Figure 10. Black rhino.

population density suggested that the carrying capacity had been reached, at least in Hluhluwe, and this prompted the translocation of 20 black rhinos to Kruger National Park in 1971.

No further removals took place until 1977 when t was agreed that a further 20 black rhinos could be made available from Hluhluwe over a 5 year period to large conservation areas within the species' former range and where habitat conditions were suitable. In the meantime, we re-assessed the population structure in Hluhluwe and Umfolozi using data from 1975—977 and found that the sex and age ratios were very similar to those reported in 1972 by Peter Hitchins, arid as recorded deaths had decreased we assumed that the population had probably not declined. This assessment was carried out during a high rainfall cycle when black rhinos were unlikely to have been under significant environmental stress, and the removals represented less than the expected rate of increase for Hluhluwe of 5%.

The next dry cycle began in 1977/78, the stocking rates of both grazers and browsers in the reserve were above carrying capacity and the habitat rapidly deteriorated. By 1979 most of the vegetation monitoring sites showed over-utilisation of the browse resources and 5 black rhino deaths were recorded in the late winter in Umfolozi. To pre-empt a population decline such as had occurred in the 1960s, Peter Hitchins and Jeremy Anderson recommended that the black rhino density in Umfolozi should be reduced, and 14 animals were removed in 1980. The dry cycle continued, so in late 1980 Tony Whateley, Jeremy Anderson and I decided to re-sample population structures throughout the area. This was made possible through a donation of helicopter hours by the Endangered Wildlife Trust. A total of 128 rhino, or 37% of the population, were contacted in 19 hours flying. The results were extremely interesting, as the percentages of immature rhino under 3.5 years old in Hluhluwe and Umfolozi (excluding the central corridor) were only 11% and 8% respectively, and no calves under a year were recorded in Umfolozi.

On the basis of this study, it was recommended that the population density of black rhino throughout Hluhluwe-Umfolozi should be depressed by removing 30 animals in 1981, and that thereafter the

'expected' rate of increase each year should be removed. A similar policy was adopted for Mkuzi and Ndumu Game Reserves, so that as from 1982 about 19 black rhino became available annually.

In this way, a total of 135 rhino have been moved from the Zululand Reserves since 1962. Within Natal, the recipients have been Ndumu (15), Itala (23) and Weenen (4); while translocations externally have been limited to Pilanesberg Game Reserve in Bophutatswana (23) and Kruger National Park in the Transvaal (70).

Reports on the performances of the black rhino in the latter two areas are most encouraging. For example, in Kruger Anthony Hall-Martin has reported that they are breeding faster than the parent Hluhluwe-Umfolozi population, this being shown by higher immature (<3.5y): adult female ratios (1.2 versus 0.4) and a higher percentage of calves under one year old (9% versus 5%). This is at a black rhino density of about 0.2/km^2 in Kruger as opposed to 0.36 in Hluhluwe-Umfolozi.

The future for the black rhinoceros in South Africa therefore looks bright, providing adequate protective measures against poaching can be maintained. However, as a precautionary measure, the Natal Parks Board is hoping to send *5* rhinos to a captive breeding project in the USA. The concept is to create a reservoir outside Africa which could be drawn on to re-stock reserves at a later date, particularly if local extinction had occurred.

Martin Brooks

Tusk Measurements Provide Insight into Elephant Population Dynamics

In the first newsletter of the African Elephant and Rhino Specialist Group, we announce a new project, funded by the New York Zoological Society, whose goal was to elaborate the relationship between ivory trade statistics and the status of the elephant populations from which the ivory comes. Ian Parker had made important progress in this area, while pointing out the need for further study. Parker's results are being thoroughly re-examined, and the full extent of their application explored.

The project has two stages, the first looking at how much information can be derived about individual elephants from individual tusks, and the second at how these results can be used to derive information about elephant populations from tusk populations.

The first stage has been completed. Using data from culled elephants provided by Ian Parker, mathematical models have been developed which use tusk measurements to determine sex and age. There were three steps to this. The first was to determine which tusk measurements are thc most reliable. This was done by comparing right and left tusks for the same elephant, recognizing that if one cannot accurately predict one tusk from the other, it would be unwise to attempt to predict anything else.

