Snow Geese: Can we pay down the mortgage?

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We are pleased that Professor Cooke and coauthors (Cooke et al., this volume) have focused on increased harvest of adults as the most efficient way to reduce numbers of Lesser Snow Geese *Anser caerulescens caerulescens* (hereafter referred to as Snow Geese), as was proposed by Rockwell et al. (1997). What remains to be determined is how many adult Snow Geese need to be harvested per year to accomplish the goal of preventing further destruction of Arctic ecosystems. Herein, we will show that despite Cooke et al.'s (this volume) commendable use of current data, some of which were unavailable to Rockwell et al. (1997), they have produced estimates of required harvest that, in absolute terms, are more erroneous (too high) than were those of Rockwell et al. (1997) (too low). First, we will note how several of their assumptions have affected the accuracy and validity of their estimates. Because our goal is to aid in the solution of a current problem, we will limit our commentary to their present-day rather than their historic estimates. Second, we will show that a simpler approach to meeting the goal of reducing the mid-continent Snow Goose population to its target level by the year 2005 is via a constant annual harvest. Finally, we will give our best "guesstimate" of that harvest.

Rockwell et al. (1997) showed that adult survival (s_a) has the greatest impact on Snow Goose population growth rate. Subsequent elasticity analyses (R.F. Rockwell, unpubl. data) show that this is true even when the original model is modified to incorporate density dependence, environmental stochasticity, and metapopulation structure. Thus, it is not surprising that s_a remains a key variable in Cooke et al.'s (this volume) analyses. They estimate that this variable currently ranges from 0.89 to 0.94 and base their harvest projections on this range. Although we can accept the lower estimate, the upper one is far too high. One of the best estimates of the growth rate of the mid-continent population of Snow Geese is based on Kerbes' breeding colony surveys done in the early 1970s and late 1990s (R.H. Kerbes, pers. commun.) and assumes no systematic change in breeding propensity or nesting success. Although we agree with Cooke et al. (this volume) that there is some variation among the growth rates of specific colonies and some variance associated with an overall estimate, the current point estimate for the overall mid-continent population is between 1.053 and 1.057 (R.F. Rockwell, unpubl. data, and Cooke et al., this volume, respectively; both based on R.H. Kerbes, pers. commun.). Substituting $s_a = 0.94$ into Rockwell et al.'s (1997) projection matrix for the mid-continent population (rather than the original $s_a = 0.88$) leads to an estimated growth rate of $\lambda = 1.11$, which far exceeds the current estimate of $\lambda \cong 1.05$. Of course, it is possible that estimates of reproductive success and/or juvenile survival in that original matrix were too high for the present; perhaps they declined during the period when adult survival purportedly increased to 0.94, thereby reducing population growth rate in a compensatory fashion. However, given the low elasticity of those variables, such a decline would have had to have been large. We examined this further and found that a 42% reduction in either variable (to 58% of its original value) or a 24% reduction in both would be required to compensate for the 7% increase in adult survival from 0.88 to 0.94. We feel that such an increase is unrealistic, especially in the face of unpublished analyses (cited in Cooke et al., this volume, Section 3.2.3) that age ratios and fecundity of the mid-continent population have not changed over time. We feel that their estimate of 0.94 for adult survival is biologically unrealistic and that harvest projections from it are not meaningful. (No doubt about it, Snow Geese are survivors, but parrots and albatrosses they ain't.)

A stated goal of the Arctic Goose Habitat Working Group was "to reduce the population growth rate to some sustained level with $\lambda < 1.0$" (Rockwell et al. 1997: 99) and monitor the resulting population size and its continuing impact on the Arctic ecosystem. To provide managers with some flexibility, scenarios were developed for reductions in adult survival that led to population growth rates of $\lambda = 0.85$ and $\lambda = 0.95$. Cooke et al. (this volume) assert that it may be prudent to use the estimated adult survival associated with $\lambda = 0.85$ "to ensure that realized growth rate is actually $\lambda < 1.0$." This appears to stem, in part, from their uncertainty as to whether the original projection matrix, based primarily on data from La Pérouse Bay, is accurate for the entire mid-continent population, owing to potential heterogeneity among nesting colonies in reproductive success or survival or to changes in these variables over time. However, as indicated above, their analyses found no change in age ratio (or fecundity) over time. Moreover, their most reasonable estimate of current adult survival of 0.89 (the one they use for their "best" projection — Section 4.4) is not that much higher than the original value of 0.88 and, if substituted, would lead to the mid-continent population growing at $\lambda = 1.06$. However, given that such a matrix differs from the original only by adult survival, the estimate of adult survival required to achieve $\lambda = 0.95$ remains the same at $s_a = 0.795$. As such, harvest projections based on this reduced value for adult survival should lead to a declining mid-continent population.

