Resolving an issue arising from translocation strategy for saving the black rhino

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Abstract
In response to the alarming decline in black rhino populations conservationists developed a plan to grow the South African population to 2000 in the shortest time possible. This was to be achieved by removing animals from the high-density population in the Umfolozi-Hluhluwe Game Reserve. These animals would be translocated to new reserves with more abundant resources. This reduction in intra-specific competition would result in faster growth rates. The magnitude of proposed removals, however, did not take into consideration some important perspectives of the managers of the source population. In this paper we attempt to provide insight into the trade-offs between the needs and perspective of source managers and those of the proponents of maximum translocation.

Keywords:***bi-objectives, simulation, conservation, black rhino, translocation***

I. Introduction

Between the years 1900 and 2000 the world population of black rhinoceros (*Diceros bicornis)* declined from over a million down to 2400. In just two decades from 1970-1990 twelve African countries lost their entire populations. Alarmed at these figures some African countries developed recovery plans. The plan in South Africa was to achieve a target of 2000 rhino as quickly as possible [1].

By far the largest population of black rhino is concentrated in the Umfolozi- Hluhluwe Game Reserve (UHGR). It has long been recognised that specific growth rates decline with increasing population density [2]. The consequence of intra-specific competition in the UHGR with its relatively high population density is that fecundity and mortality rates are lower and higher, respectively, than is optimal for maximising the overall population growth rate.

The plan to achieve the 2000 target in South Africa involves the translocation of animals from the UHGR to new reserves with suitable habitat but with no black rhino populations. The reduced intra-specific competition for both the source and translocated populations would lead to faster growth rates.

The determination of the numbers, age and sex that should be translocated from a source population to new reserves is an optimisation problem. The objective is to minimise the time taken for the total population in South Africa to reach the target of 2000 black rhino. A solution to this problem was determined in earlier work[3]. The solution, however, neglected to take into account the perspective of the managers at the UHGR. Their cooperation is vital for the successful implementation of the policy. This paper revisits the earlier work [3] but includes the managers' perspective in addressing the problem.

II. One Goal, Two Objectives

While both are committed to the conservation of black rhino, managers of the source population and the proponents of translocation have different perspectives.

The managers' perspective

Managers would like to keep the source population high for a number of reasons

- Their conservation skills with black rhino are proven
- High population density increases the chance

of a tourist encountering a black rhino during a visit to a reserve. This helps to maintain public awareness of black rhino and hence public support for their conservation

- If the growth rate one year is low managers perceive that the population is just surviving so removing animals is undesirable
- There is a sense of ownership of the animals

The translocation proponents' perspective

Small increases in the growth rate can make a big difference when population numbers are low. It is therefore important to utilise to the full any opportunity that might yield increases in the growth rate. Translocating animals away from high to low-density areas offers one such opportunity. The preference of this group is for translocation rates to be maximal.

There is clearly some tension between the two perspectives. In some respects this is a bi-objective optimisation problem: minimize the time to achieve the 2000 target while maximizing the source population. A compromise agreement between the parties is more likely to be achieved with a better understanding of the trade-offs involved between the two objectives. In particular it would be helpful to address the following questions:

- What is the relationship between the mean source population and the time-to-target for the metapopulation (sum of source and translocated population)?
- What is the relationship between the frequency of the source population dropping below some acceptable minimum and the time-to-target for the metapopulation?
- What fraction of the population should be translocated to achieve an acceptable compromise?

These questions are addressed by performing simulations for different rates of removal from the source population for translocation purposes.

III. Model Description

Full details of the model used as the basis for this work can be found in [3]. A brief description follows together with details of some changes that were necessary for this analysis.Two populations were considered: a source population and the translocated population. According to what is observable by game rangers each sex (male or female) is comprised of four age groups: Unweaned, Juveniles, Sub-adults, and Adults. Table 1 gives the age groups and the rates that affect the female groups population numbers in the source area. Similar table may be constructed for the male groups in the source area, and for both sexes in the translocated area. Predation rates of rhinos in the 0-1 and 1-2 age groups are negligible and are assumed into the death rates for these age groups.

Group	Age (yrs)	Flows In	Flows Out
F_1	0-1	Births	Aging, death
F_2	1-2	Aging	Aging, death
F_3	2-8	Aging	Aging, death
F_4	8+	Aging	Death, translocation

Table 1: Age classes for females and the rates affecting the female population numbers.

We note that F_i and M_i respectively denote the number of females and number of males in age group i=1, 2, 3, 4 and are functions of time, *t*. The ecological carrying capacity, CC, is also a function of time through its dependence on annual rainfall, $rain(t)$.

Adults from the relatively high density source population are removed each year and added to the translocated population.

