A New Environmental Monitoring Methodology

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At a basic level CyberTracker is simply a tool to gather data in a very efficient way. It can be used to gather data for scientific research, social surveys, population census, market research, agricultural pest control and environmental monitoring. CyberTracker can be used for any type of data gathering that involves field workers recording information away from the office. Normally such data would be captured on paper forms and would then be transferred to a PC back at the office.

However, CyberTracker is more than just a tool. CyberTracker represents a new way of looking at nature - a new methodology that will make it possible to monitor the environment on a worldwide basis at a level of detail that was not possible before.

A New Challenge

The Earth's climate system has demonstrably changed on both global and regional scales since the pre-industrial era, with some of these changes attributable to human activities. Ecological productivity and biodiversity will be altered by climate change and sea-level rise, with an increased risk of extinction of some vulnerable species (Intergovernmental Panel on Climate Change, 2001).

Biodiversity is the key to the maintenance of the world as we know it (Wilson, 1992). One of the most serious problems we face is that changes in complex ecosystems may be discontinuous (Bright, 2000; Lovelock, 1988). Changes in climate could increase the risk of abrupt and non-linear changes in many ecosystems, which would affect their function, biodiversity, and productivity (Intergovernmental Panel on Climate Change, 2001).

It may be fundamentally impossible to make medium to long term predictions of specific events. By the time we realise something is wrong it may be too late to do something about it. The only way to anticipate discontinuities in ecosystems may be to monitor the environment on a continuous basis so that we may detect early signs of increasing stress before a population crashes. A flow of accurate information about all aspects of the world may be essential (Lovelock, 1979).

We could never hope to "manage" the environment – the global ecosystem is simply too complex. We can only manage the impact of humans on nature by changing human behaviour. The objective of environmental monitoring should therefore be to alert us if and when human actions are having a negative impact on nature.

However, conservationists are working with limited financial resources. Given the complexity and magnitude of environmental problems, critical management decisions are often based on exceedingly limited information.

Sometimes direct intervention at local level is required, such as anti-poaching operations or reducing the utilisation of a particular plant or animal. But to deal with issues like climate change and loss of biodiversity on a global scale, we need to reform the global economy in a fundamental way (Brown, 2000). This will require political commitment – and politicians will only act if the people who vote for them demand change. We therefore need to create an awareness of what is happening to the environment. Environmental monitoring should be conducted in such a way that it would ultimately inform the general public and political leaders worldwide.

At a local level, data gathering needs to be conducted within the context of the management objectives of conservation areas. Unless conservation managers become directly involved and see a practical short-term benefit, it will fail. In particular, monitoring will only be successful if it is seen in its rightful position in a strategic adaptive management framework (Biggs, 2002). Data gathering must also be meaningful to the individuals involved on the ground. Otherwise they will simply not be motivated to gather large quantities of good quality data on an ongoing basis.

Given the likelihood that resources for nature conservation will always be scarce, we need a flexible range of methods, with varying intensity, which can change over time depending on priorities and circumstances. Environmental monitoring requires a new methodology that involves an adaptive cybernetic process with feedback at the individual level on the ground, at management level and worldwide.

Background and Philosophy

CyberTracker had its origins in tracking. The art of tracking may have been the origin of science, dating back to the evolution of the first modern humans (Liebenberg, 1990). This hypothesis is not just of academic interest – it may have very real practical implications. If tracking was indeed the origin of science, then there is no reason why traditional trackers today should not be able to conduct scientific research. Philosophically, scientific discourse can be extended beyond the confines of conventional science. Traditional San hunter-gatherers of the Kalahari make detailed observations about the movements and behaviour of animals based on hypothetical interpretations of tracks and signs. Such information can be of great value in nature conservation.

However, the best traditional trackers cannot read or write, making it difficult to apply their skills in conservation management or scientific research. To overcome this problem, the CyberTracker graphic user interface was developed for handheld computers, making it possible for non-literate trackers to record the observations they make in the field (Liebenberg, Blake, Steventon, Benadie and Minye, 1998). Solving this problem had far-reaching implications.

For the first time it became possible for non-literate trackers to accurately record very detailed geo-referenced information. An unexpected benefit of the graphic icon-based user interface was that it was also much more efficient for data capture for people who can read and write. It is much quicker to scroll through screens of visual icons than to scroll through and read long lists of text.

CyberTracker extends the capacity to gather data both quantitatively as well as qualitatively. Scientists can gather much more data than with paper-based systems. In addition, teams of field workers can be trained to record observations, increasing the quantity of data that can be gathered by orders of magnitude. Furthermore, traditional trackers can make observations based on tracks and signs that conventional scientists cannot. This means that new information can be gathered that may not have been possible before. Volunteers, including students, school children and amateur naturalists (such as bird watchers) can provide huge quantities of additional data.

Distributing CyberTracker freely as "greenware" over the Internet (www.cybertracker.org) allows independent initiatives to get off the ground. Rather than be restricted by our limited resources, greenware leverages the resources and creativity of people throughout the world. This will result in unrestricted growth of environmental monitoring projects worldwide. Sharing information about projects on the CyberTracker website collectively benefits independent projects and minimises the need for technical support.

