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Guest Editorial

Monitoring matters: examining the potential of locally-based approaches

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Abstract. Monitoring of biodiversity and resource use by professional scientists is often costly and hard to sustain, especially in developing countries, where financial resources are limited. Moreover, such monitoring can be logistically and technically difficult and is often perceived to be irrelevant by resource managers and the local communities. Alternatives are emerging, carried out at a local scale and by individuals with little formal education. The methods adopted span a spectrum, from participatory monitoring where aims and objectives are defined by the community, to ranger-based monitoring in protected areas. What distinguishes these approaches is that local people or local government staff are directly involved in data collection and (in most instances) analysis. In this issue of Biodiversity and Conservation, 15 case studies examine whether these new approaches can address the limitations of professional monitoring in developing countries. The case studies evaluate ongoing locally-based monitoring schemes involving more than 1500 community members in 13 countries. The papers are based on a symposium held in Denmark in April 2004 (www.monitoringmatters.org). Here, we review how the case studies shed light on the following key issues concerning locally-based methods: cost, sustainability, their ability to detect true local or larger-scale trends, their links to management decisions and action, and the empowerment of local constituencies. Locally-based monitoring appears to be consistently cheap relative to the costs of management and of professional monitoring, even though the start-up costs can be high. Most local monitoring schemes are still young and thus their chances of being sustained over the longer term are not yet certain. However, we believe their chances of surviving are better than many professional schemes, particularly when they are institutionalised within existing management structures, and linked to the delivery of ecosystem goods or services to local communities. When properly designed, local schemes yield locally relevant results that can be as reliable as those derived from professional monitoring. Many management decisions emanate from local schemes. The decisions appear to be taken promptly, in response to immediate threats to the environment, and often lead to community-based actions to protect habitats, species or the local flow of ecosystem benefits; however, few local schemes have so far led to actions beyond the local scale. Locally-based monitoring schemes often reinforce existing community-based resource management systems and lead to change in the attitude of locals towards more environmentally sustainable resource management. Locally-derived data have considerable unexplored potential to elucidate global patterns of change in the status of populations and habitats, the services they provide, and the threats they face, but more effort is needed to develop effective modalities for feeding locally-derived data up to national and international levels.

Introduction

Why does monitoring matter?

The title of this special issue asserts that monitoring wild nature and the benefits which it bestows on people matters, but to whom and why? Recent developments suggest at least three kinds of actors and actions for which such monitoring is becoming increasingly important.

At the international, regional, and national scales a raft of macro-policy initiatives have committed governments to achieving quantitative targets in conserving biodiversity and ensuring its benefits are distributed equitably. At the 2002 Johannesburg World Summit on Sustainable Development, for example, representatives of 190 countries committed themselves to the Convention on Biological Diversity's target of 'achieving by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional, and national level…' (UNEP 2002). Related commitments by European Union member states are more ambitious, requiring 'that biodiversity decline should be halted… by 2010' (European Council 2001). Achieving sustainable use of natural resources is also key to meeting the United Nations' Millenium Development Goals (United Nations 2000). Yet, important though these high-level goals are, policy-makers simply will not know whether the goals are being met without robust and representative systems for monitoring the changing state of nature (Jenkins et al. 2003; Balmford et al. 2005).

Likewise, monitoring is crucial at all scales for conservationists to assess the impact of their interventions. Identifying the circumstances under which different kinds of interventions succeed (or indeed fail) requires effective monitoring of managed and control areas, or of managed areas both before and after an intervention. Ways of measuring the effectiveness of different projects and programmes are also increasingly required by the institutions and individuals that fund conservation agencies and Non-Governmental Organisations (NGOs), in particular when faced with problems of measuring the impact of past project interventions (e.g. Kremen et al. 1994). Filling-in of scorecards can be very useful for rapidly assessing the urgency and intensity of threats (Margoluis and Salafsky 2001) and for examining the management effectiveness of protected areas (Stolton et al. 2003) but they provide no information on biodiversity. Growing awareness of the need for monitoring data to evaluate the impact of conservation activities is reflected in the growth of so-called evidence-based conservation (Sutherland et al. 2004), as well as the recent establishment of dedicated consortia such as the Conservation Measures

Partnership (www.conservationmeasures.org/CMP/) and the Cambridge Conservation Forum's Harmonising Measures of Success project (www.cambridgeconservationforum.org/macarthur.html).