The resources required per animal differ with age and sex group. Population density is therefore defined as the weighted average population divided by the carrying capacity of the reserve. Thus: $density = \ _i u_i(F_i + M_i)/CC$ where u_i are the appropriate weights for each population group *i*. The weights take on the respective values 0.5, 0.67, 1.0, and 1.0. The carrying capacity, $CC\ t\ = k * rain(t)$ is a product of the long term average carrying capacity and a multiplier function of the rainfall each year. The rainfall multiplier was constructed from the long sequences of historical rainfall data available for the area where the source population is located. The specific fecundity rate, *sfr*, is a declining function of density:

$$sfr\ density = \begin{cases} 0.46 & if\ density \leq 0.25 * CC \\ -0.45 * density + 0.5725 & if\ 0.25 * CC \leq density \leq 0.85 * CC \\ 0.19 & if\ 0.85 * CC \leq density \end{cases}$$

Specific mortality rates , m_i, increase with density with younger groups more affected by density than the Adults group as shown in Fig. 1.
The following system of difference equations governs the female source population:

$$\Delta F_1 = 0.5 * births - a_1 F_1 - m_1 F_1$$
$$\Delta F_2 = a_1 F_1 - a_2 F_2 - m_2 F_2$$
$$\Delta F_3 = a_2 F_2 - a_3 F_3 - m_3 x F_3$$
$$\Delta F_4 = a_3 F_3 - m_4 F_4 - RF_4$$

where ΔF_i represents the change in the population of female group *i* over one year, a_i is the specific ageing rate of group *i*, m_i is the specific mortality rate for group *i*, and RF_4 the number of females in the Adult age group that are removed from the source population for translocation. The specific aging rates are respectively 1, 1, 1/6 and are calculated from the age group intervals in Table 1. The specific mortality rates are given in Figure 1. The fecundity rate, $births$, is a third order delay of the product of F_4 and the specific fecundity rate *sfr*. We assume that births are evenly divided among the sexes. As noted above, *sfr* depends on *density* and is defined below. Conception rate is affected by density and is represented by FF_1 which is a first order delay of the fecundity function sfr, with a delay time T_1. It follows that $\Delta FF_1 = \frac{sfr - FF_1}{T_1}$.
The gestation period also introduces further delay in the density effect on conception rate and consequently birth rate. Therefore, FF_1 is subject to further delay to give the specific birth rate FF_4, and the delay is modelled by the third-order delay equations:

$$\Delta FF_i = \frac{FF_{i-1} + FF_i}{T_2}, i = 2, 3, 4$$

where FF_2 and FF_3 are intermediate variables and $3T_2$ is the gestation period. We assume that only females are fecund. Thus: $births = F_4 * FF_4$.
Similar equations govern the male source population, and the translocated populations for both sexes. The most important change in the equations for the translocated population is that animals removed from the source population become an input. Furthermore, since the density in the translocated area is initially very small relative to the carrying capacity of the area, the density effect is negligible and irrelevant. This in turn means that fecundity and mortality can all be set as constants at the values most favourable for growth.

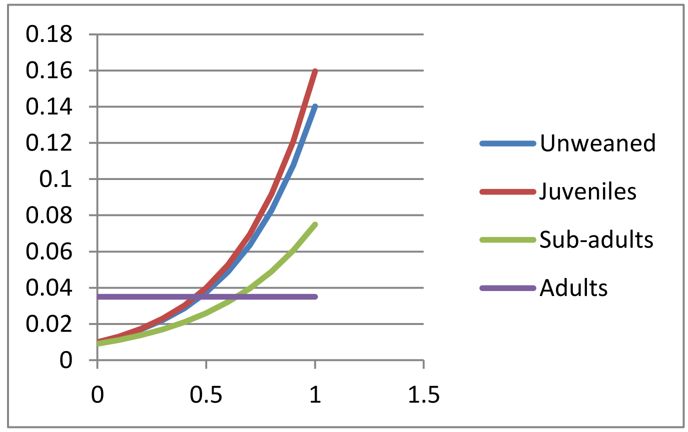

Fig.1. Mortality rates for each age group

IV. Model Implementation

The decision as to how many animals should be removed for translocation from the source population each year is based on the annual census count. This census count is believed to be between 80% and 120% of the true population [P. Goodman, Pers. Comm.]. To simulate this the total source population, POP_s, is first calculated: $POP_s = \ _i(F_i + M_i)$. The simulated census population can now be calculated as follows: $POP_c = r * POP_s * U$ where r is the fractional removal rate and U is a uniformly distributed random number lying in the interval (0.8, 1.2).
For the purposes of this analysis the current source population is set at 400 animals comprising 10, 8, 22 and 160 animals in the respective female groups from youngest to oldest. The same numbers were allocated to each male age group. In a reserve that has a carrying capacity of 480 animal units this represents an initial density of 80%. The managers of the source population agree that 350 animals is an acceptable minimum. The initial value of the metapopulation is set at 452. Seven scenarios were simulated where the fixed fractional removal rate went from 2% to 8% at 1% intervals.
Eight hundred replications of each set of Monte Carlo simulations were performed. Each simulation was run until the metapopulation reached the target of 2000 animals.

