

Annotated Bibliography – Pollination Limitation

Agren J. 1996. Population size, pollinator limitation, and seed set in the self-incompatible herb *Lythrum salicaria*. *Ecology* 77: 1779-1790.

- Tests hypothesis that small populations are less attractive to pollinators than large pollinators. Found a positive relationship between population size and seed production per flower and between population size and total seed number per plant. Detected no correlation between population size and seed production in supplementally hand pollinated plants.

Ashman T.L., Knight T.M., Steets J.A., Amarasekare P., Burd M., Cambell D.R., Dudash M.R., Johnston M.O., Mazer S.J., Mitchell R.J., Morgan M.T., and Wilson W.G. 2004. Pollen limitation of plant reproduction: ecological and evolutionary causes and consequences. *Ecology* 85: 2408-2421.

- Good integrated review and synthesis of pollination limitation. Focuses on causes and consequences (evolutionary and ecological). Outlines problems with previous empirical approaches to test pollen limitation and offers a new approach for the empirical study of pollination limitation. Good bibliography with many of the classic papers referenced.

Bierzychudek P. 1981. Pollen limitation of plant reproductive success. *American Naturalist* 107: 360-369.

- One of the first reviews of empirical studies in pollination limitation. Short, but worth checking out as it is often cited.

Burd M. 1994. Batesman's principle and plant reproduction: the role of pollen limitation in fruit and seed set. *The Botanical Review* 60: 83-139.

- Review and meta-analysis that surveys studies of 258 species for effects of pollination limitation. Good synopsis of the literature on the subject up to 1994. Huge bibliography.

Burd M. 1995. Ovule packaging in stochastic pollination and fertilization environments. *Evolution* 49: 100-109.

- Outlines the bet-hedging hypothesis that postulates that flowers in a stochastic environment will be oversupplied with ovules relative to the amount of pollen they usually receive to take advantage of really good pollen years.

Calvo R.N. and Horvitz C.C. 1990. Pollinator limitation, cost of reproduction, and fitness in plants: a transition-matrix demographic approach. *American Naturalist* 136: 499-516.

- Proposes a demographic approach based on matrix population models to evaluate effects of pollen limitation on fitness, and incorporate parameters for pollination frequency, fecundity differences and demographic cost of high fecundity into their models.

Campbell D.R. and Halama K.J. 1993. Resource and pollen limitation to lifetime seed production in a natural plant population. *Ecology* 74: 1043-1051.

- One of a handful of studies to look at both resource and pollen limitation. Results support Haig and Westoby's (1988) model -- only plants freed from pollination limitation by hand pollination responded to increased resource levels and only those plants treated with fertilizer exhibited pollen limitation of seeds per fruit.

Dudash M.R. and Fenster C.B. 1997. Multiyear study of pollen limitation and cost of reproduction in the iteroparous *Silene virginica*. *Ecology* 78: 484-493.

- One of few multi-year studies. Looks empirically at both seed set and fruit set, as well as survival and growth to evaluate if there is a cost to future growth or reproduction associated with increased fertilization due to increased pollen receipt. Examines if lifetime seed production differs between treatment and control groups.

Ehrlen J. and Eriksson O. 1995. Pollen limitation and population growth in a herbaceous perennial legume. *Ecology* 76: 652-656.

- One of few papers to look at effect of pollen limitation on population dynamics. They carry out Calvo and Horvitz's (1990) demographic approach and use matrix population models to evaluate pollen limitations effects on population growth rate and fitness.

Haig D. and Westoby M. 1988. On limits to seed production. *American Naturalist* 131: 757-759.

- Haig and Westoby produce an often referenced theoretical model where fertilization of ovules increases with more allocation to pollinator attraction, while concurrently the ability of ovules to mature decreases due to reduced allocation to seed and fruit maturation, creating an equilibrium point at which fitness is limited by both pollen and resource limitation. Suggests that the traditional theoretical dichotomy between pollen vs. resource limitation in female reproductive success is an oversimplification. A must read.

Huang S.Q. and Guo Y.H. 2002. Variation in pollination and resource limitation in a low seed-set tree, *Liriodendron chinese* (Magnoliaceae). *Botanical Journal of the Linnean Society* 140: 31-38.

- Examines pollen limitation in an endangered plant in multiple populations. One of few studies to actually count number of pollen grains deposited per stigma. Found that higher pollen loads did not consistently lead to higher seed set, suggesting that other factors like resource availability or genetic load may be affecting seed set. Sample size seems small and methods not very well

explained, but its one of only a few studies to look at pollen limitation in rare plants.

Janzen D.H., DeVries P., Gladstone D.E., Higgins M.L. and Lewinsohn T.M. 1980. Self- and cross-pollination of *Encyclia cordigera* (Orchidaceae) in Santa Rosa National Park, Costa Rica. *Biotropica* 12: 72-74.

- Point out that it may be inaccurate to conclude pollination limitation from the results of a study with only one season of artificial hand pollination experiments because increased fruit set due to hand pollination in one year may be offset by a cost in future growth, survival or reproductive capacity.

