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 as

$$\frac{\partial^2 s(q,a)}{\partial a \partial q} - \frac{\frac{\partial s(q,a)}{\partial a}\frac{\partial s(q,a)}{\partial q}}{s(q,a)} > 0. \qquad (1)$$

This is equivalent to the statement that $\frac{\frac{\partial s(q,a)}{\partial a}}{s(q,a)}$ 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

$$\frac{\frac{\partial s(q_1,a)}{\partial a}}{s(q_1,a)} > \frac{\frac{\partial s(q_2,a)}{\partial a}}{s(q_2,a)}. \qquad (2)$$

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

$$P_i(a) = \int_0^a \frac{\frac{\partial s(q_i,y)}{\partial a}}{s(q_i,y)} dy. \qquad (3)$$

Because the integrand is everywhere increasing in q, the integral is also, giving $P_1(a) > P_2(a)$. Now we note that $P_i(a) = ln(s(q_i;a/s(q_i;0))$, and since the log function is an increasing function it must be the case that

$$\frac{s(q_1,a)}{s(q_1,0)} > \frac{s(q_2,a)}{s(q_2,0)}. \qquad (4)$$

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

$$w_T = s(q,A(q,T))M(A(q,T)) \quad (5)$$

$$w_{T-1} = s(q,A(q,T-1))M(A(q,T-1)) + p_{T-1}s(q,A(q,T-1))s(q,A(q,T))M(A(q,T)), \quad (6)$$

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 $w_{T\text{-}q} > w_T$. 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 $w_{T\text{-}1} > w_T$ by noting that if the choice $a = A(q,T\text{-}1) = A(q,T)$ were made then

$$w_{T-1} = s(q,A(q,T))M(A(q,T))(p_{T-1}s(q,A(q,T)) + 1) > s(q,A(q,T))M(A(q,T)) = w_T. \quad (7)$$

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

We also wish to show that for this life history $w_{t\text{-}1} > w_t$ for all ages. We have already established that $w_{t\text{-}1} > w_T$ and can use induction to prove our result. By assumption we have $p_{t\text{-}1} > p_t$, i.e. senescence acts to lower survival rates as individuals age. Now we show that if $w_t > w_{t+1}$ then $w_{t\text{-}1} > w_t$. The reproductive values at ages t and t - 1 are

$$w_t = s(q,A(q,t))M(A(q,t)) + p_t s(q,A(q,t))w_{t+1} \quad (8)$$

$$w_{t-1} = s(q,A(q,t-1))M(A(q,t-1)) + p_{t-1}s(q,A(q,t-1))w_t. \quad (9)$$

Now we can again ask what the value of $w_{t\text{-}1}$ is when we let $A(q, t\text{-}1) = A(q, t)$.

$$w_{t-1} = s(q,A(q,t))M(A(q,t)) + p_{t-1}s(q,A(q,t))w_t, \quad (10)$$

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

References

Williams, G. C. 1966. Adaptation and Natural Selection: A critique of some current evolutionary thought. Princeton University Press, Princeton, New Jersey.