Last, and crucially, the past two decades have seen a progressive shift towards involving local communities formally and more effectively in the management of protected areas, and encouraging them to manage their own lands in ways that are compatible with agreed conservation goals (Brandon and Wells 1992; Caldecott 1998; Hulme and Murphree 1999; Dubios and Lowore 2000; Roe and Jack 2001; Jeanrenaud 2002a, b; Wells and McShane 2004; Sheil and Lawrence 2004). These newly recognised partners in conservation also require monitoring data to inform their decisions – in a form that is accessible and credible to them, and which measures those aspects of biodiversity that are of greatest local relevance.

The need for monitoring is thus clear, but who should carry it out? To date, most attention has been paid to what we here term 'professional monitoring', by trained scientists working primarily for government agencies or NGOs. Why should we be interested in looking further afield?

Challenges to professional monitoring

Professional monitoring programmes face a number of important challenges, especially in developing countries, where financial and human resources are especially limited:

1. Professional monitoring is often costly, at least relative to the budgets of most conservation agencies. Employing scientists with appropriate field and analytical skills, buying and maintaining field equipment, and running data analysis facilities, can together take up a significant fraction of an organisation's resources, without directly delivering conservation on the ground.
2. High cost in turn means that many monitoring programmes are not sustained over time. The resulting work may still be valuable as a series of one-off assessments, but it does not constitute monitoring, and it cannot provide the information on trends over time essential to the kinds of management decisions described above.
3. Professional monitoring can often be difficult, both logistically, technically, and analytically. To some extent these problems can be addressed through explicit advance consideration of the importance of systematic, unbiased and sufficiently replicated data collection. However, some aspects of biodiversity remain technically difficult to monitor – such as the extent or condition of certain habitat types which cannot be readily measured via remote sensing, and the rate of delivery of certain ecosystem services. As a consequence, only a minority of the world's major biomes, and very few key ecosystem services, are currently being monitored at a regional or global scale (Balmford et al. 2003b; Jenkins et al. 2003).

4. Monitoring is frequently perceived to be insufficiently relevant to the needs of managers (e.g. Sheil 2001), and as a consequence, may have limited bearing on management decisions. The solution to this is to involve managers, right from the outset, in identifying the objectives of the monitoring programme, and in checking, at an early stage, that these objectives are being met (Yoccoz et al. 2001; Royal Society 2003; Green et al. 2005). However, this is an increasingly difficult challenge for professional monitoring in a world where formal responsibilities for resource management are becoming devolved away from high-level government employees.
5. A related issue is that professional monitoring is often seen as paying inadequate attention to the objectives of other key stakeholders, besides professional resource managers – especially local communities whose livelihoods are often closely impacted by the resources concerned (Steinmetz 2000; Lawrence and Elphick 2002). Again, in principle, professional monitoring can and should address this, through extensive dialogue with all stakeholders at the onset and throughout the course of monitoring but in reality, shortages of money, time, and trained personnel can make this a tall order.

In the light of these challenges, a suite of alternative, locally-based approaches to monitoring have begun to emerge; these form the focus of this special issue.

Locally-based monitoring

We use the term 'locally-based monitoring' to embrace a broad range of approaches, from self-monitoring of harvests by local resource users themselves, to censuses by local rangers, and inventories by amateur naturalists; we include techniques labelled as 'participatory monitoring', 'community-based monitoring', 'hunter self-monitoring' and 'ranger-based monitoring'. Many of these approaches are directly linked to resource management, but the entities being monitored vary widely, from individual animals and plants, through habitats, to ecosystem goods and services. However, all of the approaches have in common that the monitoring is carried out at a local scale by individuals with little formal education, and that local people or local government staff are directly involved in data collection and (in most instances) analysis.