In fact, if we view the matrix as a mean with elements that vary stochastically over time and incorporate the reduced adult survival of $s_a = 0.795$, then the average growth rate of the stochastically growing population will actually be less than $\lambda = 0.95$, and the population will decline faster than 5% annually (average growth rate *sensu* $\ln(\lambda)$ of Caswell [1989], and Tuljapurkar [1990]). Although we agree that using adult survival associated with a deterministic growth rate of $\lambda = 0.85$ will reduce the population faster, it is not clear to us why such an approach is more prudent given that the goal is to reduce the population size with $\lambda < 1.0$. Clearly, use of the $\lambda = 0.85$ adult survival target will require a higher annual harvest.

Cooke et al. (this volume, Section 4.4) provide a "best estimate" of 2.1 million geese as the 1999 harvest required to adequately reduce the population, assuming a current value for adult survival of 0.89 and a target survival value of 0.72, corresponding to $\lambda = 0.85$. They note that there is uncertainty associated with this and suggest that the real estimate could be between 1.5 and 3.4 million birds. While we generally applaud the presentation of ranges, in this case it is misleading. The upper estimate assumes that current adult survival is 0.94 and uses the target survival value associated with $\lambda = 0.85$. As noted above, the former is biologically unrealistic and the latter is more extreme than needed to begin reducing the population. Using their method but restricting it to the more reasonable adult survival estimate of 0.89 and an average of their two estimates of recovery rate, we find the limits of 1.6 and 2.5 million geese, corresponding to reduction rates of 5% and 15%, respectively, in the first year. We think this is a biologically more meaningful range of estimated harvest given a goal of reducing the mid-continent population by a fixed annual rate.

To avoid its misuse, it is important to stress that Cooke et al.'s (this volume) estimate of 2.1 million geese is the total harvest for the *first year only* of a fixed annual rate reduction program. As is thoroughly explained in Rockwell et al. (1997), because such programs assume that the hunter harvest rate is a constant over the management period, the number of geese in the total harvest will necessarily decrease each year as the population declines. Representatives of at least one group that is critical of Snow Goose management plans have (inadvertently?) multiplied such first-year estimates by the projected management period to obtain absurdly high values for total harvest and then used them in arguments against the management program.

Although the foregoing method will lead to a decline in Snow Goose numbers, we feel that a more realistic alternative is to reduce the population by a fixed *number* rather than by a fixed *rate* each year. This is analogous to paying down a mortgage whereby a fixed amount is paid each month (or year) so as to pay off the principal in a fixed time given a fixed interest rate. Notably, in the first year of the mortgage, most payment goes to interest costs and little to reducing the principal. In subsequent years, increasing amounts go towards the principal.

For mid-continent Snow Geese, if we use Cooke et al.'s (this volume) adult fall flight estimate for 1994 of 5.6 million, their 20% growth rate for 1994–1999 (i.e., an annual interest rate of 3.7% [$\lambda = 1.037$]), and their estimate of 27% juveniles in the fall flight, then the projected total fall flight in 1998 was 8.87 million. This is the principal, and the question becomes: "How large is the annual payment (harvest) required to reduce a mortgage of 8.87 million Snow Geese to a specified target in a fixed time period given a 3.7% interest rate?" Unlike most mortgages where the target is zero, the goal of the Arctic Goose Habitat Working Group (Batt 1997: 118) was to reduce the mid-continent population to 50% of its current numbers by 2005. Using Abraham and Jefferies' (1997) upper estimate for 1994 of 6 million (which was then "current"), the target is 3 million, which is about one-third of the now-current number. Given these estimates and the most recent (1997) harvest statistics (required since the population growth rate reflects reproductive success and mortality, some of which stems from harvest), simple calculations show that the required annual harvest (payment) is 1.41 million.

