Issues related to Biological Inputs to Blacktip *and* Sandbar assessments

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Calculations based on the mean values agreed to by the data workshop as the best estimates for life-history parameters produce steepness values less than 0.2, the mathematical limit for that parameter. The only life history parameter estimated in the model is pup-survival; if the base case values for maturity, pup-production, and natural mortality at age-1+ are not altered, then in order for steepness to be above 0.2, pup survival must be >0.8 (or in the case of the Blacktip Gulf of Mexico model, pup survival must be >0.9). Considering that survival at age 1 was estimated to be in the range of 0.7-0.77 for these stocks, pup survivals of 0.8-0.9 may be unrealistically high.

The minimum criterion for steepness can be achieved in any number of ways. For example, a greater number of pups produced per mature female, a much younger maturity ogive, or lower natural mortality for ages one and older—or any combination of these adjustments to maturity, mortality, and fecundity. Although there is a physical limit to the number of pups a pregnant female can carry, one could argue that increasing the number of pups to the upper limit or beyond permits the possibility that there are reproductive contributions from an unexploited/unsampled portion of the stock, or possibly that additions to the population are being contributed by the Mexican stock. This was the approach taken in 2002 for this model (p.22 and p24, 2002 Report), and it was adopted again for this assessment.

The base value for natural mortality for ages one and older as recommended by the data workshop life-history group was derived from two methods that produce age-specific estimates (one based on von Bertalanffy growth equation parameters, the other, a weight-based method). Uncertainty in this parameter is likely, although it was fixed at age-specific values for the base model. A range of age-constant values for M was tested to find an upper bound that produced steepness values > 0.2 (holding all other parameters constant). For Sandbar, M must be less than 0.13 for all ages; for Blacktip, M must be less than 0.2 for the Gulf stock and less than 0.17 for the Atlantic stock. Although only an age constant value was explored, it is well established from density-independent, demographic elasticity analysis that mortality of juveniles would be the life history trait most likely to have the greatest impact on population growth rates and , by extension, steepness (see Cortes 2002, e.g). This is because mortality rates of juveniles are believed to be higher than those of adults and given that sharks typically have a protracted juvenile stage (many age classes), there may be more room for compensation. In contrast, if one assumes that a density-dependent response to exploitation would come from increased survival of age-0 sharks alone, it could be argued that age-0 mortality can approximate adult mortality (i.e., decrease in response to decreased stock levels).

A biological argument is difficult to form for lowering the maturity ogive too dramatically. But for the sake of exploring each life history parameter, a knife-edge maturity ogive was tested for each of the stocks while keeping all other parameters recommended by the data workshop fixed. For Blacktip, all sharks must be 100% mature by age 4, while Sandbar must be 100% mature by age 16.

If the assessment workshop decides that an age-structured model is the most appropriate to determine the status of the shark resources, then an adjustment to one or more of the biological inputs (fecundity, maturity, pup survival, and M for ages 1^{+}) is necessary for the models to run, and the uncertainty in these biological parameters will need to be considered in the discussion of the most appropriate choice. It is likely that this choice will influence projection outcomes.

The necessary adjustments to these biological parameters can be recast in terms of the maximum reproductive rate of a population at low density, α (Myers et al. 1999). The parameter α is related to steepness as:

$$\alpha = \frac{4 * steepness}{1 - steepness} \ .$$

The lower bound on steepness was 0.2, which translates into a lower bound of 1 for α. In terms of the life history parameters, α is:

$$\alpha = S_0 \varphi_0 = S_0 \sum_{age} fec_{age} mat_{age} \prod_{j=1}^{age-1} e^{-M_j} = S_0 \, pups \sum_{age} mat_{age} \prod_{j=1}^{age-1} e^{-M_j} \ .$$

In the above, S_0 is first year survival, fec_{age}=pups produced per female (assumed to be age constant for this assessment), and mat_{age} is maturity at age. Given the lower bound of 1 for α, then for fixed maturity at age and M at age, one can see that there is a direct increase in α by changing either first year survival or the number of pups produced per female. This relationship can be used to evaluate if proposed life history parameter combinations satisfy lower bounds on the maximum reproductive rate, which is equivalent to satisfying the lower bound on steepness.

References

Cortés, E. 2002. Incorporating uncertainty into demographic modeling: application to shark populations and their conservation. *Conservation Biology* 16:1048-1062.

Myers, R. A., K. G. Bowen, and N. J. Barrowman. 1999. Maximum reproductive rate of fish at low population sizes. Can. J. Fish. Aquat. Sci. 56:2404-2419.