MODERN TECHNOLOGY FOR RHINO MANAGEMENT

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INTRODUCTION

As rapid advances are being made in the "high-tech" fields of military surveillance, telemetry, satellite position-fixing systems, transponder devices, etc., a frustrating situation arises for those who are involved in rhino conservation programmes in Africa. While it is known that this smarter technology includes many tools which are of immediate or potential applicability to the protection and monitoring of free-ranging rhinos, there is only a vague understanding of relevant technological advances. Generally, the time needed to investigate them is limited, as are the lines of communication. The gap in communication between First World technocrats and Third World conservationists is often worsened by the confidentiality that pertains to military technology. As an attempt to narrow this gap and to stimulate lateral thinking on potential technological applications, this paper presents some hopeful ideas which stem from rhino management experience in southern Africa. Other rhino managers in Africa can, and should, add many more ideas to a "wish list" of cost-effective and efficient technological aids for field efforts in monitoring rhinos, detecting poachers, protecting the former and eliminating the latter.

RADIOTELEMETRY

Conventional VHF radiotelemetry will have a significant role in rhino monitoring for the foreseeable future, although the problem of attaching transmitters to rhinos has yet to be satisfactorily resolved. Horn implant transmitters (e.g. Pienaar & Hall-Martin, 1991) have limited operational lives because their antennae become damaged due to the combination of horn growth and horn wear. Ear tag transmitters have inadequate signal range and soon tear out. Surgically-implanted transmitters (of the size required to achieve adequate range and battery life) are probably too risky for use in rhinos, which subject themselves to much physical abuse and are prone to subcutaneous abscesses. No researcher can yet claim to have perfected a neck collar design, but this appears to be the most promising approach towards achieving a target of 90% certainty of a transmitter staying on for over one year.

The main problems with neck collars are, firstly, the rhino's wedge-shaped neck pushes a collar down onto its ears where the collar can cause serious abrasion if it is not designed appropriately. Rhinos are known to have lost their ears due to the effects of crude radiocollars. Secondly, the tendency of rhinos to push through dense, woody vegetation means that, on the one hand, if the collar is not tough it will be cut by sharp sticks and will rip apart if snagged, but on the other hand, if it is too strong a rhino could be strangled if the collar is firmly snagged. Thirdly, rhinos tend to cover their collars with slippery mud when they roll in wallows, and thereafter rub against trees or rocks to the extent that the lubricated collars are pushed over their jawbones or ears and come off. (The loss rate of radiocollars in Zimbabwe has shown a marked increase during the rainy season because of greater muddiness.) Fourthly, the snuggly fitting collars that are required to reduce these problems must be able to stretch in order to allow for neck expansion in growing rhinos. Fortunately, health-related changes in rhino body condition, and therefore in neck girth, do not appear to be significant in the portion of the neck immediately behind the ears, where the collar invariably rides.

Various designs of radiocollars have been tested in Zimbabwe but none has proved to be entirely suitable. Although some collars have stayed on for over two years, the loss rate within the first month of fitting has remained over 20%. Unfortunately, ongoing trials in Zimbabwe are subject to recent political constraints on rhino research and management, but further prototypes are being developed in the firm belief that a suitable collar design will eventually be found.

Some suggested specifications for a rhino collar are as follows: collar material(s) should have a breaking strain of about 200kg and a stretching capability of at least 5% but less than 10%, when subject to a strain of 30kg on a collar length of about 150cm. Greater elasticity may be permissible within an insert section of a collar which is made up of two or more different materials, provided the stretch characteristics of the complete collar remain approximately as suggested; the collar must not stretch too much or it will soon come off. If the collar has a cylindrical cross-section, the diameter should not exceed 40mm (otherwise the collar is so protrusive that it will be rubbed off easily). If it is in the form of a strap then this should be no more than 60mm wide (to fit between the rhino's ears and the skin fold on its neck) and it must have a soft, yet tough, surface (or pass through a sleeve such as flattened fire hose) for a length of at least 50cm behind the rhino's ears, so it does not cut them.

Provision must be made to attach the transmitter in a hermetically-sealed container. This will probably have to go under the neck, as with all existing collar designs. The transmitter must be shock-protected, with streamlined housing. One model which has proved to be suitable is the MOD-555 transmitter produced by Telonics (932E Impala Aye, Mesa, Arizona 85204-6699, USA). This model is cylindrical, with a diameter of 38mm and a length of 105mm. Battery life is about three years. It has a di-pole antenna consisting of lengths of wire braid that protrude about 450mm from each end of the transmitter. The antenna must be encased within the collar and must not be close to metal clamps, bolts, etc., unless these are made of non-magnetic stainless steel or brass.

