These are electronic appendices to the paper by Proulx et al. 2002 Older males signal more reliably. *Proc. R. Soc. Lond. B* 269, 2291—2299.

Electronic appendices are refereed with the text. However, no attempt is made to impose a uniform editorial style on the electronic appendices.

**Appendix A The Proportional Reduction in Survivorship Interpretation of the Handicap Criterion**

As described in the text, the handicap criterion for semelparous species can be stated as

\[
\frac{\partial^2 s(q, a)}{\partial a \partial q} - \frac{\partial s(q, a)}{\partial q} \frac{\partial s(q, a)}{s(q, a)} > 0. \tag{1}
\]

This is equivalent to the statement that \( \frac{\partial s(q, a)}{s(q, a)} \) is an increasing function of \( q \). This is a local condition about the costs of signalling relative to the level of survivorship. Now we note that if this is true for all values of \( a \) then for two values of \( q, q_1 > q_2 \) we have

\[
\frac{\partial s(q_1, a)}{s(q_1, a)} > \frac{\partial s(q_2, a)}{s(q_2, a)}. \tag{2}
\]

We can obtain a measure of the cumulative effect of this difference by integrating over all lower signaling levels to define

\[
P_1(a) = \int_0^a \frac{\partial s(q_1, y)}{s(q_1, y)} dy. \tag{3}
\]

Because the integrand is everywhere increasing in \( q \), the integral is also, giving \( P_1(a) > P_1(0) \). Now we note that \( P_1(a) = \ln(s(q_1, a)/s(q_2, a)) \), and since the log function is an increasing function it must be the case that

\[
\frac{s(q_1, a)}{s(q_2, a)} > \frac{s(q_2, a)}{s(q_2, 0)}. \tag{4}
\]

Thus, when the handicap criterion is met for all relevant signalling levels, the proportional reduction in survivorship for a given advertising level will be greater for low quality males.

**Appendix B: Reproductive Value Decreases with Age**

Williams (1966) first suggested that the effort put into current reproductive success should increase as individuals age. For our model we make a few simplifying assumptions which make it possible to determine how future success (reproductive value) changes with male age. We assume that a maximum age \( T \) limits the lifespan and that age specific (but quality independent) survivorship decreases with age. Thus, the reproductive values of a male in the last and second to last age class are
where \( A(q, t) \) is the optimal signalling level for a male with quality \( q \) at age \( t \) and \( p_x = 1 - \mu_x \) is the quality independent probability of surviving from age \( x \) to \( x+1 \). We wish to show is that \( w_{T-1} > w_T \). First note that at age \( T \) a male will act to maximize fitness so that the choice of \( a = A(q, T) \) maximizes \( s(q, a) \times M(a) \).

We can see that \( w_{T-1} > w_T \) by noting that if the choice \( a = A(q, T-1) = A(q, T) \) were made then
\[
w_{T-1} = s(q, A(q, T))M(A(q, T))\left(p_{T-1}s(q, A(q, T)) + 1\right) > w_T.
\]

So even if males use the same signalling strategy at \( T-1 \) as at time \( T \) then \( W_{T-1} > W_T \), so the optimal choice for \( A(q, T-1) \) must yield greater fitness, and \( W_{T-1} > W_T \).

We also wish to show that for this life history \( w_{T-1} > w_T \) for all ages. We have already established that \( w_{T-1} > w_T \) and can use induction to prove our result. By assumption we have \( p_{T-1} > p_T \), i.e. senescence acts to lower survival rates as individuals age. Now we show that if \( w_T > w_{T-1} \) then \( w_{T-1} > w_T \). The reproductive values at ages \( t \) and \( t-1 \) are
\[
\begin{align*}
w_T &= s(q, A(q, t))M(A(q, t)) + p_T s(q, A(q, t))w_{T+1} \\
w_{T-1} &= s(q, A(q, t-1))M(A(q, t-1)) + p_{T-1} s(q, A(q, t-1))w_T.
\end{align*}
\]

Now we can again ask what the value of \( w_{T-1} \) is when we let \( A(q, t-1) = A(q, t) \).
\[
\begin{align*}
w_{T-1} &= s(q, A(q, t-1))M(A(q, t-1)) + p_{T-1} s(q, A(q, t))w_T, \tag{10}
\end{align*}
\]

and because both \( p_{T-1} > p_T \) and \( w_T > w_{T-1} \) this term is greater than \( w_T \). The optimal choice of \( A(q, t-1) \) must not decrease, so \( w_{T-1} > w_T \). Thus, \( w_T \) is a decreasing function of age.

**References**