It has been suggested that such locally-based approaches have considerable potential to complement professional monitoring in developing countries by addressing some of the shortfalls we have just encountered (Danielsen et al. 2000). Specifically, it should be possible to carry out locally-based monitoring at much less cost than professional monitoring, and hence for it to be more sustainable. Through careful training and sampling design, it should be possible for locally-based monitoring to yield results which are as reliable as those of professional techniques (Yoccoz et al. 2003), and which can shed light on some aspects of biodiversity which are hard to monitor professionally. Perhaps most importantly, locally-based monitoring will by its nature tend to focus on management issues of greatest concern to stakeholders, and is thereby likely to have considerable advantage over professional approaches in its potential to influence on-the-ground management activities, and to empower and enhance capacity among local stakeholders.

Yet promising though these suggestions are, they now need testing (Danielsen et al. 2003a, b; Rodríguez 2003). How far has the potential of locally-based monitoring translated into tangible results on the ground in developing countries?

This issue

To address this question, the Nordic Agency for Development and Ecology (NORDECO, Denmark), and the Zoology Department of Cambridge University (UK) hosted a two-day symposium on locally-based monitoring in Denmark in April 2004. The symposium included 14 case studies, which form the backbone (together with an additional paper solicited since the meeting) of this special issue. In this introductory paper we begin by outlining the range of the case studies, and then review how they shed light on each of the issues raised above – the cost of locally-based monitoring; prospects for its being sustainable; its ability to generate accurate and precise data; linkages with management decisions and action; and its ability to empower local communities. We then briefly consider ways in which locally-derived data might be used to plug larger-scale monitoring gaps, before closing with a brief set of recommendations for the future.

Case studies

This special issue presents results from case studies spanning a range of continents, biomes, land tenure systems, and stakeholders. The examples also vary widely in terms of what is monitored, over what area, and at what frequency and cost (Table 1). Thirteen studies outline ongoing monitoring schemes, while one (Roberts et al. 2005) describes a planned scheme and one (Hockley et al. 2005) models general constraints on locally-based monitoring. These papers were derived from a set of more than 30 potential case studies that were proposed to the symposium organisers, and were chosen to reflect the widest possible set of situations and issues.

We have assessed the various methods used in the different symposium papers, together with a review of the relevant literature, and on this basis propose five generic methods that are suitable for locally-based biodiversity monitoring in developing countries (Table 2).

Table 1. Case studies of ongoing locally-based monitoring schemes.

Case study[a]	Country	Biome[b]	Land tenure system[c]	Type of participation by community members[d]	Who compiles data[e]	What is monitored[f]	Spatial scale. Total size of area monitored[g] (ha)	Interval between successive bouts of data collection (days)	Community member time spent on data collection (person-hours/ha/yr)	Payment provided to community members involved in the monitoring (USD)	Indicative recurrent costs of monitoring[h] (USD/ha/yr)	Indicative total funding for management (USD/ha/yr)
van Rijsoort and Jinfeng 2005	China	t	PA	I (48)	R/C	Use/Wildl	46,725 (2)	Varies	No data	Small allowance and/or free seedlings for a nursery	No data	4.87 (2000)
Bennun et al. 2005	Kenya	t	Non-PA	I (100)	C	Use/Wildl	77,000 (1)	180	0.005	0 (meals)	0.01 (2003)	50
Poulsen and Luanglath 2005	Laos	t (fw)	PA	I (30)	R/C	Use/Wildl	240,000 (1)	Varies	0.008	0 (meals)	0.02 (2002)	0.02
Stuart-Hill et al. 2005	Namibia	t (fw)	C-PA	I (200)	C	Use/Wildl	7,000,000[i] (30)	Varies	0.005[i]	100/mth[j]	0.01[i, j] (2003)	0.05–0.65[i]
Danielsen et al. 2005	Philip-pines	t (m, fw)	PA	I (350)	R/C	Use/Wildl	1,090,000 (8)	90	0.005	0 (snacks)	0.04 (2001)	1.75
Topp-Jørgensen et al. 2005	Tanzania	t	PA/non-PA	I (298)	C	Use/Wildl	144,403 (4)	Varies	0.201	0–2/day	0.05[k] (2003)	0.23
Noss et al. 2005	Bolivia	t	C-PA	II (125)	C	Hunting	400,000 (1)	1–7	0.009	Hunters: 0 Recorders: 150/month	0.13 (2003)	1.63
Becker et al. 2005	Ecuador	t	C-PA	II (10)	C/V	Birds	2,430 (1)	360	1.77	5–10/day	2.50 (2003)	2.88
Brashares and Sam 2005	Ghana	t	PA	III (0)	R	Use/Wildl	516,500 (2)	30	No community members involved[l]	No community members involved	0.06 (2003)	0.18[m]