We summarize an example projection using the fixed-number method in Table 1. The declining annual population growth rate through 2005 reflects the shift, noted

Table 1
Projections of mid-continent Lesser Snow Geese from 1998 through 2006 using a fixed annual total harvest number and estimates in Cooke et al. (this volume)

Year	Total fall flight population (millions)	Total harvest[a] (millions)	Annual growth rate
1998	8.87	1.41	
1999	8.33	1.41	0.94
2000	7.72	1.41	0.93
2001	7.01	1.41	0.91
2002	6.20	1.41	0.88
2003	5.28	1.41	0.85
2004	4.21	1.41	0.80
2005	3.00		0.71
1997 harvest rate[b]			
2005	3.00	0.25	
2006	3.11		1.037
Readjusted harvest[c]			
2005	3.00	0.34	
2006	3.00		1.00

[a] The estimate of 1.41 million is from $0.8 \times C$, where 0.8 is the retrieval rate and C is:

$$C = \frac{N_t \phi^i \lambda^i - N_{t+i}}{\sum_{j=1}^{i} \phi^{j-1} \lambda^j}$$

where:
$N_t = 8.87$ million
$N_{t+i} = 3.00$ million
$i = 7$
$\lambda = 1.037$
$\phi = 1 + [(0.73 \times 0.0915) / 0.635]$

where:
0.73 is the proportion of adults in fall flight
0.0915 is hunter kill rate estimated from 1997 harvest and fall flight
0.635 is the proportion of adults in the harvest (correct correspondent to Cooke et al.'s [this volume] harvest age ratio of 0.575)

[b] If harvest in 2005 is reduced to the rate associated with the 1997 harvest, the population will grow.

[c] If harvest is readjusted using the fixed-number approach, the population does not grow.

above, from "more interest" in the payment to "more principal" as the mortgage period proceeds. To compare projections from this method to one based on a fixed rate of reduction, we note that our example corresponds to an overall fixed annual reduction rate of 14.5% ($\lambda = 0.857$). Using the corresponding target annual adult survival rate of 0.725 from Rockwell et al. (1997) and the same example estimates from Cooke et al. (this volume), the first-year total harvest required under a fixed-rate program is 2.12 million — a value 50% higher than that required under the fixed-number method.

It is important to stress that our method achieves the target population size of 3 million in 2005 using a fixed total number of geese in the annual harvest. If that fixed harvest is removed after the target date and harvest returns, for example, to a total based on the harvest rate that existed before the reduction program, then the population will begin growing at the original rate (Table 1). Again using the 1997 harvest rate estimates as a basis, if we readjust harvest from 0.25 million to a fixed total of 0.34 million, the population does not grow ($\lambda = 1.0$). The small size of this adjustment (0.09 million) shows how reasonably the mid-continent population can be managed at a level more in tune with its Arctic ecosystem *once its numbers are reduced*. This small number also provides some insight as to how the population might have gotten out of hand. Small payment shortfalls will be quickly translated into increased principal and rapidly accruing compound interest. Such extreme sensitivity is an inherent property of fixed-number harvests and is the reason management plans using such strategies must be closely monitored (e.g., Cooch et al., in review). We note that close monitoring is also required for fixed-rate strategies, as explained in Rockwell et al. (1997).

We think that reducing the Snow Goose population by a fixed number per year is a sensible approach given that there is a relatively fixed number of Snow Goose hunters who will hunt a relatively fixed number of days per year. Further, we think that an annual harvest of 1.41 million Snow Geese is easily attainable by these hunters and, perhaps, more easily monitored than recovery and harvest rates associated with fixed-rate strategies. In the 1997–1998 season, before any special seasons or regulations were in place, hunters harvested 720 000 mid-continent Snow Geese, more than 50% of the target number. Information provided by representatives from the Central and Mississippi flyways indicates that more than 1 million Snow Geese were harvested during the 1998–1999 season. This is a remarkable accomplishment, given that only 14 of 24 states and one Canadian province used at least some of the special options that became available for only the latter part of the 1998–1999 season.

We are confident that, given the opportunity, hunters can easily exceed the target harvest of 1.41 million Snow Geese, especially in the first several years of this endeavour. Note that any excess harvest in the first years reduces the need to harvest as much in later years (analogous to making "extra" payments on a mortgage). Such savings will also accrue from the adult bias in harvest that appears to occur, at least initially, using electronic callers (A.D. Afton, pers. commun.) or that which should occur in low-productivity years. The increased harvest not only will begin solving the problem but also will provide part of the data critical for monitoring the mid-continent population. We must now focus on the various analyses and research projects that are needed to evaluate our first attempts to manage an overabundant waterfowl population and to improve our estimates of its demographic variables. There is much that can be learned about Arctic ecosystems, Snow Goose dynamics, Snow Goose behaviour, and hunting. So, let's just keep paying down the mortgage.

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