Supplementary materials for 'Can low-quality parents exploit their high-quality partners to gain higher fitness?'

Here, we modify the model in the main text by allowing individuals to base their care effort on both their own and their partner's quality. Mating is still random with respect to quality: effectively, we assume that individuals can perceive their partner's quality after choosing a mate but before deciding how much care to provide. For simplicity, we continue to focus on a 'sealed bid' model, whereby each individual decides how much care to provide independently of its partner's care decisions. All other assumptions are carried over from the analytic model in the main text. In particular, there are two quality levels, high (H) and low (L). New recruits are high-quality with probability p_H. Each breeding season, individuals pair up at random to reproduce. The fitness value of a brood $b(c_1; c_2)$ is an increasing function of the total care $c_1 + c_2$ provided by both partners (see eq. 6 in the main text). The probability $m_Q(c)$ that an individual dies between breeding seasons is a quality-dependent function that increases with the care c that individual provided in the current breeding season (eq. 2 in the main text).

Let us write an individual's care effort as $c_{Q_1Q_2}$, where Q_1 is the individual's own quality and Q_2 is the quality of its current partner. There are thus four co-evolving care effort variables, given by $c = (c_{HH}, c_{HL}, c_{LH}, c_{LL})$. We write $m_{Q_1Q_2} = m_{Q_1}(c_{Q_1Q_2})$ for the probability that a resident individual of quality Q_1 dies after pairing with another resident individual of quality Q_2. Under random mating, each individual pairs with a high-quality or low-quality individual with probabilities N_H/N and N_L/N respectively, where N_Q is the number of individuals of quality Q and N is the total number of individuals in the population. The probability that a high-quality individual dies after breeding is then $\frac{N_H}{N}m_{HH} + \frac{N_L}{N}m_{HL}$. For a low-quality individual the probability of mortality is $\frac{N_H}{N}m_{LH} + \frac{N_L}{N}m_{LL}$. The expected number of deaths after each breeding season is thus:

$$m_{\text{total}} = N_H\left(\frac{N_H}{N}m_{HH} + \frac{N_L}{N}m_{HL}\right) + N_L\left(\frac{N_H}{N}m_{LH} + \frac{N_L}{N}m_{LL}\right) \tag{S1}$$

At demographic equilibrium for large N, the number of deaths of high-quality individuals must equal the number of new high-quality recruits:

$$p_H m_{\text{total}} = N_H\left(\frac{N_H}{N}m_{HH} + \frac{N_L}{N}m_{HL}\right) \tag{S2}$$

Solving this equation simultaneously with the constraint $N_H + N_L = N$ yields:

$$N_H = 2p_H m_{LL}\Big(2p_H m_{LL} - p_H m_{LH} + (1-p_H)m_{HL} + \sqrt{(p_H m_{LH} - (1-p_H)m_{HL})^2 + 4p_H(1-p_H)m_{HH}m_{LL}}\Big)^{-1} N \tag{S3}$$

Now let us consider a mutant individual with care strategies $\hat{c} = (\hat{c}_{HH}, \hat{c}_{HL}, \hat{c}_{LH}, \hat{c}_{LL})$. If the mutant has quality Q, then its expected fitness gain in a single breeding season is:

$$w_Q(\hat{c}_{QH}, \hat{c}_{QL}) = \frac{N_H}{N}b(\hat{c}_{QH}; c_{HQ}) + \frac{N_L}{N}b(\hat{c}_{QL}; c_{LQ}) \tag{S4}$$

The probability that the mutant dies after any given breeding season is:

$$m_Q(\hat{c}_{QH}, \hat{c}_{QL}) = \frac{N_H}{N} m_Q(\hat{c}_{QH}) + \frac{N_L}{N} m_Q(\hat{c}_{QL}) \tag{S5}$$

The expect lifetime fitness of a mutant with quality Q is therefore:

$$W_Q(\hat{c}_{QH}, \hat{c}_{QL}) = \frac{w_Q(\hat{c}_{QH}, \hat{c}_{QL})}{m_Q(\hat{c}_{QH}, \hat{c}_{QL})} \tag{S6}$$

Since the mutant is of quality Q with probability p_H, its expected lifetime fitness averaged over each quality level is simply:

$$W(\hat{c}) = p_H W_H(\hat{c}_{HH}, \hat{c}_{HL}) + (1 - p_H) W_L(\hat{c}_{LH}, \hat{c}_{LL}) \tag{S7}$$

The selection gradients on mutant care strategies are given by:

$$\boldsymbol{s} = \nabla W(\hat{c})|_{\hat{c}=c} \tag{S8}$$

We calculated evolutionarily stable strategies by for care effort by solving $\boldsymbol{s} = \boldsymbol{0}$ numerically. (See Fig. 3 in main text for results)

An agent-based simulation similar to the one designed for the base model and described in detail in the main text was constructed for the modified model. The results for this simulation are given in Fig. S1. The simulation results are superimposed with those of the modified analytical model in Fig. S2.