For black rhinos, the entire collar must be of adjustable length to fit snugly (before stretching) around neck diameters of 135 - 160cm, with the final fitting and trimming on a drug-immobilised rhino being a quick process (15 minutes at the most). The collar material must be resistant to ultraviolet rays as well as to the very severe impacts and abrasive forces that rhinos create.

There are various transmitter models that perform well enough to justify the risk and expense of immobilising rhinos, as well as the ongoing financial and manpower expenditure required to radio-track the rhinos. Activity (mortality) sensors can be incorporated at little extra cost. These sensors change the pulse rate of the signal from an "active" rate (e.g. 60 beats per minute [bpm]) to an "inactive" rate (e.g. 30 bpm) if the rhino remains still for a predetermined period. Some rhino managers have specified a delay time of several hours in order to avoid false alarms when a rhino is resting. However, problems may be experienced when a rhino dies and the transmitter goes back into "active" mode for long periods after being agitated by scavenging animals.

A short delay period (one or two minutes) may be more appropriate. Firstly, this will conserve battery life because the transmitter will reduce its pulse rate as the rhino rests, but the faster pulse rate (which makes radiotracking easier) will be triggered when the rhino is mobile. Secondly, it becomes useful initially to detect an "inactive" pulse rate when a rhino is resting (as rhinos often do in the midday hours) and then to hear the signal change to an "active" phase as the rhino lifts its head when disturbed by the search party's voices, footsteps, aircraft engine, etc. This means that a rhino in thick bush need not actually be seen (which may take a long time, and a lot of fuel if an aircraft is being used) or disturbed further in order to verify that it is alive. If the delay period is too long, the sensor will never "go inactive" while a healthy rhino is following its normal, diurnal behavioural pattern. Research has been underway in Save Valley Conservancy to determine how long a rhino typically "goes inactive" when it rests, in order that an appropriate alarm period can be specified for the reception of the "inactive" signal. This period varies greatly, with bulls "going inactive" for much longer (several hours) than cows with suckling calves.

A hypothetically useful type of rhino poaching alarm - not presently available in Zimbabwe - would be some passive (i.e. not battery-powered, or having only a small battery) electronic device that could be embedded in one or both of the rhino's horns. It would be capable of influencing the signal from the neck-collar transmitter, such that removal of the horns would change the signal as the modulating device is moved away from the main transmitter. Such a horn implant should be no larger than a domino, and should be cylindrical, if possible, in order to make it easier to drill a hole, within which it would be embedded using dental acrylic. Since poachers in Zimbabwe have invariably cut radiocollars off rhinos which they have killed, another option may be some circuitry which also changes the signal when the collar is severed.

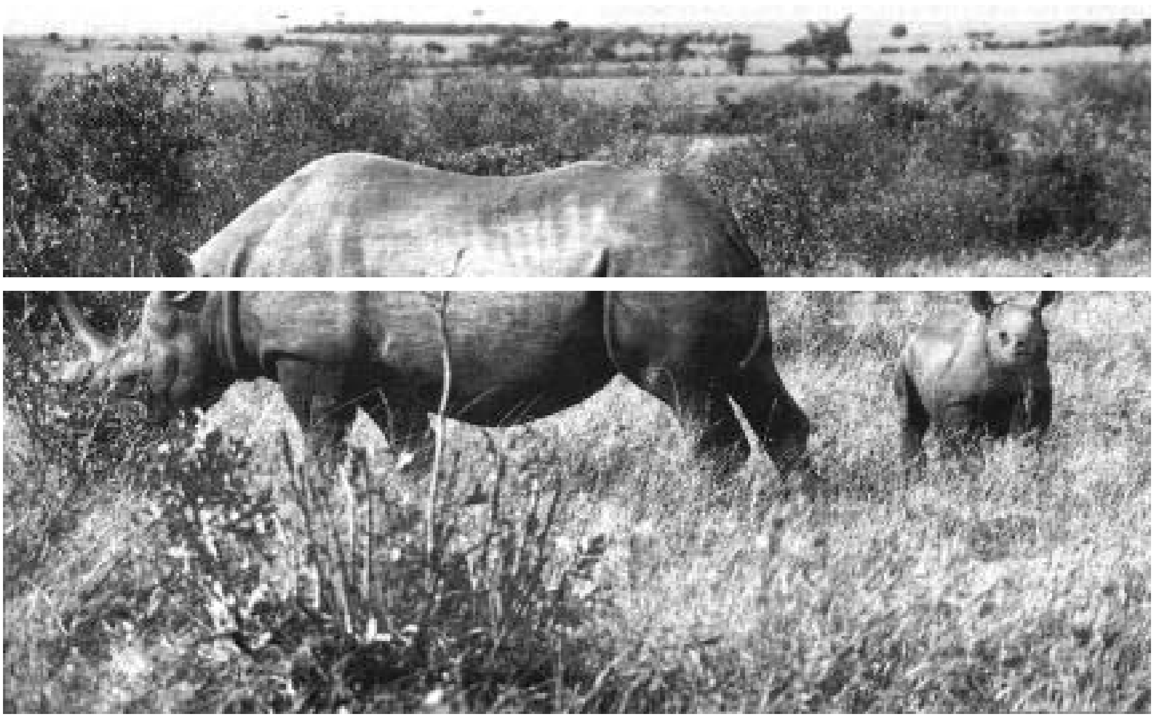
VHF signal ranges of 10km or more, as are presently achieved from high points in typical bushveld areas, are satisfactory for routine monitoring. However, the receivers that are now available in Zimbabwe are not robust enough or cheap enough (reputable models are each over US$700) to be used in typical anti-poaching contexts. They have been developed for wildlife research purposes rather than for law-enforcement purposes and would have short lives in the hands of game scouts.

