12 Conservation of Small Populations: Effective Population Sizes, Inbreeding, and the 50/500 Rule

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Introduction and Background

Population size is extremely important in evaluating conservation priorities for a species. Small populations are at risk of going extinct because of demographic stochasticity and genetic drift. In this exercise, you will learn about three of the meanings of "effective population size" and how to estimate two of them. You will then learn how to apply these techniques to specific conservation situations, using the concepts of inbreeding, the minimum viable population size, and the 50/500 rule.

Effective Population Size

Population size has a major impact on the dynamics of a population. For example, in chapter 11 you used simulations to see that genetic drift reduces allelic diversity much faster in small populations of woggles than in large ones. Population size also influences the chances of extinction through demographic stochasticity, the random change in population size over time due to random variation in individual survival and reproductive success. Such events have a proportionally large effect in small populations. For example, in a population of 10 individuals, one accidental death would reduce the population size by 10%. In contrast, if the population were made up of 1000 individuals, one accidental death would reduce the population size by only 0.1%. Thus, small populations are much more likely to go extinct due to demographic stochasticity than are large populations.

Effective population size (N_e) helps us quantify how a particular population will be affected by drift or inbreeding. Effective size takes into account not only the current census size of a population, but also the history of the population. Effective population size is the size of an "ideal population" of organisms (ideal refers to a hypothetical population in the Hardy Weinberg sense with a constant population size, equal sex ratio, and no immigration, emigration, mutation, or selection) that would experience the effects of drift or inbreeding to the same degree as the population we are studying. For example, if our actual population of 50 animals experiences the effects of drift at the same rate as an ideal population of 20 animals, the population has a drift effective size of 20.

There is no such thing as "*the* effective size" of a population. Different effective population sizes help us estimate the impact of different forces. The effective size you estimate will depend on the scientific question you are trying to address (box 12.1). Estimating the appropriate effective population size is crucial in conservation biology; in most (but not all)

Box 12.1 Different Ways to Measure Effective Population Size

There are a variety of population effective sizes that have different mathematical and biological meanings. The terms are sometimes confused or misunderstood as synonymous. Such confusion can have serious implications for understanding and managing populations of endangered or threatened species, as we see below.

Inbreeding effective size, N_{ef}, refers to the size of an ideal population that would allow the same accumulation of pedigree inbreeding as the actual population of interest. Pedigree inbreeding occurs when an offspring inherits two copies of a gene from its parents which are identical by descent—that is, they are both directly descended from a single allele present in one of the founders of that population (perhaps the parents are cousins and each inherited the particular allele from the same grandfather). N_{ef} is the measure of effective population size that emphasizes the effect that small population size has on the chances of relatives mating with each other. Such matings lead to a loss of heterozygosity in the population. Thus, this effective size gives you an indication of the likely loss of heterozygosity across all alleles in your population.

Calculation of N_{ef} ideally requires pedigree data. However, you can estimate the inbreeding effective population size (N_{ef}) by calculating the *harmonic mean* of the population size over time from the founding generation to the penultimate generation. The symbol t represents the number of generations for which we have population size data. $N(0)$ is the size of the founding population, $N(1)$ is the size of the population after one generation etc. and, $N(t-1)$ is the size of the population one generation ago.

$$\text{(a) } N_{ef} = \frac{t}{\dfrac{1}{N(0)} + \dfrac{1}{N(1)} + \cdots + \dfrac{1}{N(t-1)}}$$

Variance effective size, N_{ev}, refers to the size of an ideal population that would accumulate the same amount of variance in allele frequencies as the population of interest; thus, this effective population size indicates how rapidly allele frequencies are likely to change. This is important because it also affects how rapidly isolated populations diverge from one another under genetic drift. Again, the symbol t represents the number of generations for which we have population size data. $N(1)$ is the size of the population after one generation, etc., and $N(t)$ is the size of the current population.

$$\text{(b) } N_{ev} = \frac{t}{\dfrac{1}{N(1)} + \dfrac{1}{N(2)} + \cdots + \dfrac{1}{N(t)}}$$

In addition, the following correction can be used at each generation if operational sex ratios are not 1:1. This corrected population size reflects the increased effects of both inbreeding and drift when the sexes are not contributing equally to the allele pool.

$$\text{(c) } N_s = \frac{4N_m N_f}{N_m + N_f}$$

(continued on following page)

Notice the difference between formula (a) and formula (b). While the *inbreeding effective size* is more sensitive to the *number of original founders* [$N(0)$], the *variance effective size* is more sensitive to the *number of offspring in the current generation* [$N(t)$]. This is because, as stated above, N_{ef} focuses on the loss of heterozygosity due to pedigree inbreeding in the population; with a small initial founding population, close relatives are likely to mate with each other. In contrast, N_{ev} gives an indication of the increase in variance of allele frequencies between subpopulations due to drift, and depends on the number of offspring produced by those founders and by each subsequent generation, up to the present-day $N(t)$.