Jennersten O. 1988. Pollination in *Dianthus deltoides* (Caryophyllaceae): effects of habitat fragmentation on visitation and seed set. *Conservation Biology* 2: 359-366.

- Analyzes the effect of habitat fragmentation on pollination success. Found that flowers in a fragmented area received fewer pollinator visits and had lower seed set than plants in an area of continuous habitat. Found insect richness 9 times higher in continuous site. Hand pollination increased seed set in the fragmented pollination 4.1 times compared to control plants, but no difference detected in seed set between control and hand pollinated plants in the area of continuous habitat.

Johnston M.O. 1991. Pollen limitation of female reproduction in *Lobelia cardinalis* and *L. siphilitica*. *Ecology* 72: 1500-1503.

- Based on the research of Zimmerman and Pyke (1988), compares whole (rather than at the individual flower level) plant seed and fruit set between control and hand pollinated plants. Typical of many pollen limitation studies, this one only collects data for one year and does not look at potential future cost to reproduction, growth or survival from increased seed/fruit set.

Kearns C.A., Inouye D.W. and Waser N.M. 1998. Endangered mutualisms: the conservation of plant-pollinator interactions. *Annual Review of Ecology and Systematics* 29: 83-112.

- Covers the general topic of the increasing anthropogenic threat to pollination systems. Addresses potential causes of pollinator limitation. Has a huge bibliography (although not specific to pollen limitation, it is still useful).

Larson B.M. and Barrett S.C. 2000. A comparative analysis of pollen limitation in flowering plants. *Biological Journal of the Linnean Society* 69: 503-520.

- Review and meta-analysis. Analyzes 224 species to test predictions about pollination limitation. Classifies species for six life history traits: self-compatible vs. self-incompatible, autogamous vs. non-autogamous, specialized vs. unspecialized floral morphology, nectariferous vs. nectarless, monocarpic vs. polycarpic, and herbaceous vs. woody. Compares pollen limitation of species in contrasting categories to see if any generalizations can be made about life-history and a propensity for pollen limitation. Also analyzes influence of phylogenetic history on propensity for pollen limitation.

Larson B.M. and Barrett S.C. 1999. The ecology of pollen limitation in buzz-pollinated *Rhexia virginica*. *The Journal of Ecology* 87: 371-381.

- One of the few studies to go beyond supplemental hand pollination and look at the ecological mechanisms involved in pollinator limitation. Observed pollinator abundance and rate of floral visitation to particular plants over one season. Also quantified the amount of pollen removed with each bumblebee visit.

Mattila E. and Kuitunen M.T. 2000. Nutrient versus pollination limitation in *Platanthera bifolia* and *Dactylorhiza incarnata* (Orchidaceae). *Oikos* 89: 360-366.

- One of the few studies that examines availability of resources and pollinators in the same study. Uses a fully factorial design to examine pollen limitation in 2 species of orchid. Also looks at floral traits like flower size and nectar production in relation to pollen limitation.

Mitchell R.J. 1997. Effects of pollination intensity on *Lesquerella fendleri* seed set: variation among plants. *Oecologia* 109: 382-288.

- Greenhouse experiment where different levels of pollen deposition are evaluated with relationship to seed set. Found variation in seed set between replicates for the same pollen treatment and concludes that plants even within the same population respond differently to the same amount of pollen. But, he did not count out pollen grains applied in each of his treatments – variation could be explained by different numbers of pollen grains deposited even within the same treatment.

Moody-Weis J.M. and Heywood J.S. 2001. Pollination limitation to reproductive success in the Missouri Evening Primrose, *Oenothera macrocarpa*. *American Journal of Botany* 88: 1615-1622.

- Examines the effect of habitat fragmentation and conspecific plant density on pollinator limitation in a hawk moth pollinated rare herb.

Timmerman-Erskine M. and Boyd R.S. 1999. Reproductive biology of the endangered plant *Clematis socialis*. *Journal of the Torrey Botanical Society* 126: 107-116.

- One of few papers to look at pollen limitation in a rare plant. Examines the whole reproductive biology including herbivory, predation of fruits and resource availability. Found evidence of pollinator limitation, herbivory, and heavy post-maturation achene predation.

Vaughton G. 1991. Variation between years in pollen and nutrient limitation of fruit-set in *Banksia spinulosa*. *Journal of Ecology* 78: 389-400.

- One of the few studies to empirically evaluate pollen and resource limitation simultaneously. It also represents one of the few multi-year studies on pollination limitation.

Zimmerman M. and Pyke G.H. 1988. Reproduction in *Polemonium*: assessing the factors limiting seed set. American Naturalist 131: 723-738.

- This study is referenced in almost every paper written on pollination limitation after 1988. Argues that improved performance by experimentally pollinated flowers may come at the expense of other flowers on the same plant due to reallocation of resources for seed or fruit maturation, and recommends analysis and manipulation at the whole plant level to test for pollination limitation.