Article:

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Dual effects of insect fecundity overdispersion on the *Wolbachia* establishment and the implications for epidemic biocontrol

Appendix S1: A list of articles used in the study and the data recorded

We obtained a total of 56 articles that met our criteria, which involved 47 species. Table S1 shows the estimates of dispersion parameter θ (sorted from less dispersion to larger dispersion across species), along with the sample sizes, mean values and variances of fecundity, and records of whether zero values were included in the analyses. For comparison, we excluded all zero values from a zero-included dataset and took the remaining data as the zero-free dataset of that species, when we did not find an independent zero-free dataset for the species.

Table S1 Empirical estimates of the over-dispersion in realized fecundity of various insects.

Species	Sample size	Average fecundity, $\bar{x}$	Variance of fecundity, S^2	Estimated overdispersion, θ	Zeros included?	References
Grain aphid, *Sitobion avenae*	163	26.09	23.74	Inf[a]	No	Lukasik et al. (2013)
Housefly, *Musca domestica*	7	532.00	17710.63	16.48	No	Lee et al. (1985)
Waterstrider, *Aquarius remigis*	87	87.29	552.25	16.39	No	Preziosi et al. (1996)

Drosophila mauritiana	57	226.82	4517.18	11.99	No	Meany et al. (2019)
Seed beetle, *Callosobruchus maculatus*	805	77.46	582.14	11.89	No	Hallsson & Bjorklund (2012)
Soybean aphid, *Aphis glycines*	80	42.86–45.08	172.38–295.98	7.26–15.96	No	Riosmartinez & Costamagna (2017)
Parasitic wasp, *Nasonia vitripennis*	57	39.27	184.96	10.59	No	Bordenstein & Werren (2000)
Rhyzobius lophanthae	25	633.70	39880.09	10.23	No	Stathas (2000)
Mosquito, *Culex pipiens*	639	154.62	2552.48	9.97	No	Vézilier et al. (2012)
Bug, *Lygus hesperus*	139	115.90	1581.60	9.16	No	Brent et al. (2011)
Galling adelgid, *Pineus similis*	50	186.26	4913.52	7.34	No	Sopow & Quiring (1998)
Palmetto weevil, *Rhynchophorus cruentatus*	22	207	7942	5.54	No	Weissling & Giblin-Davis (1994)
Brown planthopper, *Nilaparvata lugens*	45	376.49	30913.38	4.64	No	Lu et al. (2018)
Drosophila simulans	392	100.36	2309.15	4.56	No	Behrman et al. (2015)
European corn borer, *Ostrinia nubilalis*	27	539.60	68856.75	4.26	No	Binder et al. (1999)
Checkerspot butterfly, *Euphydryas editha*	76	83.63	1842.79	3.98	No	Agnew & Singer (2000)
Beetle, *Phoracantha semipunctata*	45	521.33	69168.56	3.96	No	Bybee et al. (2005)
Drosophila melanogaster	240	139.44	5414.46	3.68	No	Behrman et al. (2015)
Light brown apple moth, *Epiphyas postivittana*	64	272.59	21676.67	3.47	No	Danthanarayana (1975)

Wax moth, *Galleria mellonella*	80	436.45	60070.60	3.19	No	Dubovskiy et al. (2013)
Winter moth, *Operophtera brumata*	67	205.04	13563.10	3.15	No	Salis et al. (2018)
Galling adelgid, *Pineus pinifoliae*	97	68.72	1601.52	3.08	No	Sopow & Quiring (1998)
Gypsy moth, *Lymantria dispar*	98	558.66	107100.70	2.93	No	Hough & Pimentel (1978)
Kissing bug, *Mepraia spinolai*	20	94.70	3254.54	2.84	No	Botto-Mahan et al. (2017)
Speyeria mormonia	36	229.87	23505.85	2.73	No	Boggs (1986)
Bollworm, *Helicoverpa armigera*	100	1163.57	521881.90	2.60	No	Reigada et al. (2018)
Diaspidid, *Cornuaspis beckii*	1613	22.08–23.41	232.26–236.85	2.32–2.57	No	Boyero et al. (2007)
Trichogramma semblidis	8	47.90	1021.52	2.36	No	Delpuech et al. (2010)
Mantis, *Paratenodera angustipennis*	24	429.40	83341.61	2.22	No	Matsura & Morooka (1983)
Diaspidid, *Parlatoria pergandii*	1618	5.59–6.07	20.88–22.47	2.04–2.25	No	Boyero et al. (2007)
Pea aphid, *Acyrthosiphon pisum*	374	11.05	71.80	2.01	Yes	Hopkins et al. (2017)
Pea aphid, *Acyrthosiphon pisum*	442	56.21	211.94	20.29	No	Lukasik et al. (2013)
Carabid beetle, *Amara aenea*	82	34.88	754.58	1.69	Yes	Saska (2008)
Carabid beetle, *Amara aenea*	74	38.65	690.44	2.29	No	Saska (2008)
Whitemarked tussock moth, *Orgyia leucostigma*	100	167	19600	1.44	No	Thurston & MacGregor (2003)
Aedes albopictus	180	13.02	191.33	0.95	Yes	Bibbs et al. (2018)
Aedes albopictus	177	13.24	191.65	0.98	No	Bibbs et al. (2018)
Aedes albopictus	76	38.01	1507.28	0.98	Yes	Costanzo et al. (2015)

