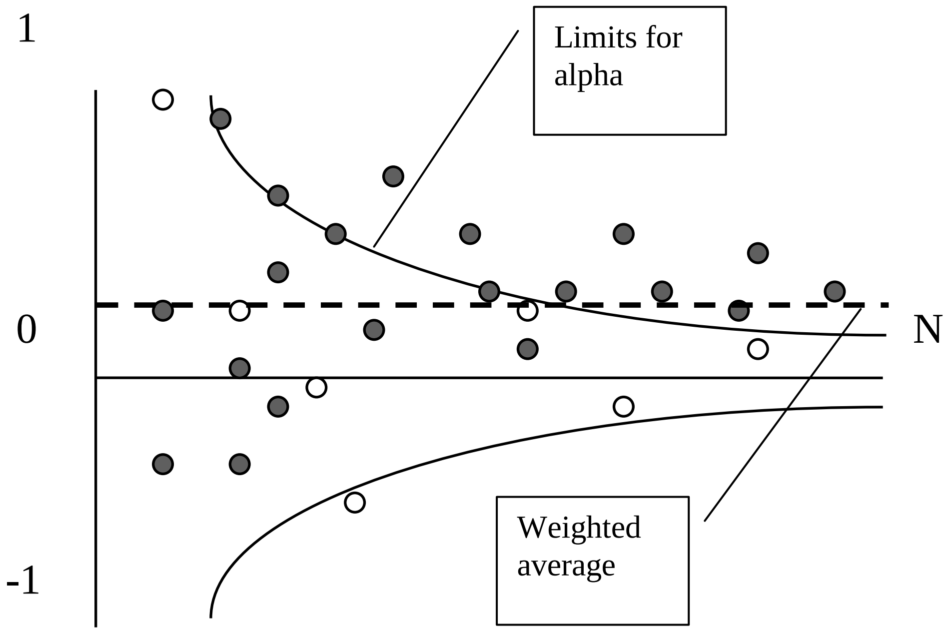
META - ANALYSIS

* Reviews are very influential for the way we think about ecological problems: often cited and influential
* MA is the quantitative analysis of multiple studies.
* MA offers objective ways of summarizing and synthesizing reserach in a particular area (i.e., perform reviews), and offers a unique "control" of type II error rates.
* Has a long history in social sciences, then used in in medical sciences, more recently put to use in other areas.

* ***Basic theorem***: The quantitative result of any given study estimates a true effect size. Other similar studies estimate similar true effect sizes, modified by the experimental/observational setting. Across multiple studies, the variance in effect sizes (V_d) can be described and analyzed as:

V_d = random sampling error + fixed/random effects factors

The possible impact of error in single studies depends on the quality of the study (e.g., the number of observations or other quality criteria). Effect size versus sample size can look like this "**funnel plot**":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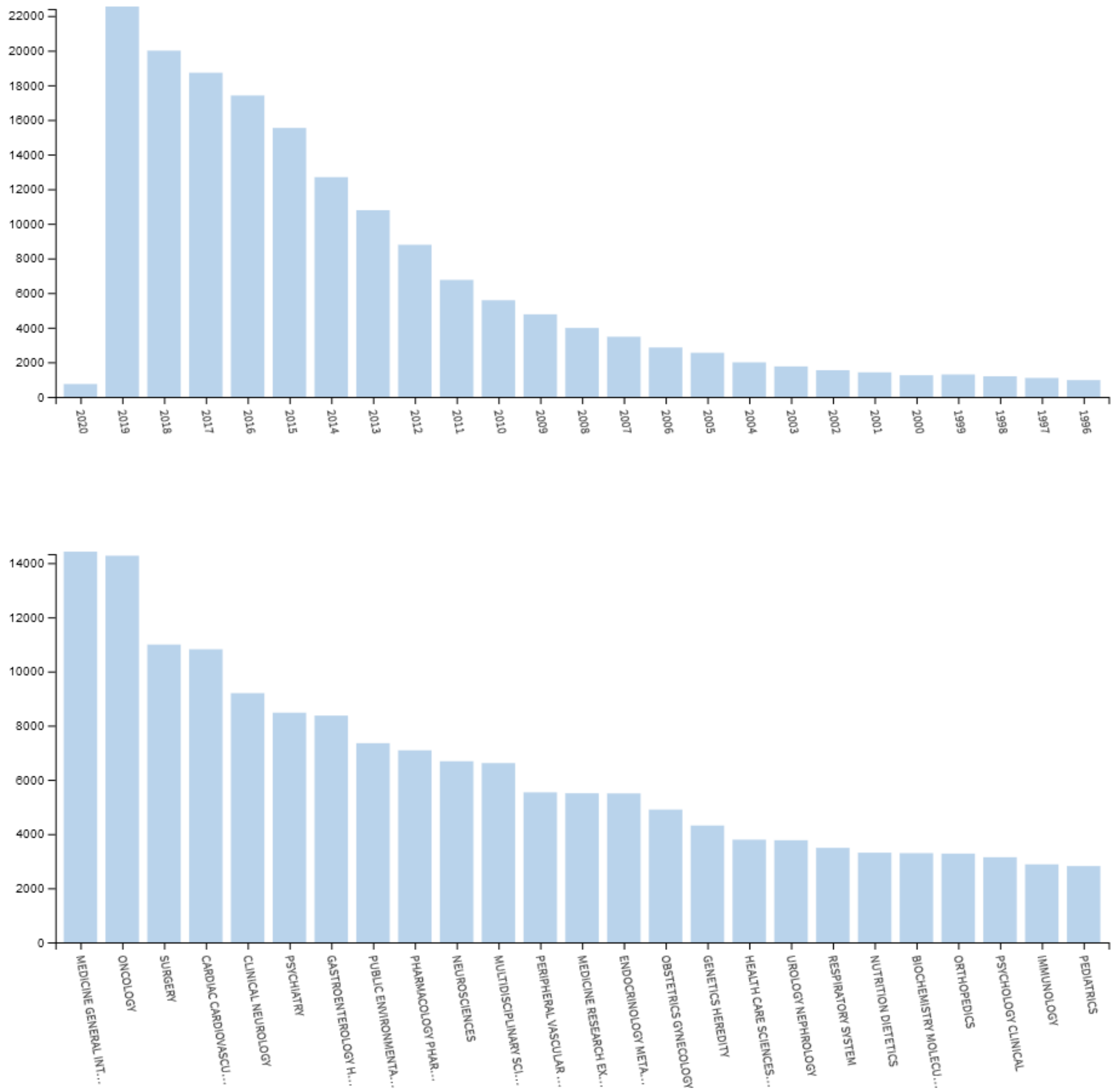
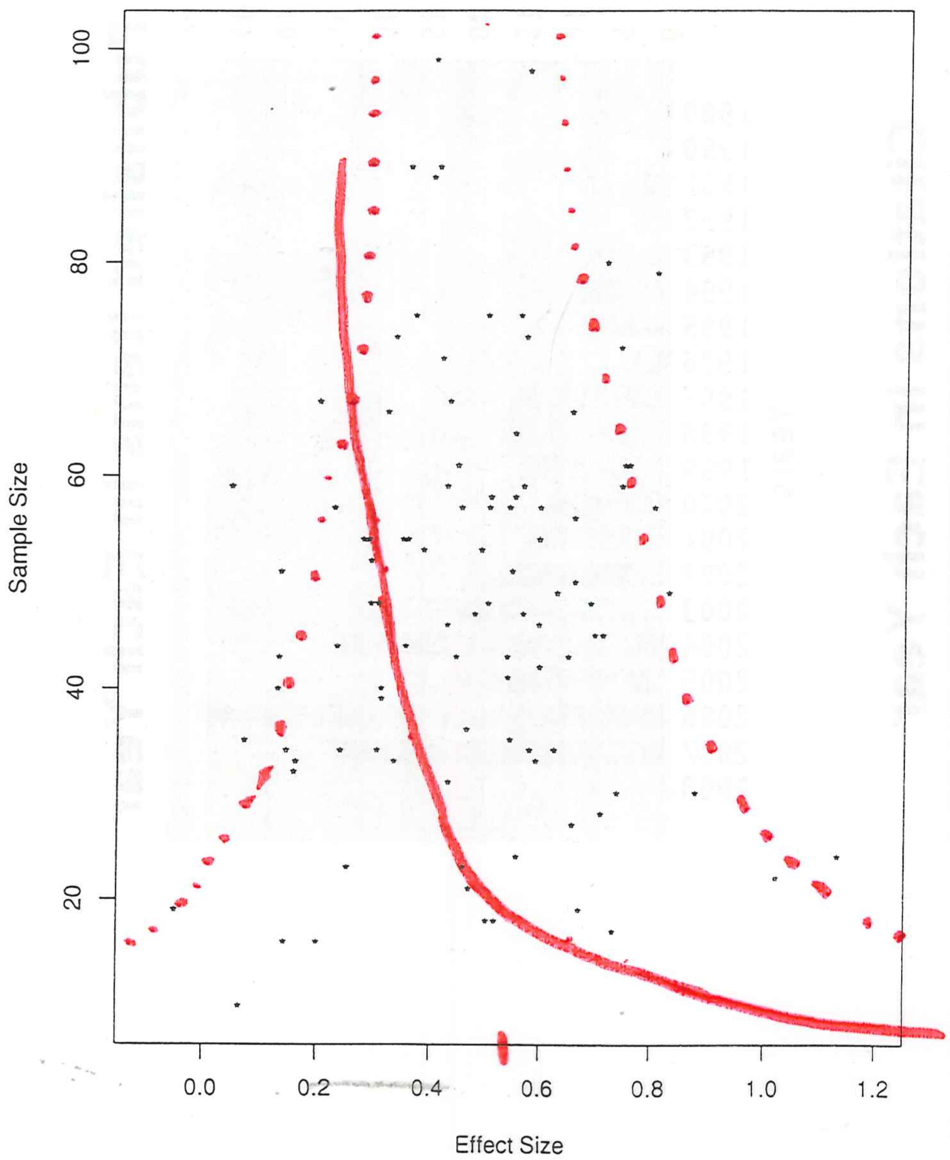
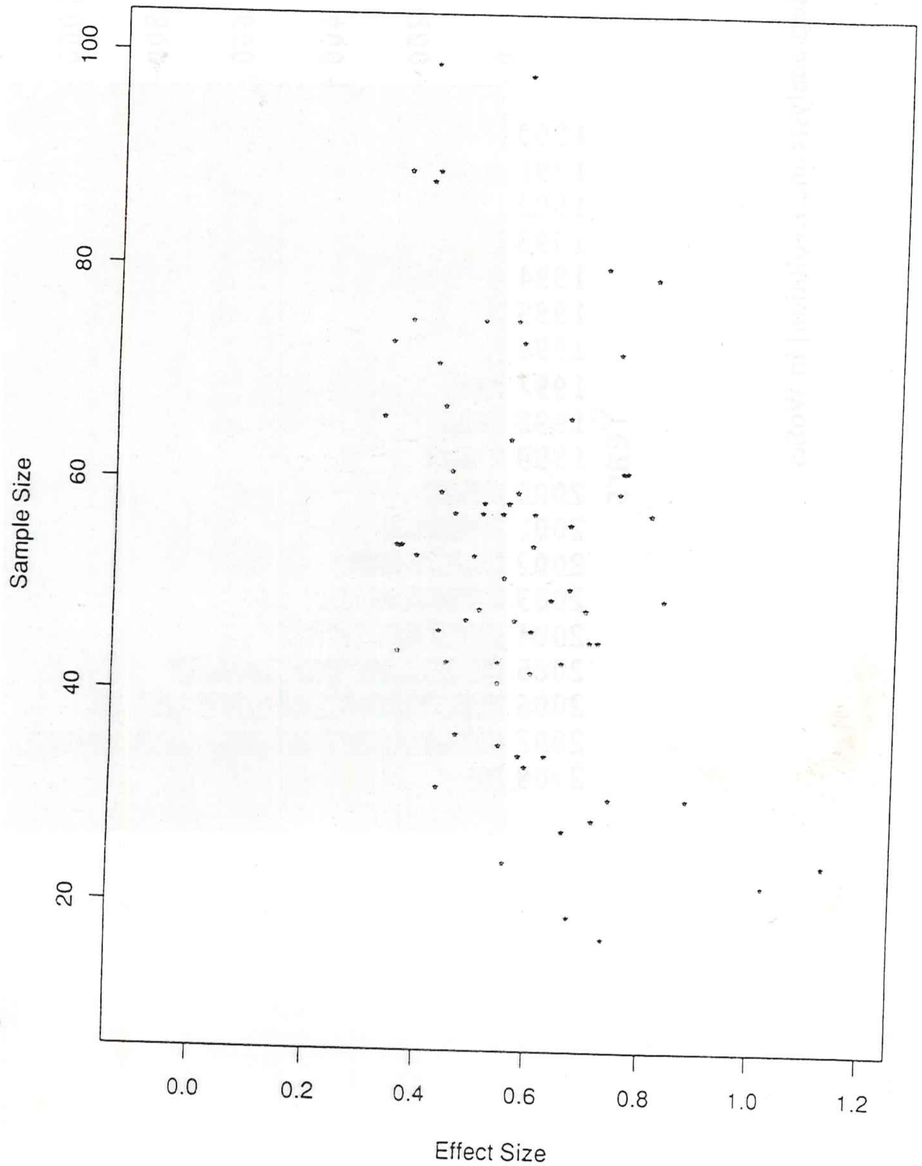