All tusk measurements are quite reliable. Weight and lip circumference are best, and equally good, followed by total length. It is interesting that two of these measures, length and weight, are of dimensions altered by wear and breakage. This is a clear indication that tusk wear is remarkably even.

Single-tusked elephants provide a useful test for the importance of wear and breakage, since their one tusk, as their only tool, should be much more affected by the stresses of use. Elephants with just one tusk do tend to have shorter tusks than those with two, but not nearly to thc extent expected. Almost one third actually have longer tusks. This is almost certainly due to a high degree of individual variation.

Though important, individual variation is a minor factor in comparison with sexual dimorphism. Male and female elephants have significantly different tusk sizes and shapes. This allows tusks to be separated by sex, which must be done if estimates of age are to be correct. Because differences resulting from individual variation, sexing of tusks can be done quite accurately.

Lip circumference and length can be used in combination to determine sex at a high level of accuracy. The table below presents the results of a sex of predictions.

Correct female guesses	371
Wrong female guesses	52
Correct male guesses	303
Wrong male guesses	53

A total of 674 guesses of 779, or 86.5% were correct.

Tusk weight can also be used to determine sex, but it is much less accurate. Tusks weighing more than 14 kg are almost certainly from male elephants, but below that weight guesses must be made on a stochastic basis. This reduces the absolute accuracy of any one guess, but for large samples the distribution of guesses should adequately duplicate the actual sex distribution.

Once tusks have been separated by sex, the age of the elephants they came from can be predicted. Age is a much finer prediction than the binary division by sex, and individual variation is a much more important factor. Models for guessing age from tusk dimensions must not only be as accurate as possible, they must also include a clear and explicit evaluation of their accuracy. Therefore, the models provide both a prediction, which is essentially a mean of all possible values, and a variance, which can be used to calculate the range within actual values will vary from predictions.

The accuracy of the models is fairly good. With reasonably large samples, the mean of the actual values will fall within about a five (± 21/2) year range for males, and within an eight (± 4) year range for females. Females are more difficult to age because their rate of tusk growth slows with age while individual variability continues to increase. The ranges may seem a bit wide, but they are really quite reasonable for an animal with a 60 year lifespan.

Given the models presented, a tusk can provide a great deal of information about the elephant it came from. Lip circumference and total length, in combination, can determine sex, and lip circumference or weight can predict age. Sex and age together can be used to construct mortality patterns, which give a clear idea of the elephants killed to supply any ivory consignment which has had basic tusk dimensions recorded.

Mortality patterns are not only useful in themselves, but have great potential for extending our knowledge. They are the product of the interaction of population structure and hunting patterns, and provide a basis for trying to determine the status of elephant populations. The conclusions must be tentative, as a number of assumptions are required, but the possible applications are both varied and important.

Some work has already been done on the mean tusk weights that can be expected from given population structures and hunting patterns. This can be of great help in evaluating a region's hunting policy using lust the mean tusk weight of ivory consignments. Another possibility is to examine the reproductive consequences of given mortality patterns. It is clear that at some level of hunting intensity elephants will be killed faster than they can replace themselves. If this level, and the mortality pattern which signals it, could be worked out through population modeling, situations of population decline could be spotted very quickly.

The most important application combines the previous two. It should be possible to determine hunting patterns which will produce the greatest amount of ivory per elephant. This would be to the advantage of both the ivory trade and the elephants which supply the trade. Achieving that goal will be difficult and complex, but clearly worthwhile.

Sex	Measure	Age	Variance
Male	Circumference(c)	$e(-4.25 + 2.12 \ln c)$	$15.11[\frac{1}{m} + \frac{1}{354} + \frac{(c-25.58)^2}{9205389}]$
Male	Weight(w)	$e(1.76 + .58 \ln w)$	$12.04[\frac{1}{m} + \frac{1}{1116} + \frac{(w-7.42)^2}{81741203}]$
Female	Circumference(c)	$e(-5.24 + 2.77 \ln c)$	$39.26[\frac{1}{m} + \frac{1}{424} + \frac{(c18.88)^2}{3933555.4}]$
Female	Weight(w)	$e(2.25 + .72 \ln w)$	$38.19[\frac{1}{m} + \frac{1}{1399} + \frac{(w-3.37)^2}{12493308}]$

Tom Pilgram
David Western