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Replacement Yield of Hooded Seals in the Northwest Atlantic

by

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Introduction

The purpose of this document is to calculate the replacement yield of hooded seals in the northwest Atlantic using a simple population model.

The Model

The population dynamics are assumed to be described by a Leslie matrix model using the following assumptions:

1. Adult female natural mortality, m, is constant.
2. Natural mortality during the first year of life is between 1 and 3 times adult mortality.
3. Natural mortality, m, was assumed to be between 0.07 and 0.13 (NAFO 1983).
4. Sex ratio at birth is 50:50.
5. The matrix model only considers females.
6. The sexual maturity is assumed to be constant over time. Females begin to give birth at age 4; 35% of the females are mature at age 4, 60% at age 5; 75% at age 6; 80% at age 7; 90% by age 8 and 100% by age 9 (based on data from Newfoundland 1979 and 1985, Stenson unpblished data).
7. If females reproduce, they have one pup a year, and the pregnancy rate is 94% (Born 1982).
8. The maximum lifespan is assumed to be 25.

The replacement yield is simply the harvest that would result in no population growth at a stable age distribution. We consider three cases: (1) pup harvest only, (2) adult harvest, and (3) a harvest that is 60% pups. We must assume that the impact of adult hunting mortality is equal on all ages older than 1.

The Model-Replacement Yield

Let P_j be the survival probability of members of age class j. Let F_i be the fertility coefficients, i.e. the number of age class 1 individuals at time $t+1$ per age class i individuals at time t.

The characteristic equation is

$$1 = \sum_{i=1}^{s} F_i \lambda^{-i} \left(\prod_{j=1}^{i-1} P_j\right),$$

where s is the maximum age and λ is the largest real eigenvalue of the projection matrix. The population does not grow when $\lambda = 1$. The mortality associated with a harvest such that $\lambda = 1$ will be defined here as the replacement yield. Replace yields were estimated in terms of the ratio of the catch to the total pup production. This approach allows the estimates of replacement yield to be made independently of estimates of pup production.

If the harvest is only on pups we can easily do the above calculations to determine the number of pups that could be taken from an equilibrium age-structured population so that the population remained stable. This involves calculating the harvest number that produces a stable population under different assumptions.

For the case of a hunt on adults only, we calculate the adult hunting mortality, f, that would be required to produce a $\lambda = 1$. For a given a present pup production, this will produce an "equilibrium" harvest.

The case in which the hunt takes 60% pups is a little more difficult to calculate because it is a two stage process. For a given level of pup harvest we then estimate the corresponding adult hunting mortality that results in a adult harvest of 60% of the pup harvest. A root finding algorithm is then used to determine the pup harvest in this case that results in a solution to the equation above with $\lambda = 1$.

Results and Discussion

The resulting harvest rates (Table 1), given in terms of the pup production, depends greatly on the mortality rates.

TABLE 1. Replacement harvest expressed as a proportion of pup production (catch/pup production) for $m_0 = m_1$ and $m_0 = 3m_1$.

	Mortality			
	$m_0 = m_1$		$m_0 = 3m_1$	
Catch	0.07	0.13	0.07	0.13
Pups only	0.72	0.44	0.68	0.27
60% pups	0.69	0.37	0.61	0.20
1+ only	0.62	0.30	0.51	0.14

To determine the actual harvest levels, these rates (Table 1) can be multiplied by the results from survey estimates of pup production such as those reported by Stenson et al. (1994) for Newfoundland in 1990 (82,000, SE =12,600), Hammill et al. (1992) in the Gulf of St. Lawrence in 1991 (2,000, SE=190), or Bowen et al. (1987) for Davis Strait in 1984 (18,600, 95% C.I. 14,000 - 23,000).

The major uncertainly of the analyses is the adult and juvenile mortality rates. If a substantial hunt is undertaken, an unbiassed age sample should be obtained so that present adult mortality rates can be estimated.

Caveats and Limitations

The following are limitations of the simple model:

1. There is no density-dependence in the model. As the population size increases mortality may increase or birth rates may decrease. If either process occurs our estimate of yield may be biased.
2. There is unknown uncertainty caused by the lack of a current age structure.
3. The adult harvest is assumed to result in a mortality rate that is constant with age. It is more likely that younger animals would be taken preferentially because they are inexperienced. If we used an adult hunting mortality that was greater on younger animals, then we would obtain larger estimates for the replacement yield for the adult hunt.

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