Over time, technology will become more powerful and cost will be reduced. Moore's law predicts that the power of computers will double every two years. Conversely, for the same power, the cost will halve every two years. As the cost of handheld computers is reduced over time, more and more people will be able to participate. As computers become more powerful, we will be able to process more data, and share data on a worldwide basis, even in the remotest wilderness areas.

Increased awareness and participation can result in an exponential growth of data. Eventually it may be possible to integrate data from projects worldwide, creating the opportunity to monitor environmental change on a worldwide scale.

Requirements for Valid Data

Collecting huge quantities of data would be of no value if data were not accurate.

At the most basic level, CyberTracker automatically records the time and date, a GPS position for every observation, a unique Device User Name (for the handheld computer) and the observer's name. The GPS Timer can be set to automatically take a position every minute.

With a unique Device User Name and the GPS Timer readings, data can be analysed based on the path followed by the observer. For example, CyberTracker can automatically calculate the effort of the patrol and index of abundance for selected observations.

Recording the names of the observers who collected the data makes it possible to validate the accuracy of the data. The accuracy of data depends on the knowledge and skill of the observers. Good quality data can only be ensured by high standards of training and evaluation. Evaluations need to be conducted according to objective criteria that can stand up to independent scrutiny.

It cannot be assumed that all traditional trackers are experts in their field. Even amongst traditional hunter-gatherers, only a small percentage of hunters were expert trackers.

Hunting and gathering as a means of subsistence is disappearing, so expert traditional trackers are few and far between. The younger generation must be trained to develop their tracking skills and evaluated to ensure high standards.

As long as objective criteria are used to evaluate observers, data collected by a whole range of participants can be used and analysed. If observers were evaluated and classified in a hierarchical manner, it may be possible to automatically analyse large quantities of data with different levels of confidence. For example, even school children may be able to gather good basic data on common species. But when a six-year-old records data on an obscure bird species, you may be less confident that it is accurate. However, if the data has been validated by a qualified ornithologist, you would be more confident that the data is accurate. On the other hand, a scientist may not be able to identify the track of a small mongoose. However, an expert tracker (who may not be able to read or write) should be able to tell from the tracks not only which species of mongoose it was, but also accurate information on its behaviour.

In the near future, digital books (Stevenson, Haber and Morris, 2003; Wilson, 2003) will allow a more rapid learning process for new users, while giving experienced users direct access to a detailed reference library. This will result in more reliable data, since it would make accurate identification of species in the field easier.

Automatic data analysis makes it possible for people working in the field to get immediate results. Immediate feedback is important to keep field workers motivated and to guarantee good quality data.

To gather quality data on an ongoing basis also depends on the motivation of the people working in the field. Repetitive data collection can be tedious, which could result in deterioration of data quality over time. While basic data may be repetitive, it should be varied with more interesting observations. Even if some of the more interesting observations do not appear to have immediate value, the fact that it may make the overall data collection more stimulating could ensure that the basic data is more accurate.

The efficiency of field workers also depends on factors like physical fitness, time spent collecting data during the day, duration of field trips, social dynamics within the group working in the field and their relationships with people in management positions. Financial incentives (better salaries) and promotion to positions that reflect their level of skill and expertise may also be important to motivate individuals to work more consistently. Social and human relations are therefore also important in collecting data.

Methods of Data Collection

CyberTracker can be used to collect data for conventional statistical methods, such as line transect methods or distance methods (see Mayes, 2002 and Beyers, 2002). While CyberTracker can be used as a tool to make data capture more efficient, it does not make any fundamental difference to the basic methodology.

While conventional statistical methods may be the most reliable, it is necessary to ask whether a population estimate is needed, or whether an index of abundance is sufficient for management purposes (Krebs,1999). It is also important to distinguish between statistical significance and biological significance. When experiments are difficult or management actions needed, we may not have the luxury of obtaining statistical significance before needing to act on our hypotheses (Hilborn andMangel,1997).

Ecological systems are complex. For this reason, we can hope to observe only a very small fraction of the possible variables. The largest field research programmes barely scratch the surface of what could be measured. Therefore, the key questions in the design of ecological research are what experiments to perform, what to measure, and how to measure it. Whole new avenues of research have opened up based on new measurement methodologies such as radiotracking and individual identification of animals by natural marks (Hilborn and Mangel,1997).

CyberTracker makes it possible to develop a fundamentally new methodology for the collection of patrol data and data collected by trackers. In addition, these new methods can be combined with conventional statistical methods and technologies.

In the past, paper-based patrol data were of very limited value. Incidental observations were written down in ranger diaries or paper forms, usually with inaccurate methods of geo-referencing. Often it was not worth trying to process the data, since it would be of little or no statistical significance.

CyberTracker makes it possible for patrols to gather large quantities of geo-referenced data (Froment, 2003). In addition, an automatic GPS timer takes a position every minute, making it possible to measure the patrol path and patrol effort with a high degree of accuracy. This in turn makes it possible to automatically calculate an index of abundance for a particular type of observation.