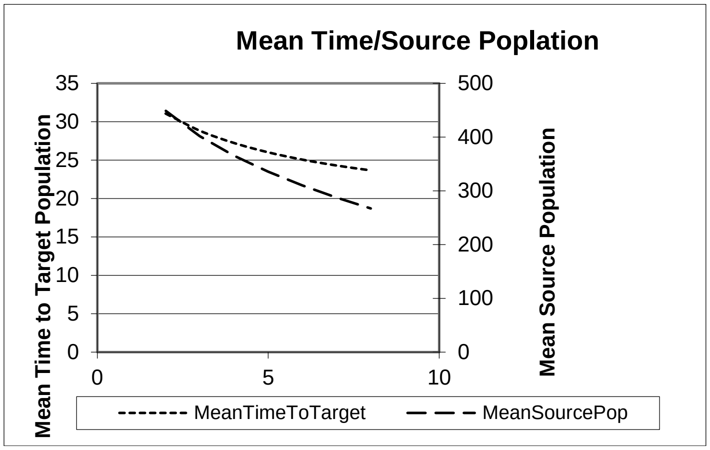

Fig. 2 Effect of Removal rates on the Mean Source Population and the Mean Time-to-Target

V. RESULTS

In can be seen in Fig.2 that by increasing the removal rate from 2% to 8% the target population can be achieved six years more quickly. This achievement is at the cost of the mean source population dropping well below the 300 level and significantly below the acceptable level of 350 animals. In Fig. 3 the frequency at which the source population drops below the minimum acceptable level is shown for each of the removal rates considered.

It seems clear that consensus between the groups is most likely to be attained with a removal rates of either 4% or 5%. Table 2 provides further results to inform discussions around these values.

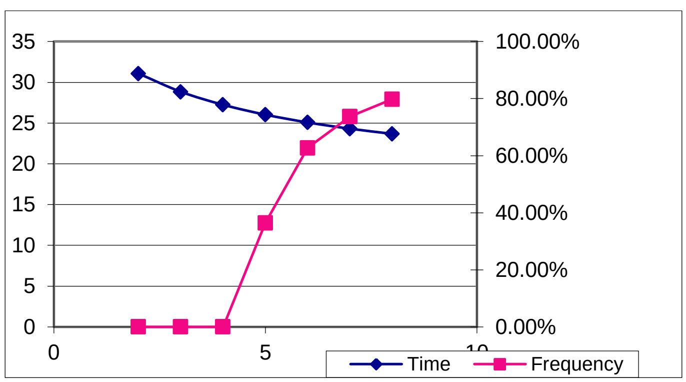

Fig. 3. The frequency that the source population drops below the acceptable level is shown for different removal rates. Also shown is the time taken to reach the metapopulation target at each removal rate.

Removal Rate	**4%**	**4%**	**5%**	**5%**
Percentile	**Source (rhinos)**	**Time-to-target (years)**	**Source (rhinos)**	**Time-to-target (years)**
0%	348	26.9	320	25.7
10%	358	27.1	328	25.9
20%	361	27.2	331	26
30%	363	27.2	333	26
40%	364	27.2	334	26
50%	366	27.2	336	26
60%	367	27.3	337	26.1
70%	369	27.3	339	26.1
80%	371	27.3	341	26.1
90%	374	27.4	344	26.1
100%	390	27.5	358	26.3
Mean	**366**	**27.2**	**336**	**26**

Table 2: Comparison of removal rates at 4% and 5%.

VI. CONCLUSION

The 8% translocation strategy yields an expected time-to-target of around 24 years but population levels are unacceptably low from the source managers' perspective. On the other hand a very conservative 2% removal rate extends the expected time-to-target out to about 31 years. Good compromise solutions would appear to be at 4% or 5% removal rates. A removal rate of 5% implies the source population is below the source managers' 'minimum acceptable' level. But it is within 5% of this somewhat arbitrary level. On the other hand, source managers should be very comfortable with 4% and the mean time-to-target is only extended by a little more than a year. The model has also been useful in giving source managers a better understanding of density-dependent population dynamics .

VII. REFERENCES

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