Appendix C

Negative effects of increasing maturation rate on per capita recruitment

For some species, declines in age at maturity have been associated with reduced size at maturity, which may be associated with lower levels of per capita recruitment, such as through reduced energy investment into fecundity or rearing of young (Stearns and Koella, 1986; Murawski et al. 2001). To simulate this tradeoff between the rate of maturation and per capita recruitment, we modify α in eqn. 2 to model a proportional decline in α_t, the maximum per capita recruitment at time t, as m_t increases. The cost of faster maturation is quantified by $d\alpha/dm$, and higher values of this parameter thus correspond to a greater negative effect of reduced age at maturity on the number of offspring produced by an adult:

$$\alpha_t = \alpha\left(1 + \frac{d\alpha}{dm}\frac{m_t - m_{min}}{m_{max} - m_{min}}\right) \qquad \text{(C.1)}$$

for $-1 < d\alpha/dm \leq 0$.

Note that α_t is highest (i.e., $\alpha_t = \alpha$) at $m_t = m_{min}$, and is minimized at $m_t = m_{max}$. Examining a range of values for $d\alpha/dm$, we determine when the cost of maturing faster becomes too great for compensatory maturation to enhance the persistence of the population (h_c, h_{half}) by comparing populations following a Type I and a Type 0 ($m_t = \mu = m_{min}$) functional form.

We find that for populations of both short and long-lived individuals, compensatory increases in maturation rates (from m_{min}=0.5 to m_{max}=1) enhance population persistence even when they are accompanied by nearly a two-fold decline in per capita recruitment rates (Fig. C1). Generally, the benefits of compensatory increases in maturation rates on persistence increased for populations with a lower baseline maturation rate (m_{min}) and/or lower survival rates, and such populations could thereby accept a greater cost of earlier maturity. However, we note that in all cases, higher values of dα/d*m* reduced the difference in harvest levels between h_{half} and h_c, reflecting a more abrupt collapse in population size as harvest levels approach h_c.

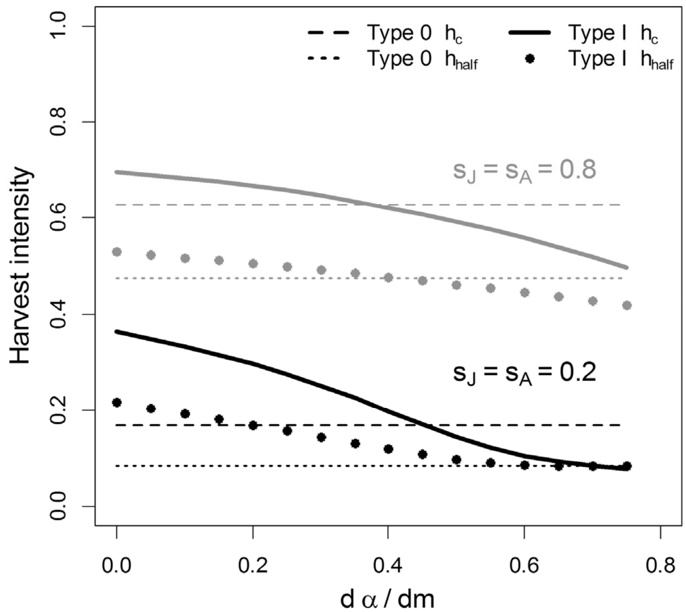

FIG. C1. Effects of declining per capita fecundity levels with compensatory increases in maturation rates on the harvest levels at which adult abundance declines by 50% (compared to zero harvest; h_{half}, dotted lines), and at which populations collapse (h_c, solid and dashed lines). Higher values of dα/d*m* reflect a greater decrease in maximum per capita recruitment levels (from α=10 at m_t=m_{min}) as m_t increases from m_{min}=0.5 to m_{max}=1 under a Type I density-dependence in maturation rates (bold curves). Horizontal lines give values of h_c and h_{half} for a Type 0 functional form, with m_t fixed at μ=0.5. Grey and black curves show these trends for populations with high and low survival levels, respectively.

LITERATURE CITED

Murawski, S. A., P. J. Rago, and E. A. Trippel. 2001. Impacts of demographic variation in spawning characteristics on reference points for fishery management. ICES Journal of Marine Science 58:1002–1014.

Stearns, S. C., and J. C. Koella. 1986. The evolution of phenotypic plasticity in life-history traits: predictions of reaction norms for age and size at maturity. Evolution 40:893–913.