These differences can lead to large discrepancies between these two different effective population sizes in real populations. For example, *increasing populations* generally have a larger N_{ev} than N_{ef}, while *declining populations* will generally have larger N_{ef} than N_{ev}. Hence, a population coming through a bottleneck may have a low inbreeding effective size, but it can have a larger variance effective size if the population bounces back rapidly (as is the case with the Southern white rhinoceros population, which you will work on in class).

There are other measures of effective population size that focus on different population genetic parameters. For example, *eigenvalue effective size, $N_{e\lambda}$*, focuses on the rate at which unique alleles are lost from a population. For this exercise, we will examine only the two effective population size estimates discussed above.

cases, effective population size will be smaller than the actual number of organisms in the population. Think for a moment about why this is so. A conservative rule of thumb used by some biologists is that N_e is usually about one-fifth of the total population size (Mace and Lande, 1991). Using such a rough estimate is risky because N_e can be *larger* than the census size of the population, depending on the history of the population and the particular N_e under consideration.

Demographic stochasticity, genetic drift, and environmental variation can interact to doom a small population to extinction. This is called an extinction vortex, and it is due to a positive feedback loop (figure 12.1): the negative consequences of lower effective population size make the population smaller, causing stronger negative effects, leading to an even smaller population size (Gilpin and Soule, 1986). For example, a random environmental change might lower population size, leading to a higher chance of population reduction due to demographic stochasticity. This could lower inbreeding effective population size even more, leading to severe inbreeding depression and reduced fertility. This further reduces the population size. Chains of events such as these mean that the extinction probability for a small population can be extremely high. For example, Pimm et al. (1988) showed that the extinction risk for birds on small islands off the coast of Britain rises with decreasing numbers of nesting pairs. Conservation biologists realize that an extinction vortex can begin when humans cause major reductions in the population size of a species.

Calculating Effective Population Sizes

Consider the data in table 12.1 for a population of Eastern fence lizards, *Sceloporus undulatus*, at Tyson Research Center in eastern Missouri: You can estimate the inbreeding effective

