Supplementary Material for: The efficacy of natural selection in producing optimal sex ratio adjustments in a fig wasp species

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**1. Calculating the probability of sibmating**

The inbreeding coefficient, *F*, determines the relatedness of daughters to a mother and in turn *F* = *s*/(4-3*s*), with *s* being the fraction of females that are sibmated [1]. When sex ratios vary conditionally upon foundress number (*n*), then sex ratio affects *s* and hence *F*, giving

, (1)

with λn = the probability of an *n*-foundress fig, *rn* = proportion of sons laid by a female in an *n*-foundress fig and *c*n = the clutch size in an *n*-foundress fig [2].

Herre [3] argued that since *r*n increases as *n* increases while *c*n decreases as *n* increases, it will be approximately correct to assume that all *nc*n(1 - rn) are equal to each other so that (1) simplifies to

, (2)

with *n*h = the harmonic mean foundress number. Frank [2] assumed that *c*n are identical to obtain his equation (6). If we in addition assume that all *r*n are identical, we obtain

,

 (3)

with *n*a = the arithmetic mean foundress number. The true value of *s* must fall between equations (2) and (3), with (2) being too high and (3) being too low. In *C. galili* *n*h = 1.624 and *n*a = 2.909. Given that clutches are only constrained for three and more females, the truth should be between these two points. When females have different clutch sizes and compositions the degree of inbreeding increases [2,4].

**2. Derivation of the optimal sex ratio for indiscriminate females**

We consider figs with two foundresses of which at least one is a *C. galili* female. Let *p* be the fraction of figs containing two *C. galili* females and 1 - *p* be the fraction of figs containing one *C. galili* and one *C. arabicus* female, then a fraction 2*p*/(1 + *p*) of *C. galili* females are in a two-foundress fig and (1 - *p*)/(1 + *p*) of *C. galili* females are actually in a one-foundress fig. The fitness effect of each female is equivalent as they all produce approximately the same number of daughters (figure 2c). If the kin value, *K,* of each sex is the product of the sex's reproductive value and relatedness to the foundress, then for males *K*m = ½ and for females *K*f = , where *F* is the inbreeding coefficient and *s* is the fraction of females that are sibmated [5,6]. Consider a mutant foundress that produce a sex ratio (= fraction of sons) of *r*2 in a population where females produce sex ratios of . If all females lay the same clutch size, then the fitness per egg can be written as

and the ESS sex ratio, *r*2\*, can be found by setting the partial derivative of *w* with respect to *r*2 equal to 0

and solving for *r*2\* gives,

*r*2\*

**3. Supplementary Tables**

**Table S1**. A comparison of the frequencies of wasp abundance as numbers of figs and number of wasps for figs with and without *Ceratosolen galili*.

|  |  |  |  |
| --- | --- | --- | --- |
|  | *C. galili* present |  | *C. galili* absent |
| Presence of *C. arabicus* and *S. sycomori*  | number of figs | % of figs | % excluding neither | number of wasps | % of wasps |  | number of figs | % of figs |
| Neither | 158 | 48 |  | 492 | 51 |  | - | - |
| *C. arabicus* | 105 | 32 | 62 | 267 | 28 |  | 594 | 62 |
| *S. sycomori* | 46 | 14 | 26 | 129 | 13 |  | 231 | 24 |
| Both | 22 | 6 | 12 | 76 | 8 |  | 132 | 14 |
| Total | 331 |  |  | 963 |  |  | 957 |  |

**Table S2**. The number of 263 figs that did not contain *S. sycomori* that contain a specific number of foundresses of each *Ceratosolen* species. Percentages rounded to nearest 1 below numbers in italics; left open in case it equals 0. Bold type indicates figs with less than three foundresses. The total percentage of figs containing a certain number of *C. galili* females are given in the final row.

|  |
| --- |
| Number of foundresses |
| *C.* |  | *C. galili* |
| *arabicus* |  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 17 | 19 | 23 |
| 0 |  | **65 *25*** | **22** ***8*** | 25 *10* | 16 *6* | 8 *3* | 5 *2* | 4 *2* | 1 | 4 *2* | 5*2* | 1 | 0 | 1 | 0 | 1 |
| 1 |  | **30 *11*** | 14 *5* | 6 *2* | 3*1* | 3 *1* | 4 *2* | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 |  | 13 *5* | 3*1* | 1 | 5*2* | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| 3 |  | 7*3* | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 |  | 21 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 5 |  | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 |  | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total % |  | 46 | 16 | 12 | 10 | 4 | 5 | 2 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 |

**Table S3**. The number of 758 *C. galili* females found in 263 figs without *S. sycomori* that contain a specific number of foundresses of each *Ceratosolen* species. Percentages rounded to nearest 1 below numbers in italics; left open in case it equals 0. Bold type indicates figs with less than three foundresses. The total percentage of females in figs containing a certain number of *C. galili* females are given in the final row.

|  |
| --- |
| Number of foundresses |
|  | *C. galili* |
| *C. arabicus* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 17 | 19 | 23 |
| 0 | **65*****9*** | **44*****6*** | 75*10* | 64*8* | 40*5* | 30*4* | 28*4* | 8*1* | 36*5* | 50*7* | 11*1* | 0 | 17*2* | 0 | 23*3* |
| 1 | **30*****4*** | 28*4* | 18*2* | 12*2* | 15*2* | 24*3* | 7*1* | 8*1* | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 13*2* | 6*1* | 3 | 20*3* | 0 | 6*1* | 0 | 0 | 0 | 10*1* | 0 | 12*2* | 0 | 0 | 0 |
| 3 | 7*1* | 2 | 0 | 0 | 0 | 6*1* | 0 | 8*1* | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 2 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 19*3* | 0 |
| 5 | 1 | 2 | 0 | 41 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total % | 16 | 11 | 13 | 13 | 7 | 9 | 5 | 3 | 5 | 8 | 1 | 2 | 2 | 3 | 3 |

**Table S4**. Three figs with unusually high sex ratios that were discarded from analyses.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| treatment | foundress number | sons | daughters | sex ratio |
| 2 Foundresses | 2 | 254 | 148 | 0.63 |
| Mixed species | 1 | 52 | 45 | 0.54 |
| Mixed species | 1 | 150 | 18 | 0.89 |

**Table S5**. Summary of the mean *C. galili* clutch composition for each treatment.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Treatment | Sex ratio | Clutch size | Number of Daughters | Number of Sons |
| 1 Foundress | 0.14 | 202.7 | 175.4 | 27.3 |
| 2 Foundresses | 0.18 | 232.6 | 190.3 | 42.3 |
| 3 Foundresses | 0.26 | 153.3 | 113.6 | 39.7 |
| Mixed species | 0.23 | 184.4 | 142.1 | 42.3 |

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