For the field monitoring situation, the most appropriate radiotracking system would probably involve radio receivers at two levels of sophistication: the scouts should have simple, rugged, single-frequency receivers which need not have direction-finding capability, while centralised reaction units would use the typical, multi-channel receivers with Yagi antennae (e.g. the Telonics TR4 unit). In this system, it would be desirable for each collar to be capable of propagating signals on two frequencies, instead of only one as is presently the case. In Zimbabwe, the legal frequency range for animal radiotelemetry is 146.83 - 147.23MHz, thus giving plenty of available channels to deal with monitoring needs in any particular area (where it is unlikely that more than 50 channels would be required).

One frequency could be assigned as a common "alarm channel". All collars should be capable of transmitting on this frequency when their mortality sensors operate after a predetermined inactive period (possibly two hours for cows and three hours for bulls). Each collar should also be capable of transmitting on a frequency that is uniquely assigned to each rhino, as is the case in conventional wildlife telemetry. The unique channel should be subject to signal pulse variation in accordance with an activity sensor which has a short delay time (e.g. one minute), for the reasons outlined above. Ideally, instead of having two, completely separate transmitters in each collar (which would be expensive, since a pair of commercially available transmitters would probably cost over US$600), some circuitry, the antenna or at least the battery unit should be shared so that, in effect, the dual frequency transmitter would be enclosed within a single housing unit. There are probably technical constraints to simultaneous transmission by one unit on two frequencies, but these constraints appear to be overcome in, for instance, aircraft emergency beacon transmitters. Perhaps transmission could alternate between two minutes on the unique frequency and two minutes on the alarm frequency, once the latter is activated by the mortality sensor. The alarm transmission circuitry would not require much battery power, since it would not be in continuous operation.

The receivers carried by game scouts could thus be very rudimentary, with only an on/off switch (no channel selection required) and a simple omni-directional aerial. An alternative to portable alarm receivers would be a network of stationary receivers fixed on high points throughout the rhino range and operating off 1 2V lead-acid batteries charged by solar-voltaic

Photo credit: Holy Dublin



A black rhino with her caff in Kenya.

panels. Scouts could regularly monitor these receivers to check for alarm signals. If they hear such a signal, they will not know which rhino has died or where it has died (or lost its collar), although they should have a good idea, from their knowledge of the rhinos' home ranges and through the overlap of reception of the alarm signal by other receivers. The scouts would then radio for a reaction unit to come with a conventional, directional-finding, multi-channel receiver and Yagi antenna (ideally mounted on an aircraft), to track the collar via its uniquely assigned frequency and to establish the cause of the alarm.

It may be worthwhile to set the alarm signal of each transmitter at a different pulse rate (e.g. 30, *45*, 60, 75 and 90bpm). Obviously, some collars will have to share the same pulse rate, but if collars are being fitted to resident rhinos within reasonably well defined home ranges, an attempt can be made to ensure that collars with the same alarm pulse rate are put on rhinos which are out of the signal range of each other. If this can be achieved, then game scouts will have a good chance of determining which rhino has died or has lost its collar, even before the reaction unit arrives.