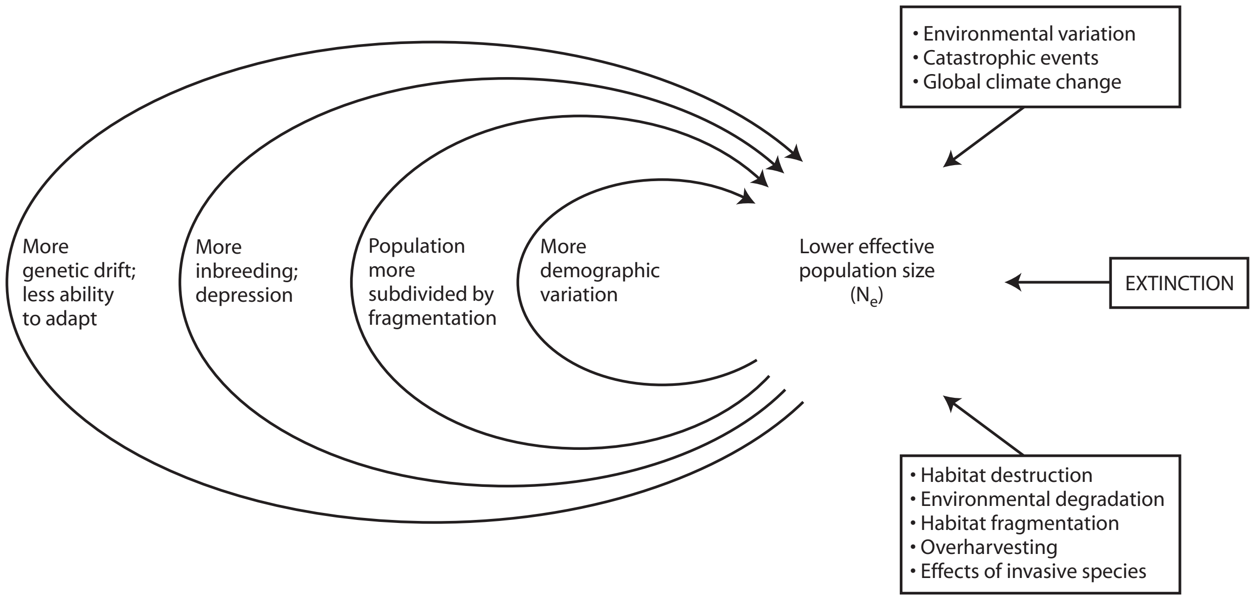

FIGURE 12.1. Extinction vortex. Population size decreases in a positive feedback loop, eventually resulting in the extinction of the population (from Primack, 2000).

size for this population using formula (a) from box 12.1. In this case, t=4 generations; we calculate the *inbreeding effective population size* as:

$$
\begin{aligned}
N_{ef} &\approx \frac{t}{\frac{1}{N(0)}+\frac{1}{N(1)}+\frac{1}{N(2)}+\frac{1}{N(3)}} \\
&= \frac{4}{\frac{1}{140}+\frac{1}{250}+\frac{1}{110}+\frac{1}{26}} = \frac{4}{0.058} = 68.9 \approx 69
\end{aligned}
\qquad (12.1)
$$

Try this calculation yourself—it can get confusing taking all of these reciprocals!

This estimated effective population size (69) means that, in terms of genetic inbreeding, this population (with a mean census size of 148 lizards over 5 years) will accumulate the

TABLE 12.1.
Sceloporus population at Tyson from 1996 to 2000.

Year	Population count
1996	140
1997	250
1998	110
1999	26
2000	180

effects of inbreeding at the same rate as a population that had a constant size of only 69 individuals.

In contrast, the *variance effective size*, estimated with formula (b) in box 12.1, is

$$N_{ev} \approx \frac{t}{\frac{1}{N(1)} + \frac{1}{N(2)} + \frac{1}{N(3)} + \frac{1}{N(4)}}$$
$$= \frac{4}{\frac{1}{250} + \frac{1}{110} + \frac{1}{26} + \frac{1}{180}} = \frac{4}{0.05655} = 70.73 \approx 71. \tag{12.2}$$

This effective population size (71) means that, in terms of genetic drift, this population (with a mean size of 148 over 5 years) will accumulate the effects of drift at the same rate as a population that had a constant size of 71 individuals. Note that, in this example, the mean size of the population over time reflects neither how it will accumulate inbreeding nor how it will experience drift. Although the difference between variance effective size and inbreeding effective size appears small in this example, the point is that these are not two ways of estimating *the* effective size; these are two different effective population sizes. In the examples you work with in this exercise, you will see how one population can have very different effective sizes that inform us about very distinct risks for the population.

Effective Population Size, Inbreeding, and Extinction

Just as there are a number of different meanings of effective population size, there are a number of different meanings of inbreeding. Because breeding with close relatives typically reduces the pool of genes contributing to the next generation, one measure of inbreeding is F, inbreeding as a measure of drift. In addition to increasing the impact of drift, inbreeding can increase the proportion of deleterious homozygous gene combinations in a population, which leads to lower survival of young and thus lower reproductive output; this is called inbreeding depression. To begin to evaluate the potential impacts of small population size on inbreeding, we can use the following estimation (from Soule, 1980):

$$\Delta F = 1 - \left[1 - \frac{1}{2N_{ef}}\right] t. \tag{12.3}$$

In this equation, ΔF is the increase in the inbreeding coefficient over time; N_{ef} is the inbreeding effective population size; and t is the number of generations. We can use this equation to predict how much the inbreeding coefficient in a small population will increase over time. If ΔF is 0.6 or higher, the fecundity of individuals in the population may be reduced, and the population could be at higher risk for extinction. For example, we can calculate the increase in the inbreeding coefficient after 100 generations for the population described above. For the fence lizards, N_{ef} was 69. This means that $\Delta F = 1 - (1 - 1/138)^{100} = 0.52$. We would conclude that after 100 generations the fence lizards are experiencing some inbreeding; however, because $\Delta F < 0.60$ it may not threaten the population. Of course, the inbreeding coefficient will continue to increase over time, possibly to dangerous levels, if the population remains small and isolated. Note that the estimate of ΔF ignores gene flow—and even moderate gene flow can greatly reduce the effect of genetic drift, slowing the rate of increase in the inbreeding coefficient over time. So even moderate gene flow can help maintain genetic diversity. This is one reason why many conservation biologists advocate the maintenance of corridors connecting small, isolated populations of a species.