Number of hits for papers (per year) in a search for “meta-analysis” in WoS and their topics.





Type II error rate ≈ 25%....

META - ANALYSIS: the basic procedure....

1) Formulate a problem/hypothesis for the research synthesis

2) Getting the data: the field work...
   * Literature searches (multiple sources)
   * Personal contact with investigators

3) Evaluating the data: judging the quality of single studies
   * Explicitly identify quality/reliability criteria

4) Identify a possible set of effect variables (moderator variables)
   * Typically various “grouping” variables

5) Extract data from single studies
   * Estimate effect size - convert to a common currency
   * Score the quality

6) Statistically analyze variance in effect size across studies
   * Choose model (e.g., fixed or random effects model)
   * V_d = moderator variables + random error (related to quality)
   * Single studies are “weighted” by their quality/reliability in the analysis
   * Statistical inferences

7) Summarize and present your findings
   * Visual and numerical presentations

8) Biological and mechanistic inferences and conclusions

Table 1. Comparison of the outcome of experiments addressing the effects of multiple mating on female egg production, fertility, offspring production and longevity

Female fitness component	Group	Number of experiments	Mean response ratio (RR) with 95% confidence limits
Egg production	No nuptial feeding	69	$1.04 \le 1.11 \le 1.18$
	Nuptial feeding	28	$1.23 \le 1.35 \le 1.49$
	($Q_{B\,1}$=11.58, P<0.001)		
Fertility	No nuptial feeding	37	$1.07 \le 1.20 \le 1.40$
	Nuptial feeding	11	$1.00 \le 1.09 \le 1.22$
	($Q_{B\,1}$=0.68, P=0.453)		
Offspring production	No nuptial feeding	26	$1.26 \le 1.52 \le 1.84$
	Nuptial feeding	18	$1.44 \le 1.83 \le 2.32$
	($Q_{B\,1}$=1.38, P=0.240)		
Longevity	No nuptial feeding	37	$0.79 \le 0.88 \le 0.98$
	Nuptial feeding	22	$0.93 \le 1.06 \le 1.21$
	($Q_{B\,1}$=4.37, P=0.036)		

Response ratios higher than unity indicate positive effects of increased female mating rate and those lower than unity indicate negative effects.