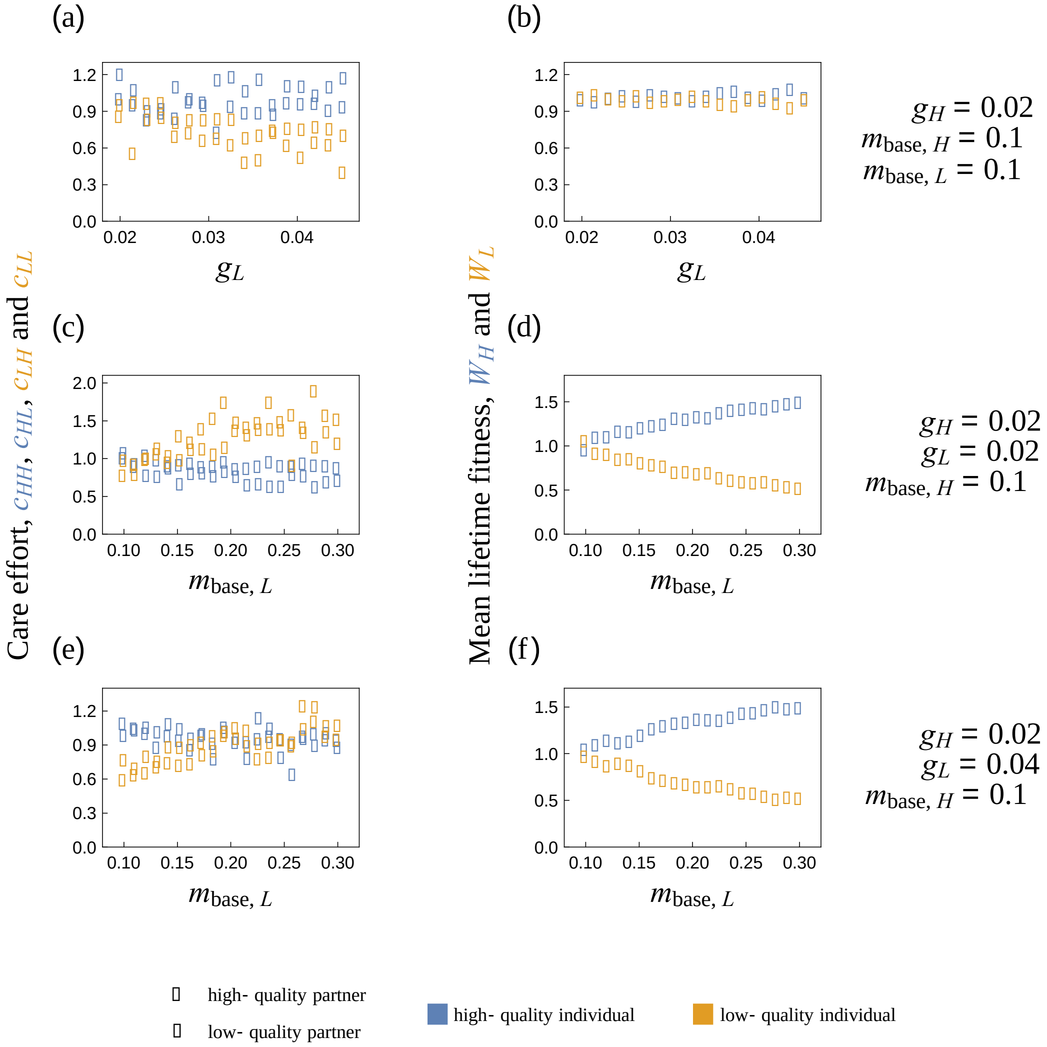

Figure S1: Evolutionarily stable care strategies and lifetime fitness for low- and high-quality individuals, based on the simulations designed for the modified analytical model. $\mathrm{m}_{\mathrm{base},Q}$ determines the baseline mortality of an individual with quality $\mathrm{Q} \in \{\mathrm{H}, \mathrm{L}\}$ (H: High-quality, L: Low-quality), whereas g_Q represents how steeply such an individual's mortality increases its care effort (see figure panels for values). The circles and triangles in panels a, c, e indicate the care effort of high (blue) /low-quality (orange) individuals with high and low-quality partners respectively. Circles in panels b, d, f indicate the mean lifetime fitness of high (blue) and low (orange) quality individuals. Each circle