Minimum Viable Populations and the 50/500 Rule

You know that demographic stochasticity and genetic drift can negatively affect small populations. Demographic stochasticity leads to the random extinction of small populations, while genetic drift can cause a reduction of genetic diversity within a population. These factors can interact in an extinction vortex (figure 12.1 discussed above) that can eventually lead to the extinction of a population.

To decide when these factors might be important for a population of an endangered species, Shaffer (1981) proposed the concept of the minimum viable population (MVP). He defined the MVP as the smallest isolated population (of a given species in a given habitat) having a 99% chance of remaining in existence for 1,000 years, despite the foreseeable effects of demographic stochasticity, genetic drift, environmental stochasticity (random changes in the environment), and natural catastrophes (Shaffer, 1981). Shaffer chose the percentage and time scale to represent what most scientists consider a good chance for survival of a species. Quantitative objectives like the MVP provide specific guidelines for gauging the success of conservation programs (Foose et al. 1995). Populations smaller than the MVP are considered to be at significant risk of entering into the extinction vortex and becoming extinct, so a conservation program can be considered successful only if it raises the effective population size above the MVP.

A related concept is the 50/500 rule, proposed by Franklin (1980). The "50" part of the 50/500 rule states that populations with an inbreeding effective population size (N_{ef}) under 50 are at immediate risk of extinction. This is because, in such small populations, inbreeding and demographic stochasticity can quickly push the population into an extinction vortex. The "500" part of the rule means that populations with a variance effective size (N_{ev}) of less than 500 are at long-term risk of extinction. In these populations, genetic drift may be a strong force, leading to eventual loss of genetic variation (Franklin, 1980). After variation is lost, the population will no longer be able to respond to environmental changes, and may be reduced in size or go extinct if any such changes occur. Even when properly understood, Franklin's rule is quite controversial. Some authors question its generality, and others suggest that the numbers are too small. For example, Lande (1995) suggested that any population with N_{ev} less than 5,000 will be subject to strong genetic drift, which will deplete the genetic variation in a population and cause long-term extinction risk. Recent experimental tests of the rule in captive housefly populations also suggest that populations must be higher than implied by the 50/500 rule in order to survive and maintain genetic diversity (Reed and Bryant, 2000). As a conservation biologist, you may not use the 50/500 rule, but it is essential that you understand where the 50 and 500 come from.

Homework for this exercise takes approximately 45 minutes.

Case Studies and Data

European Adders

The European adder (*Vipera berus*) is a small, venomous snake (figure 12.2) distributed throughout Europe (Arnold and Burton, 1978). This snake occupies a wide geographic range, but within that range snakes are often found in small, isolated populations separated from each other by hundreds to thousands of meters. Under natural conditions, gene flow between these subpopulations is high, because the male snakes disperse widely when