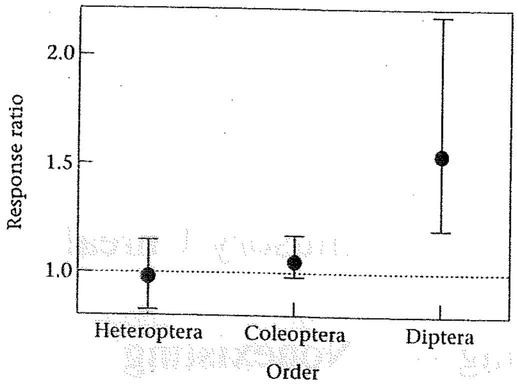


Figure 4. Average effect size (response ratio±95% bootstrap CL) of the effects of increased mating rate on female fertility in three insect orders.

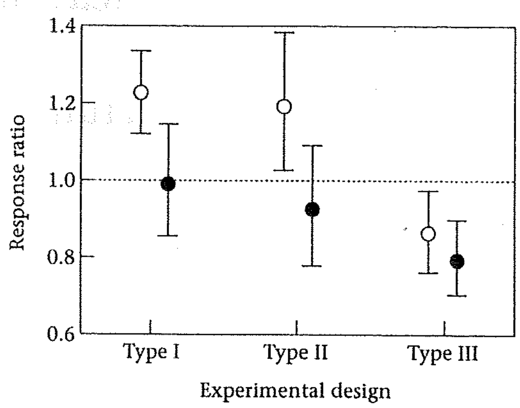


Figure 3. Average effect size (response ratio±95% CL) of the effects of increased mating rate on female egg production (o) and longevity (•) in species where no nuptial feeding occurs. Type I represents studies comparing females mated once versus a few times (A versus B in Fig. 2), type II once versus many times (A versus C in Fig. 2) and type III a few versus many times (B versus C in Fig. 2).

The effects of increased mating rate on eg did not differ significantly between i ($Q_{B\,2}$=2.86, P=0.239). While the effects wei in magnitude among studies involving ($1.15 \le 1.35 \le 1.57$) and Lepidopterans 1.57), they tended to be somewhat lov opterans ($0.82 \le 1.08 \le 1.41$). The ambient i not significantly affect the outcome of (Q_{B1}=0.003, P=0.955) and neither did the experiment, that is whether experiments we entire female life span or not (Q_{B1}=0.12, P=0.727). However, studies in which females were kept constantly with males showed a significantly higher positive effect of increased mating rate ($1.41 \le 1.65 \le 1.94$), compared with studies in which life-long male–female cohabitation did not occur ($1.12 \le 1.24 \le 1.37$; Q_{B1}=8.88, P=0.003). None of these four grouping variables affected the effects of mating rate on fertility ($Q_{B1} \le 0.84$, $P \ge 0.092$; in all three cases; cf. Table 1).

The positive effects of increased mating rate on offspring production (Table 1) did not differ significantly between orders ($Q_{B\,3}$=1.04, P=0.792) and none of the three design variables affected the outcome ($Q_{B1} \le 0.21$, $P \ge 0.648$; in all three cases). In terms of female longevity

orders in the response to increased mating rate 17, P=0.058; $Q_{B\,2}$=1.85, P=0.395 when excluding era from the analysis). Furthermore, neither ilability (Q_{B1}=2.32, P=0.127) nor experimental per se (Q_{B1}=2.87, P=0.089) significantly affected the strength of the effect. In direct contrast to studies of species with nuptial feeding (see above), studies in which females were kept constantly with males had a significantly lower positive effect of increased mating rate ($0.93 \le 1.01 \le 1.10$) than those without constant male–female cohabitation ($1.13 \le 1.23 \le 1.35$; Q_{B1}=9.79, P=0.002). Most importantly, however, the type of experimental design used had a very strong effect on the outcome of primary experiments ($Q_{B\,2}$=22.63, P<0.001) and differences between types of experiment corresponded to our qualitative a priori predictions (see Fig. 3 and Methods). The difference between types of experiment remained strong when the analysis was restricted to studies performed during females' complete life span,