represents the mean fitness and care effort of the last 1000 individuals of that quality that died before the simulation run was terminated. A proportion $p_H = 0.5$ of new recruits were assigned to be high-quality. In the simulations, a population of 1000 individuals evolved for 100 000 breeding seasons. Individual care effort strategies for both quality levels were chosen initially from a normal distribution with $\mu_{\text{initial}} = 1$ and $\sigma_{\text{initial}} = 0.05$. Mutations occurred with a probability of $\pi_{\text{mut}} = 0.1$ per allele per generation and mutational effects had a standard deviation of $\sigma_{\text{mut}} = 0.05$.

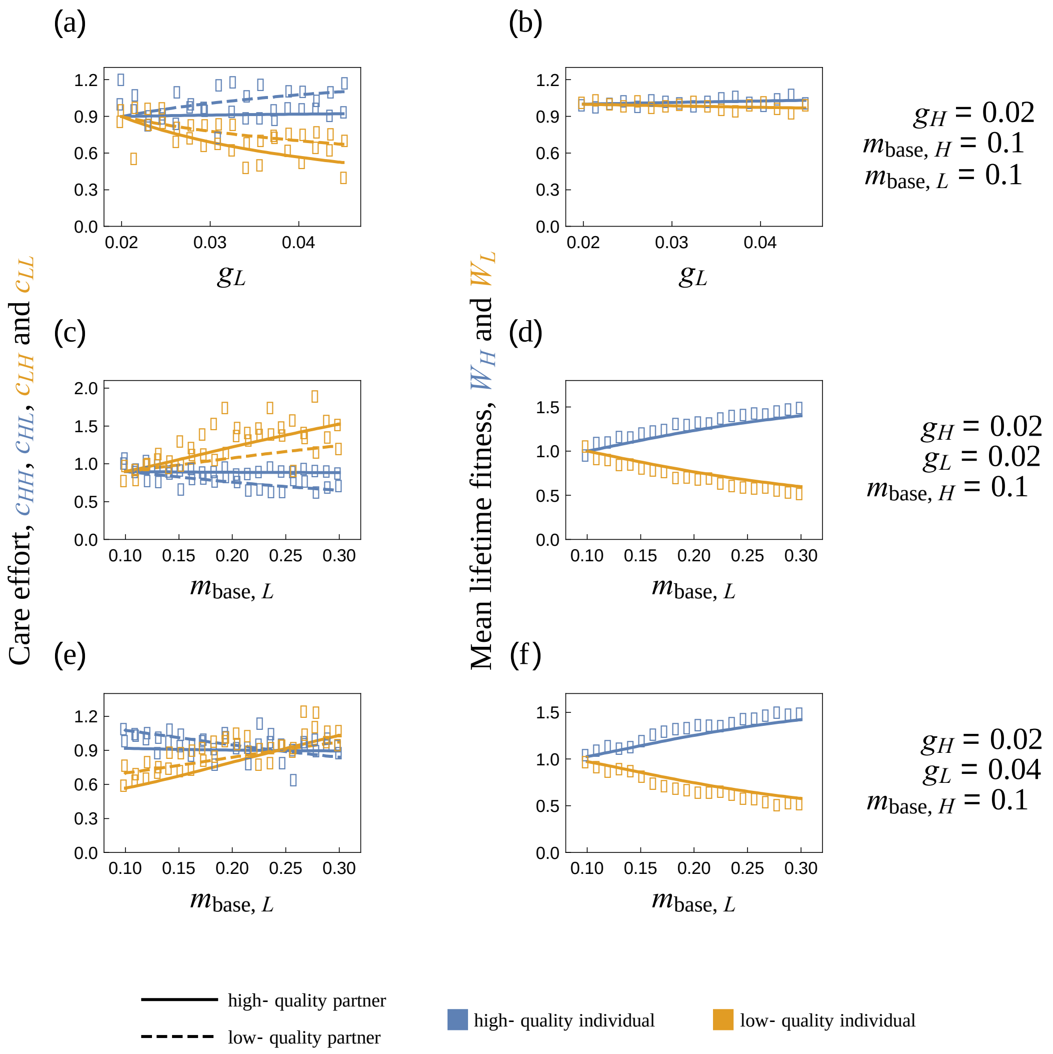

Figure S2: This image superimposes Figure 3 of the main text and Figure S1 of the supplementary material.