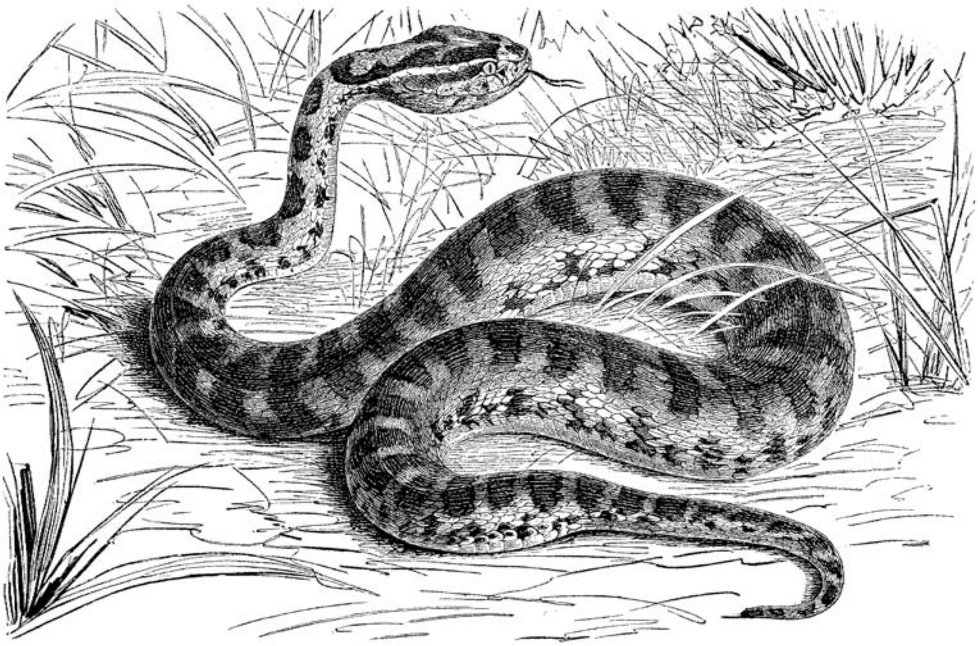

FIGURE 12.2. European adder *Vipera berus.*

searching for females during the spring (Madsen et al., 1993). However, in certain regions humans have disturbed adder habitat through agriculture and urban encroachment. Now we see extremely isolated small populations of adders, surrounded by large areas of unsuitable habitat (Madsen et al., 1996). Consider the isolated population of adders at Smygehuk, on the south coast of Sweden. These adders are separated from the nearest population by 20 km of farmland, which is unsuitable habitat for adders (Madsen et al., 1996). Use the data in tables 12.2 and 12.3 (Madsen et al., 1996) to answer the following questions.

Questions to Work on Individually Outside of Class

1. Table 12.2 gives data on the population size of the adders for each year from 1984 to 1990.
   (a) Plot the total number of adult adders (y) over time (x).
   (b) Use these data to calculate the inbreeding effective size and the variance effective size of this population of adders.
   (c) Explain why the inbreeding effective size and the variance effective size of this population differ.
   (d) Recalculate the variance effective size of this population with the new information on the sex ratios of snakes in the population (table 12.3).
   (e) Dr. Fern Skipe has argued that there is no such thing as the "real" effective population size. Do you agree with this statement? Why or why not? Use the results above in your argument.
   (f) Based on these data and your calculations, make a recommendation to the Swedish government concerning this population of vipers.

TABLE 12.2.
Total number of adult adders at Smygehuk

Year	Total number of adults
1984	138
1985	40
1986	34
1987	42
1988	37
1989	41
1990	34

TABLE 12.3.
Adult male and female adders in each year

Year	No. of adult females	No. of adult males	Corrected population size
1984	98	40	
1985	29	11	
1986	24	10	
1987	32	10	
1988	27	10	
1989	29	12	
1990	27	7	

Small-Group/In-Class Exercise

Please bring graph paper and a calculator to class to complete the next part of this exercise. First, read the following background information on African rhino conservation.

African Rhino Conservation

Background The rhinoceros is an example of a "charismatic megavertebrate" that has played a central role in promoting worldwide conservation efforts. The five extant species of rhino are the last representatives of a large group of species that reached a peak in diversity between 25 and 5 million years ago (Estes, 1991). Two of the five extant species occur in Africa: the white rhinoceros (*Ceratotherium simum*) and the black rhinoceros (*Diceros bicornis*). Despite their names, both species are a dull gray color, and can be distinguished by the shape of their mouthparts (figure 12.3). The black rhino has a hook-shaped triangular upper lip that allows it to obtain its food by browsing leguminous herbs and shrubs. The white rhino, on the other hand, has a very wide, square mouth, and is specialized in grazing areas of dense grasses. All rhinos have poor eyesight and relatively small brains, but ex-