Since anti-poaching patrols already carry rugged, military specification, fully synthesised radios for voice communication (the eight-channel Motorola GP300 model is widely used in Zimbabwe), a desirable alternative would be to make the alarm frequency compatible with a receive-only channel on these Motorola transceivers, which can be programmed to operate anywhere in the 146.0 -174.0MHz band. However, preliminary trials in Zimbabwe suggest that the attainment of a reasonable reception with these Motorola radios requires that the radiocollars transmit alarm signals with a greater pulse width than is presently the case (about l4mSec). Also, more sensitive antennae may be required for the Motorola radios (although not as sophisticated or as cumbersome as Yagi antennae). Regular switching between the standard voice-communications antennae and any new radiotelemetry antennae raises the problem of the durability of the antennae connectors on these radios.

With the lithium batteries that are used in standard radiocollars, long periods of non-use can result in "passivation' which means that the batteries may not work when they are required to send the alarm signals. This problem can be overcome if the circuitry for the transmission of the regular signal on the unique frequency is connected to the same battery unit as the alarm circuitry. Alternatively, the alarm circuitry could be designed to transmit not only in the inactive (alarm) mode but also at a slow pulse rate (e.g. 6bpm) in the active mode. This would verify whether the alarm circuitry is actually working. Another advantage with continuous transmission at a very slow pulse rate is that the strength of reception of these signals would enable scouts to judge their proximity to a collared rhino.

The use of satellites for radiotracking is often suggested, particularly by laymen who are convinced that "eye in the sky" technology is now so advanced that this must be the most effective way to meet out rhino monitoring objectives. However, the limitations of satellite tracking (using the ARGOS system) remain much as they were a few years ago when Thouless *et al.* (1992) tried this technology in a study of elephant movements in Kenya. Satellite transmitters are considerably more expensive than conventional transmitters, as well as being heavier and having a shorter battery life owing to greater power consumption. Unless considerable investment is incurred in establishing a "local user terminal", satellite position "fixes" have to be relayed (e.g. via telefax) from ARGOS data processing stations (such as the one at Toulouse, France), and service charges are entailed in this indirect transfer of data. For various reasons, including the limited passing over of tropical areas by ARGOS satellites in their polar orbits, locational inaccuracies of 500 - 5000m are the norm.

Despite the present constraints of the ARGOS system, satellites will undoubtedly play an increasing role in wildlife radiotelemetry, but through the very different Global Positioning System (GPS). Most readers will be familiar with the abilities of this system, which include 10 – l00m accuracy in position-fixing using signals which are received by the radiocollar (from a constellation of satellites) rather than from the radiocollar. A GPS receiver in a radiocollar can store locational data in memory, for periodic transfer via the ARGOS system (in this case merely used as a data transfer system rather than as a position-fixing system) or via direct FM transmission to a ground receiver within radio range of the animal. Present configurations entail fairly bulky collars and require a GPS antenna mounted on top of the collar (i.e. above the neck), which would be problematic with rhinos, owing to the need to avoid pressure against their ears. However, the GPS "receiver engines" are steadily decreasing in size and require smaller batteries as they evolve from 5.OV, 200 - 2S0mA versions to 3.3V, l50mA versions (Tomkiewicz, 1996). Downloading of GPS data via local radio receivers, rather than via ARGOS, will probably be the most cost-effective option as GPS technology becomes ever more applicable to rhino monitoring needs. GPS collars will each require a conventional VHF back-up beacon and power supply so that the rhino or its shed collar can be located directly.

TRANSPONDERS

Over the past decade, there has been increasing use of implantable, inductive transponder microchips to enable accurate identification of individual animals throughout their lifetimes. A transponder consists of an integrated circuit, combined with an antenna which transmits a signal when activated by an appropriate low-frequency electromagnetic or infrared stimulus from an external source. This transmission may be achieved without any internal power source (i.e. the transponder is "passive") if the reception distance is short. Typically, transponders which are used for animal identification are very small (about the size of a grain of rice), sealed in bio-compatible glass, and can be injected subcutaneously or intramuscularly. Simple transponders transmit a unique alphanumeric code when activated, but the receiving devices generally have to be within 5 - 20cm of the transponder, thus requiring that a wild animal is immobilised or dead. These readily available devices have been used whenever possible to "tag" rhinos in Zimbabwe. They are generally injected into the forehead between the ears and the eyes, in the hope that this gristly tissue will remain on the skull of a dead rhino for some time, whereas softer flesh will slough off or be removed by scavengers. Transponders should also be inserted in each horn base, by drilling a small hole and using epoxy resin to plug the hole after the transponder has been pushed in.