Since patrol data is by its very nature biased, CyberTracker also makes it possible to measure the bias. For each observation, CyberTracker can record the method of patrol and the path type. Data may be biased depending on whether it is a foot patrol or a vehicle patrol. Or data may be biased by the fact that the foot patrol is following a road, a narrow path or open terrain. In addition, for each observation the environmental context may be recorded, such as the type of vegetation, the density of vegetation cover and the type of ground. The type of ground, whether soft soil or hard rocky ground, will determine how many tracks and signs may be found.

Researchers have in the past used trackers to assist them in locating animals and to record data on behaviour based on tracks and signs (Stander, 1997). CyberTracker makes it possible for trackers to gather data independently, and to gather large quantities of very detailed data (Liebenberg, Steventon, Benadie and Minye, 1999). Teams of trackers can also collect significantly more data than a researcher assisted by one tracker. Researchers working with teams of trackers using CyberTracker can therefore conduct a lot more research over a wider area on a continuous basis.

CyberTracker can also be combined with other technologies to provide information that cannot be obtained by either alone. Combining CyberTracker with radiotracking makes it possible not only to monitor a particular individual animal (which may not always be possible without radiotracking), but to gather more detailed data as well, for example on the behaviour of an animal (which radiotracking would not provide). CyberTracker field observations have been used for satellite image geo-referencing and interpretation, and for map validation at a level of detail never achieved before (Janvier and Mayaux, 2002). Conversely, satellite images can be used to extrapolate CyberTracker data to other areas.

Optimal Methodology

Given the complexity of ecosystems, it is impossible to monitor everything. Priority should be given to critical areas of biodiversity, rare and endangered species, keystone species and indicator species. In addition, financial limitations require cost-benefit considerations. The optimal methodology requires a flexible approach involving a range of methods.

Patrol data may be the most cost-effective way to monitor large conservation areas on a continuous basis. Patrol data can indicate, for example, a drop in the index of abundance over time for a particular species. In many cases an index of abundance is sufficient. However, due to the potential bias in patrol data, this information can sometimes be subject to uncertainties that are difficult to measure. But, it may indicate a potential problem and form the basis of a working hypothesis that can then be investigated in more detail.

This is illustrated by the CyberTracker data that shows the impact of Ebola in Lossi Sanctuary in the Republic of Congo (Froment, 2003). At the time of the outbreak no conventional statistical data was available, since the impact of Ebola involved a discontinuity in the ecosystem that was not anticipated by scientists working in the area. The only data available was CyberTracker patrol data that showed the presence of lowland gorilla before the outbreak of Ebola, and absence of gorilla over a large area after the outbreak. In addition, index of abundance data also suggested a drop in chimpanzee, duiker and bushbuck numbers. At the time it was not known that Ebola could kill these species and in addition it was not known whether the index of abundance data was statistically significant. However, the index of abundance data calls for further research (Jean Marc Froment, pers. comm.).

The most cost-effective way to investigate a potential problem may be to use trackers to gather more detailed data on a specific species. In particular, tracking may be the most effective method to study animals that are difficult to see, such as woodland and forest species, nocturnal species, rare and endangered animals, and very small populations. More detailed tracking data can indicate whether or not a trend is significant and help generate additional hypotheses on possible causes.

Once a problem has been identified, conventional statistical methods may be used to measure and quantify the real extent of the problem. Conventional statistical methods may be the best way to collect objective data, but they are very labour intensive and expensive. These methods should therefore be reserved for critical, high-priority problems.

To anticipate discontinuities in ecosystems, such as outbreaks of diseases, the impact of climate change, over-utilisation of resources by humans, or other catastrophic events, it may be necessary to monitor large areas on a continuous basis. This can only be achieved by using the most cost-effective methods, while using more intensive methods when specific problems are identified.

Public Perceptions of Reality

Apart from data collected by scientists and trackers, CyberTracker makes it possible for volunteers (such as bird watchers) and school groups (see Parr, Jones and Songer, 2003) to make a meaningful contribution to environmental monitoring. Anyone can download the software and use CyberTracker to get involved in environmental monitoring. In this way a new form of participatory research may help to democratise science.

Television, computers and the Internet give us access to a huge amount of information. But today most people live in cities, surrounded by an artificial urban environment. In a very fundamental way technology can alienate people from nature (O'Meara, 2000). Their perception of nature is limited to the perspectives offered by the media.

The only way to get a more realistic understanding of nature is for people to go into wilderness areas and literally get in touch with nature. Paradoxically, to counter the alienating effect of technology, CyberTracker makes use of cutting edge technology to get people back in touch with nature itself.

Science and technology determines what we can do. But ultimately it is morality that determines what we agree we should do. A conservation ethic is that which aims to pass on to future generations the best part of nature. To know it well is to love and take responsibility for it (Wilson, 2002).

Only when the general public develops a better understanding of nature and the potential problems created by climate change and loss of biodiversity, will politicians factor environmental consequences into policy decisions.

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