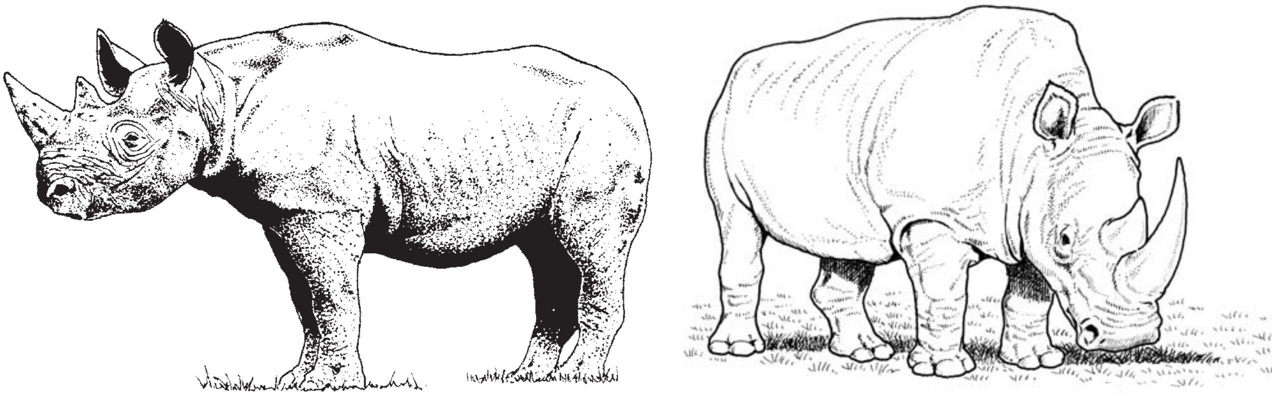

FIGURE 12.3. Black (left) and white (right) rhinoceri.

tremely sensitive hearing and smell (Estes, 1991). Both African species of rhino show geographic variation. The black rhino has been divided into four subspecies, western (*Diceros bicornis longipes*), eastern (*D. b. michaeli*), southwestern (*D. b. bicornis*), and south central (*D. b. minor*). The western subspecies is the rarest and most isolated, with only a few individuals living in western Africa. The white rhino has been divided into two subspecies, the northern (*Ceratotherium simum cottoni*) and southern (*C. s. simum*). These two subspecies occupy separate ranges and are more distinct, both morphologically and genetically, than the subspecies of black rhinos (Emslie and Brooks, 1999).

Both species of rhino have undergone major reductions in their ranges in the past several hundred years. Early colonial explorers reported that black rhinos were widespread in distribution and fairly common, while white rhinos were more restricted in range. After European colonization, southern white rhinos were very quickly reduced to near-extinction, reaching a low of just 20 individuals in 1895. Since then, numbers of the southern white rhino have steadily increased; there are over 8,000 alive today. The northern white rhino, on the other hand, has shown a dramatic decrease in recent years, declining from over 2,000 in 1960 to only 25 individuals in 1998. Numbers of black rhinos have also declined since colonial times. Declines were especially severe between 1970 and 1992, when black rhinos declined 96%. The species has recently shown some potential for recovery (Emslie and Brooks, 1999). The main reason for the decline of all rhinos is hunting by humans. European colonists killed hundreds of thousands of rhinos during the nineteenth century. More recently, rhinos have been killed by poachers supplying markets in Asia and the Middle East with rhinoceros horns. In Asia, rhino horns are used in traditional Chinese medicine, whose practitioners believe that the horns lower fevers, increase male potency, and can cure a host of diseases. In the Middle East, they are used as handles for ornamental daggers called jambiyas (Emslie and Brooks, 1999). Although rhino horns have been used for these purposes for hundreds of years, recent increases in demand put serious pressure on wild rhinos, and poaching for horns is the major threat to African rhino populations today (Emslie and Brooks, 1999).

***Black Rhinoceros* Diceros bicornis** Black rhinos were formerly the most widespread and abundant species of rhino (Estes, 1991), but are now listed in the IUCN Red Book as critically endangered. Direct counts of black rhinos have shown declines of over 80% in

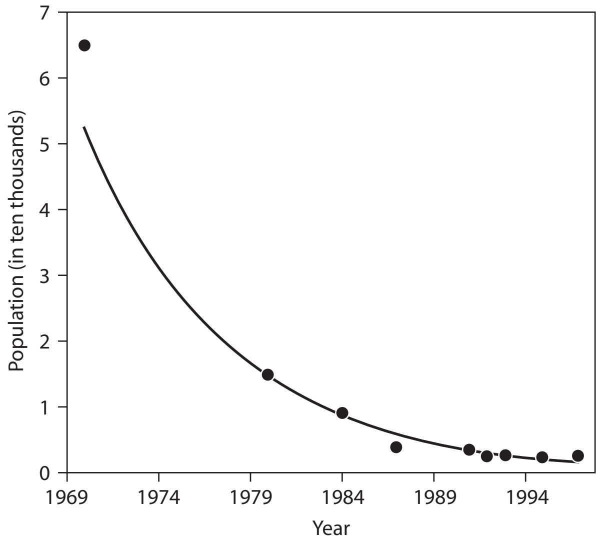

FIGURE 12.4. The black rhinoceros has been in severe decline in recent years and is entering a population bottleneck (data from Emslie and Brooks, 1999).