While this technology is extremely useful for rhino identification at this basic level, there are many possibilities for increasing transponder applications. The major constraint is that of reception range. The power emitted by most commercially-available readers is apparently restricted to a very low level (of the order of 0.05 watts) in order to ensure that there is no risk of human radiation. The reflected signal of a passive transponder is therefore weak. Nonetheless, coin-sized passive transponders used in the USA for monitoring vehicle traffic on toll roads have a range of about six metres, while ranges of 20 - 30m are claimed for domino-sized passive transponders which have been developed in Australia (originally for transport and mining applications). Range can be increased by including batteries with the transponders, but the devices may then become too large to be safely implanted. The size limit is probably the Australian "domino" model; a cylindrical shape would be more convenient for implantation in rhino horns.

Two potential applications of small implantable transponders with extended signal ranges are immediately apparent. The first is an automatic monitoring system, whereby tagged rhinos which visit waterholes, middens or other localities that they frequent, have their identity numbers recorded and stored by concealed readers. A range of at least five metres (preferably 20m or more), and a waterproof reader operating on long-life batteries would be required for such a system to be worthwhile. The second application would be identification of rhinos by game scouts, particularly in thick vegetation where the visual identification features such as ear notches cannot be readily ascertained. Here, a reader with a range of at least 50m would be ideal to enable the scouts to approach downwind and to obtain the identification signal without disturbance of the rhino and without risk to themselves.

The Natal Parks Board worked with a South African military electronics firm to develop a proposal for "Operation Radio Rhino" in 1993. This envisaged the use of battery-powered transponders which could be regularly interrogated via a system of direction-finding (DF) hilltop repeater stations, automatically relaying information on the location of each rhino to a central computer processing facility. The proposed system would have been expensive (over US$300,000 to establish a system for about 150 rhinos using 12 DF stations and two control stations) and raised the problem of implanting battery-powered transponders (each about the size of a cigarette box) in rhinos. A similar project was planned subsequently in Zimbabwe, but using battery-powered transponders on collars rather than implanted devices. The advantage of such transponders was their longer battery life (over five years) compared to conventional radiotransmitters, but as mentioned above, this is largely negated by the current lack of collar design to keep a transponder on a rhino for this length of time. For various reasons, these projects have not been implemented but their concept is still being refined by electronics experts who are associated with the South African initiative.

GLOBAL POSITIONING SYSTEM TECHNOLOGY

Apart from the use of GPS devices in radiocollars (where they can be combined with transponder plications as well as convcntional transmitter applications), GPS technology has a potentially major role in the computerisation of monitoring law enforcement effort, poaching activity and wildlife abundance. It is a matter of common sense that routine anti-poaching work should be quantified in standardised units (e.g. kilometres patrolled or manhours on active duty) in order to enable spatial and temporal comparisons of, for instance, rhinos seen per kilometre or poachers' snares found per hour. This standardised monitoring approach would in turn allow for the systematic evaluation of animal population trends and of the effectiveness of anti-poaching or management strategies for the species of concern. Basic principles of recording patrol effort and thereby deriving "catch per unit effort" indices of poaching activity and wildlife abundance are outlined by Bell (1984) and Leader-Williams (1996).

While the theory is clear, the fact that such approaches have not been widely implemented in field programmes (Leader-Williams, 1996) is primarily because their requirements for data recording and data analysis become impractical in terms of the constraints of time and expertise that generally pertain to manpower within protected areas. Standardised technological aids are needed to facilitate the recording of relevant data and the subsequent manipulation of these data to yield outputs that are of immediate use to field staff. A combination of advanced hardware (in the form of GPS devices and personal computers) and advanced software (in the form of GPS data transfer systems and Geographical Information Systems [GIS]) must be obtained for time-effective and cost-effective patrol reporting at a useful level of detail.