Gray and Kalpers 2005	Uganda, Rwanda, DRC	t	PA	III (0)	R	Use/Wildl	78,600 (3)	Varies	No community members involved	No community members involved	1.26 (2003)	36.1[n]
Townsend et al. 2005	Ecuador	fw	C-PA	I (150)	C	River turtles	1,200[o] (1) along river	10–14[p]	9.92	Nest reporters: 0.25/nestThose who census the river by canoe: 100/month	10.0 (2003)	No data
Andrianandrasana et al. 2005	Mada-gascar	fw	Non-PA	II (155)	C	Use/Wildl	42,810 (1)	360	0.065	2/day (+prizes)	0.09 (2002)	0.14[q]
Uychiaoco et al. 2005	Philip-pines	m	PA/non-PA	II (54)	C	Use/Wildl	74,885 (9)	180	28.8	0 (meals)	14.0 (2003)	30

[a] Source of information (this special issue, and correspondence with the authors).
[b] t = terrestrial; fw = freshwater; m = marine (bracketed biomes account for a minor portion of the area under monitoring).
[c] C-PA = protected area managed by the local communities; non-PA = outside of protected area; PA = protected area under government authority.
[d] I = Monitoring scheme intended to involve the community members in the local design of the monitoring as well as in data collection, data analysis, and monitoring-based decision-making; II = Monitoring scheme intended to involve the community members mainly in data collection and monitoring-based decision-making; III = Monitoring scheme not currently intended to involve community members. The number of community members directly involved in the monitoring is indicated in brackets.
[e] C = community members; R = government rangers; V = volunteers (from abroad).
[f] Use = resource use; Wildl = wildlife (species/populations and habitats).
[g] The number of areas monitored is indicated in brackets.
[h] Year in brackets; excluding depreciation of equipment.
[i] Many conservancies are located in large deserts.
[j] Funds generated locally from trophy hunting or tourism.
[k] Funds generated locally from user fees.
[l] The rangers however often come from local communities.
[m] This figure includes the costs of monitoring.
[n] Data from Uganda (Mgahinga Gorilla National Park) and Rwanda (Parc National des Volcans) only.
[o] The Cofán-managed territory of 120,000 ha benefit from this monitoring.
[p] River census.
[q] Excluding salaries and competition prizes.

Table 2. Five non-exclusive generic methods suitable for locally-based monitoring of biodiversity in developing countries.

