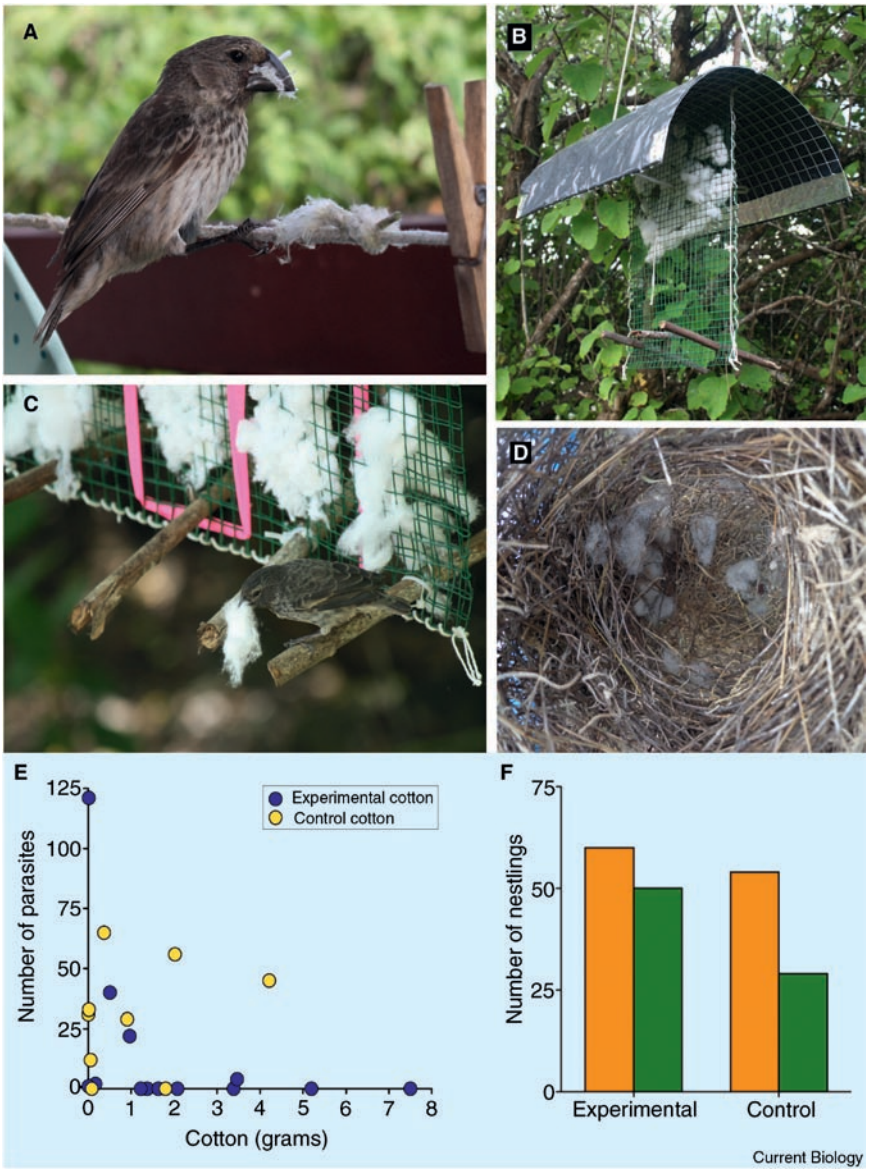

Figure 1. Incorporation of permethrin-treated cotton into nests by Darwin's finches.
(A) Female medium ground finch (*Geospiza fortis*) removing fibers from a cotton laundry line at the Charles Darwin Research Station, Galápagos. (B) Cotton dispenser at the field site; cotton has been removed from the lower half by finches. (C) Small ground finch (*G. fuliginosa*) removing cotton from a dispenser in a preliminary experiment. (D) Finch nest containing about one gram of cotton. (E) Parasite abundance was negatively correlated with the mass of experimental cotton (Spearman rank correlation: r_s = -0.62, P = 0.03), but not with the mass of control cotton (r_s = 0.22, P = 0.58). (F) Experimental nests treated with permethrin fledged more offspring than control nests treated with water (Fisher's Exact test: P = 0.001). Orange bars are the total number of nestlings monitored; green bars are the total number of nestlings that fledged.

cotton into their nests to kill ticks that vector Lyme Disease. However, the effectiveness of the method is not clear [8]. Self-fumigation might also be useful for controlling the fleas that vector plague, which can contribute to the local extinction of black-tailed prairie dogs (*Cynomys ludovicianus*) [9]. Because prairie dogs incorporate plant fibers into their burrows, it might be possible to encourage them to use fumigated materials. Self-fumigation also has potential for the control of parasites in other threatened and endangered bird species. For example, it might be useful for combating explosive increases in lice that appear to have contributed to the decline of the Hawaiian endemic akepa honeycreeper (*Loxops cocineus cocctneus*) [10].

Supplemental Information

Supplemental Information including experimental procedures and one figure can be found with this article online at http://dx.doi.org/10.1016/j.cub.2014.03.058.

Acknowledgments

We thank the Galápagos National Park, Charles Darwin Research Station, Fred Adler, Elena Arriero, Emily DiBlasi, Jordan Herman, Michael Thompson and Sarah Windes for assistance. We thank Charles Brown, Sarah Bush, Franz Goller, Jennifer Koop, Cagan Sekercioglu, and two anonymous reviewers for comments on the manuscript. The work was supported by NSF grant DEB-0816877 to D.H.C. and a University of Utah GCSC grant and RocketHub Crowdfunding to S.A.K. We are grateful to U.S. Cotton™ for donating supplies.

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