GPS devices should be obtained which meet military specifications for humidity, dust, shock, etc., and which have inbuilt antennae, instead of external antennae on swivel mounts which are prone to snapping off. These devices need not have as many functions as are typically provided by commercial handheld GPS models; the basic requirements are the storage of positions at the push of a button and at fixed time intervals (e.g. every six or 12 minutes), together with a data transfer capability to allow post-patrol downloading of the locational and time data into a personal computer at a base station. Software must be developed to input these GPS data into a GIS so that map displays of patrol routes, sightings, incidents, etc. can be automatically generated. The protected area could be divided into geographical cells (a grid system, e.g. two by two kilometres or five by five kilometres) so it would become possible to say, for instance, "in cell D8, patrol coverage in June consisted of 27km of patrolling; three rhinos were seen (i.e. 0.11 rhino/km patrolled); 20 elephants were seen (0.74 elephant/km); seven poachers' snares were found (0.26 snares/kin)", etc. GIS mapping could then show spatial gradients in patrol effort, animal abundance and poaching activity, and trends over months or years could also be investigated.

Literate game scouts would be able to record sightings (animals, poaching signs, etc.) in notebooks together with their positions as displayed on their GPS devices for later debriefing and input of this information into the GIS database. An even simpler system could be based upon a non-display GPS similar to that in a radio collar, with only an on/off switch, a data storage and downloading capability, and a timer function to store positions at pre-determined intervals automatically. Scouts could then be issued with inexpensive digital watches to allow them to record the time of any sighting/event. The grid cell location of the sighting! event from the patrol chronology/route, which would be downloaded from the GPS, can be estimated later using the computer programme. This chronological approach would allow patrol effort to be quantified in terms of time in the field as well as distance covered, thus allowing trends based on sightings per hour to be cross-checked with trends based on sightings per kilometre.

With this customised technology, debriefing would be reduced to downloading the GPS data into a personal computer along with the entry of scouts' notebook records of times and/or GPS positions of sightings/ events during the patrol. This would obviate the need for maps to be consulted by scouts and their commanders in order to record manually patrol routes and the positions of sightings/events, thus saving time and improving locational accuracy, which would make patrol reporting far more practical. User-friendly software could be developed to enable middle-level managers to derive indices of relative wildlife abundance, poaching activity and patrol effort, together with trends in these indices, and to plan anti-poaching and wildlife management accordingly.

FURTHER POSSIBILITIES

Various additional technological possibilities are being investigated by rhino managers in southern Africa in terms of field performance and cost-effectiveness.

One example is a gunshot detector (T. Conway, Natal Parks Board, pers. comm.), which transmits a dio signal alarm to a control station if it is activated by the shock-wave of a firearm discharge or if it is tampered with. The claimed range for gunshot detection is one kilometre, which would constitute radial coverage of about three square kilometres. Depending upon their purchase and maintenance costs, these devices might be positioned systematically throughout the range of a rhino group, or they could be confined to likely sites of rhino poaching, such as waterholes.

Another example, which is of potential applicability to biological monitoring of rhinos rather than anti-poaching, is a device which can produce an odour spectrum from a sample of rhino dung or urine. Since rhinos rely heavily on their olfactory senses for intraspecies communication, to the extent of recognising other unseen rhinos and determining their reproductive status merely by sniffing their dung middens or urine sprays, there is obvious potential for the development of some apparatus which rhino managers could use to "tune into" the rhinos' olfactory communication system. Researchers and commercial agencies in UK (and probably elsewhere) are developing "electronic noses" for use in security systems, pollution control and even monitoring blood oestrogen levels in women who merely breathe into such devices. It is hoped that this technology for individual recognition and pregnancy/oestrus determination will be tested on free-ranging rhinos in Zimbabwe.

Among other important technological requirements in the biochemical field are the need for DNA "fingerprinting" of rhinos to facilitate parentage analysis (which is not as straighfoward as in humans), and the need for a urine analysis technique to monitor the extent to which black rhinos are ingesting plant secondary compounds in the form of phytotoxins, which are produced by plants to protect themselves from herbivory. As a black rhino population density begins to exceed the level of "maximum productivity carrying capacity" it can be expected that the rhinos will be forced to feed upon a greater proportion of chemically-defended plants. Analysis of phenolic metabolites in urine (or ideally in dung) may become possible as a way of checking that rhino populations are being kept safely in balance with their browse resources.

CONCLUSION

Further elaboration of perceived technological requirements, however naive these might prove to be, can only help to facilitate some adaptive research and development efforts with relevant agencies. Perhaps a regular "technology forum", in *Pachyderm* would be appropriate, to include other ideas, together with suggestions for technical agencies that might be able to help but which may have to be approached directly (since they are unlikely to subscribe to *Pachyderm).* Many conservationists view rhino conservation as a race against time. While end-markets for rhino horn are being tackled, it is probably more realistic to keep the rhino species alive by tipping the balance against the poachers through the introduction of some "high-tech" aids for field protection and management.

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