Aedes albopictus	53	54.51	1262.16	2.46	No	Costanzo et al. (2015)
Planthopper, *Prokelisia marginata*	60	51.69	3858.48	0.71	Yes	Denno & McCloud (1985)
Planthopper, *Prokelisia marginata*	32	98.23	2699.25	3.89	No	Denno & McCloud (1985)
Metamasius callizona	93	31.97	1535.59	0.68	Yes	Frank et al. (2006)
Metamasius callizona	75	39.64	1600.00	1.01	No	Frank et al. (2006)
Butterfly, *Colias philodice*	251	30.31	1645.50	0.57	Yes	Watt (1992)
Butterfly, *Colias philodice*	149	51.06	1712.43	1.57	No	Watt (1992)
Aedes aegypti	103	24.15	1091.27	0.55	Yes	Harris & Cooke (1969)
Aedes aegypti	119	32.52	1338.23	0.81	Yes	Calkins & Piermarini (2017)
Aedes aegypti	95	65.03	552.26	8.68	No	Calkins & Piermarini (2017)
Aedes aegypti	47	68.55	4567.84	1.04	Yes	Briegel (1990)
Aedes aegypti	180	14.36	207.2	1.07	Yes	Bibbs et al. (2018)
Aedes aegypti	168	15.39	206.21	1.24	No	Bibbs et al. (2018)
Aedes aegypti	180	31.8	715.38	1.47	Yes	Lee et al. (2018)
Aedes aegypti	22	24.99	423.15	1.57	Yes	Costanzo et al. (2015)
Aedes aegypti	15	36.65	193.21	8.58	No	Costanzo et al. (2015)
Aedes aegypti	77	73	2772	1.97	No	Chang et al. (2018)
Aedes aegypti	82	69.2	2403.94	2.05	No	Muttis et al. (2018)
Aedes aegypti	97	23.98	260.45	2.43	No	da Silva et al. (2009)
Aedes aegypti	45	46.27	596.82	3.89	No	Gutiérrez et al. (2020)
Aedes aegypti	72	36.94	307.04	5.11	No	Gleave et al. (2016)
Aedes aegypti	60	51.38	512.51	5.72	No	Gonzalez & Harburguer

						(2020)
Aedes aegypti	20	65.1	720	6.47	No	Yadav et al. (2019)
Aedes aegypti	29	38.41	237.97	7.39	No	Qureshi et al. (2019)
Carabid beetle, *Amara similata*	82	32.57	2011.23	0.54	Yes	Saska (2008)
Carabid beetle, *Amara similata*	68	39.27	2161.99	0.73	No	Saska (2008)
Parasitoid wasp, *Diadegma semiclausum*	17	142.54	38688.43	0.53	Yes	Winkler et al. (2006)
Parasitoid wasp, *Diadegma semiclausum*	8	302.61	32684.42	2.84	No	Winkler et al. (2006)
Paropsis atomaria	240	82.08	17057.15	0.40	Yes	Ohmart et al. (1985)
Paropsis atomaria	135	145.92	21008.47	1.02	No	Ohmart et al. (1985)
Marula fruit fly, *Ceratitis cosyra*	119	35.33	3354.27	0.38	Yes	Malod et al. (2017)
Marula fruit fly, *Ceratitis cosyra*	68	61.82	4245.01	0.91	No	Malod et al. (2017)
Carabid beetle, *Amara familiaris*	82	9.42	244.48	0.38	Yes	Saska (2008)
Carabid beetle, *Amara familiaris*	37	20.88	302.48	1.55	No	Saska (2008)
Red flour beetle, *Tribolium castaneum*	120	23.50	1732.80	0.32	Probably yes	Arnaud et al. (2002)
Red flour beetle, *Tribolium castaneum*	34	17.21	66.35	6.02	No	Jiang et al. (2013)
Haematophagous bug, *Rhodnius prolixus*	90	3.86	63.68	0.25	Yes	Schilman et al. (1996)
Haematophagous bug, *Rhodnius prolixus*	36	9.64	103.43	0.99	No	Schilman et al. (1996)
Mealworm beetle,	120	8.93–16.84	522.65–	0.07–0.37	No	Zanchi et al. (2012)

Tenebrio molitor			1393.92			
Red ant, *Myrmica rubra*	1000[b]	0.23	5.01	0.01	Yes	Elmes (1973); Pech & Heneberg (2015)
Red ant, *Myrmica rubra*	13	18.00	70.83	6.13	No	Pech & Heneberg (2015)

[a] The dataset conforms to the Poisson distribution (the Kolmogorov–Smirnov test, $P = 0.58$).

[b] Pech and Heneberg (2015) measured the fecundity of 13 queens in their control group, and that number of queens corresponds to 987 workers based on the workers-to-queens ratio estimated by Elmes (1973), which was 75.95.

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Appendix S2: pooling multiple groups

Assume that the sample size, the mean value and the variance are n_i, $\bar{x}_i$, and S_i^2 for the data of group *i*. When all data are pooled together, the sample size and the mean value can be easily determined by $n = \sum n_i$ and $\bar{x} = \sum n_i \bar{x}_i / \sum n_i$. Note that

$$\overline{x^2} = \sum n_i \overline{x_i^2} / \sum n_i \qquad \text{(eqn S1)}$$

Given $S_i^2 = \overline{x_i^2} - \bar{x}_i^2$, we substitute it into equation S1 and get

$$\overline{x^2} = \sum n_i \left(\bar{x}_i^2 + x_i^2\right) / \sum n_i \qquad \text{(eqn S2)}$$

Therefore,

$$S^2 = \overline{x^2} - \bar{x}^2$$

$$= \sum n_i (S_i^2 + \bar{x}_i^2) / \sum n_i - \left(\sum n_i \bar{x}_i / \sum n_i\right)^2 \qquad \text{(eqn S3)}$$