the last 50 years (Emslie and Brooks, 1999). The total population size of black rhinos in 1970 was estimated at 65,000. Historically, black rhinos occupied a large range throughout Africa. Today, black rhino populations are fragmented, and the species is rapidly declining in numbers (figure 12.4). The species has been divided into four subspecies, each occupying a separate geographic range: the western, eastern, southwestern, and south-central black rhinos. The ranges of each subspecies have different climates and habitats. They can sometimes be distinguished by characters such as skin texture and horn length and shape. There may also be genetic and behavioral differences across these subspecies. The western black rhinoceros is the most range-restricted and endangered of all the subspecies of black rhinos: the entire subspecies is represented by only a few scattered individuals in Cameroon. This subspecies, separated from the rest of the black rhinos by hundreds of miles, may represent a genetically distinct lineage, but is threatened with extinction in the immediate future. The largest population of black rhinos is in Kenya, while the main population of southwestern black rhinos is in Namibia. The south-central black rhino is the most common subspecies, with large numbers in South Africa and Zimbabwe, and smaller populations in southern Tanzania and Mozambique. The goal of your group is to establish a conservation plan for black rhinos as a whole. You need to decide how much money needs to be allocated to each of the four subspecies, and which populations will have the highest conservation priority.

***White Rhinoceros* Ceratotherium simum** White rhinos have always been less common and more limited in distribution than black rhinos (Emslie and Brooks, 1999). This is probably a function of their specialized grazing diet. This feeding strategy makes the white rhino unique, as it is quite different from that of black rhinos and, in fact, from all other rhinos in the world (Estes, 1991). The white rhino is one of the largest purely grazing herbivores that has ever lived. Southern white rhinos are separated from northern white rhinos by 2,000 km, and no white rhino has ever been recorded in the intervening area. These two subspecies are genetically distinct, with more genetic variation between these two subspecies than among the four subspecies of black rhino (Smith et al., 1995).

***Southern White Rhinoceros* Ceratotherium simum simum** Southern white rhinos were on the brink of extinction in 1895, when overhunting had reduced them to just 20 individuals in one population in South Africa. Their numbers have since recovered substantially (figure 12.5). The recovery of the southern white rhino is one of the major success stories in modern conservation biology. Before their decline in the ninteenth century, their range included much of southern Africa. After initial recovery of the source population, many translocations were carried out; these have successfully reintroduced rhinos into areas where they had been wiped out. Southern white rhinos are now the most numerous subspecies of rhino; populations can be found in South Africa, Botswana, Namibia, Swaziland, and Zimbabwe. They have also been introduced into Kenya, Ivory Coast, and Zambia, all outside their native range. The rhinos have functioned as a major source of funding in South Africa, where national parks have sold excess rhinos to private game parks for as much as U.S.$25,000 apiece.

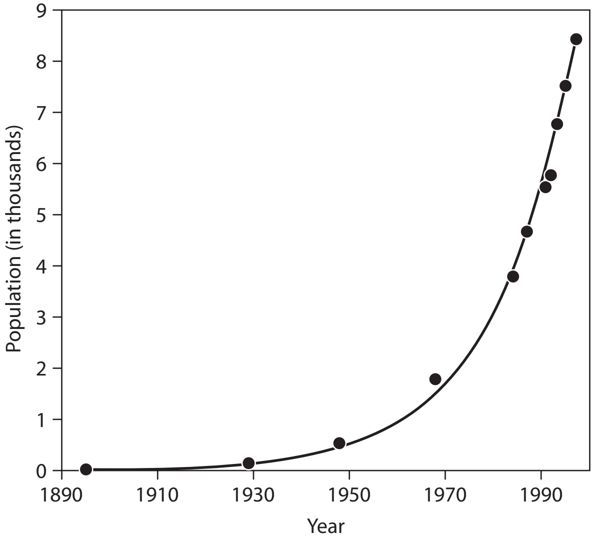

FIGURE 12.5. The southern white rhinoceros has recovered from near extinction at the turn of the last century and the current growing population is descended from a bottleneck population of only 20 animals (data from Emslie and Brooks, 1999).

***Northern White Rhinoceros* Ceratotherium simum cottoni** Northern white rhinos have shown a striking decline in recent years, and are now perilously close to extinction. Table 12.4 gives data on northern white rhinoceros populations by country from 1960 to 1998 (Emslie and Brooks, 1999). Although the range of northern white rhinos once included parts of Uganda, Chad, Sudan, the Central African Republic, and the Democratic Republic of Congo, they are now restricted to a small area in the northeast of the Democratic Republic of Congo (Emslie and Brooks, 1999). This population numbered only 25 individuals in 1998, and DRC has been suffering from tremendous political instability over the past 20 years. Conservation biologists have not lost hope of preserving the subspecies,

TABLE 12.4.
Northern white rhinos by country, 1960–1998.

	1960	1971	1976	1981	1983	1984	1991	1995	1998
Central African Republic	Few	Few	Few	Few	Few	0?	—	—	—
Chad	Few	Few	?	?	0?	0?	—	—	—
Democratic Republic of the Congo	1,150	250	490	<50	13–20	15	30	31	25
Sudan	1,000	400	?	<300	<50	0?	0?	0?	0?
Uganda	80	Few	Few	Few	2–4	0?	—	—	—
Total	2,230	650	500+	<350	<70	15	30	31	25

however, and cite the recovery of the southern white rhino, which has grown from a total population of around 20 individuals in 1895 to over 8000 today. The northern white rhinos currently surviving in the Democratic Republic of Congo represent the last survivors of a unique lineage of rhinos; their extinction would be a great and irreversible tragedy.

Your Job: Help Create Species Survival Plans for African Rhinos (Questions 2–6)

Species Survival Plans (SSPs) coordinate the management of rare and endangered species to maintain healthy breeding populations, retain genetic variation, and minimize "inbreeding." SSPs often have the conflicting goals of preserving species in a captive environment while at the same time minimizing evolutionary change in the species and minimizing loss of genetic diversity from inbreeding or drift (Templeton, 1991). These can be significant forces affecting wild (in situ) and captive populations that are entering or emerging from population bottlenecks. Your job will be to use real data to help the IUCN Rhino-Rescue Team generate an SSP for the two species of African rhinos. After you answer questions 2–5, the entire class will meet as a committee of the whole to allocate funds for the conservation of African rhinos.

2. Your instructor will assign you to one of the three rhino species or subspecies on which we have data. First, you need to assess the current genetic situation for black rhinos, or southern or northern white rhinos. This assessment should include the inbreeding and variance effective sizes for the wild populations. You should be able to project accumulation of inbreeding in wild populations if they are maintained at current levels. (Assume equal sex ratios and a generation time of 8 years. For black rhinos and southern white rhinos you will need to estimate census sizes from figures 12.4 and 12.5) Your instructor will copy table 12.5 on the board and you can share your results with the other groups.

3. For your species or subspecies, discuss the long-range plan for maintaining the genetic health of the population. Address the recommendations and the theoretical framework of Franklin's 50/500 rule in your plan.

4. You should also discuss the situation for your species in the wild and decide whether you want to use the wild population to supplement the captive zoo population or vice versa.

5. Finally, your plan must include priorities for both species and for different populations within each species. The reality is that there are limited funds available for rhino conservation, and you must generate guidelines about where resources should be spent.

TABLE 12.5.
Population census and effective sizes of African rhinos.

	Census size, 1997	Inbreeding effective size (N_{ef})	Variance effective size (N_{ev})
Black rhinoceros *Diceros bicornis*	$N = 2{,}600$		
Southern white rhinoceros *Ceratotherium simum simum*	$N = 8{,}440$		
Northern white rhinoceros *Ceratotherium simum cottoni*	$N = 23$		

6. Each group will have a few minutes to describe the situation for their rhinos and propose an allocation of the $500,000 which African Rhino Rescue has raised. Once each group has made their brief presentation you will have a chance to convince each other (and your instructor) to take your recommendation.

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