Method	Habitat coverage	Equipment	Pros	Cons	Remarks	Case studies using method
1. Patrol records. Filling-out routine patrol sheets on key species, habitats, or extent of resource exploitation (incl. GPS recordings of infringements; ranger event books)	Useful both on land and in water	Notebook, pen, identification guide[a] and binoculars	Easy to integrate in labour schedule of rangers. Simple and easy to grasp even for people without training. Encourages rangers to be observant of changes; and increases the motivation for their work. Powerful at generating management interventions to protect species and natural habitats	Will produce biased results if the patrolling are localised, or if patrol routes sample different habitats unrepresentatively; both problems are likely	Some effort correction possible, if data is confined to specified locations and a constant number of informants, or patrol coverage is measured by use of toponyms/GPS	Brashares and Sam 2005; Danielsen et al. 2005; Gray and Kalpers 2005; Poulsen and Luanglath 2005; Stuart-Hill et al. 2005; Topp-Jørgensen et al. 2005
2. Transects. Simple dedicated transects of wildlife and human resource use (incl. reef fish visual census and manta tow estimates of hard coral and sand cover; canoe transects of river turtles)	Useful both on land (transect walk) and in water (transect cruise/swim)	Notebook, pen, identification guide, binoculars, watch, water container with water, food (mask/fins for transect swim)	Minimal training of data collectors needed. Corrected for effort.Relatively easy interpretation. Data also useful for tracking large-scale vertebrate population trends (see Fig. 1)	Data collectors need species identification skills. The transects should be censused by the same person every time. Biased by seasonal changes in detectability of wildlife. In freshwater wetlands, access to permanent routes may be constrained by water dynamics, invasive plants etc.	Careful selection of transect routes is critical	Andrianandrasana et al. 2005; Becker et al. 2005; Danielsen et al. 2005; Townsend et al. 2005; Uychiaoco et al. 2005
3. Species lists. Presence/ absence of species on fixed-time lists (incl. 1-day index of abundance)	Useful both on land and in water	Notebook, pen, identification guide, binoculars	Capture *ad hoc* sightings routinely gathered by e.g. birdwatchers	Lists perhaps biased towards rare species. Observers might be attracted to the more desirable places for recording species. In addition, variation of effort is a source of bias (see Roberts et al. 2005).	The usefulness of this method for generating conservation management interventions has not yet been assessed	Bennun et al. 2005; Hockley et al. 2005; Roberts et al. 2005

4. Simple photography. On-the-ground fixed point photography	Useful both on land and above water in wetlands. Particularly useful in undulating terrain and along curved coastlines	Notebook, pen, camera (Single Lens Reflex) with battery, films, compass, and, if possible, a tripod. A topographic map, a GPS, and paint for marking the site permanently would also be useful	Minimal training of data collectors needed. Data-set is objective, independent of observer and identification skills and of permanent value. Useful for generating convincing inputs to local level awareness-raising and education work	Data collectors need camera operation skills	Careful selection of sites is critical. Sites should be easily accessible, from where one can see the surrounding landscape	Bennun et al. 2005; Danielsen et al. 2005; van Rijsoort and Jinfeng 2005
5. Village group discussions. Discussions between government staff and local volunteer members of 'community monitoring groups' (incl. hunter self-monitoring; interviews; village log books; fish/shellfish capture recording)	Useful in both land and water habitats	Large sheets of paper, markers, identification guide, food	Relatively easy interpretation. Provides an opportunity for villagers and authorities to discuss management. Powerful at generating local bylaws, joint government/community actions, and actions to ensure local flow of ecosystem benefits (Danielsen et al. 2005)	Data is qualitative. Information is not objective. People may be reluctant to provide information on resource use as they fear restrictions. Ineffective in areas with poor relationship between the authorities and the local people	The information is based on local communities' own perceptions of trends. Data gathered continuously from a number of representative communities can however provide a valid picture of general trends	Andrianandrasana et al. 2005; Danielsen et al. 2005; Noss et al. 2005; Poulsen and Luanglath 2005; Topp-Jørgensen et al. 2005; Townsend et al. 2005; Uychiaoco et al. 2005; van Rijsoort and Jinfeng 2005

(a) For a review of the usefulness of identification guides for environmental management, see World Bank 1996.

Patrol records

The first of these methods involves filling-out sheets with observations and records provided by local people on key species, habitats, or the extent of resource use during patrols. This method provides quantitative data on changes in abundance of species or the extent of threats to habitats. It has been adapted for use in both protected areas by employed rangers (e.g. Brashares and Sam 2005; Gray and Kalpers 2005 (this issue)) and also within village-based monitoring systems where the participants are either volunteers or members of environmental committees involved with the management of the resource (e.g. Stuart-Hill et al. 2005; Topp-Jørgensen et al. 2005 (this issue)). So long as the methodology and the forms used are simple enough then the method can be sustained at village level, but temptations to make the recording methodology more complex – for example by changing from simple school exercise books that are available at village level, to photocopied forms that cannot be reproduced locally – are often hard to resist.

Transects

The second set of methods uses simple dedicated transects of wildlife and human resource use to collect quantitative data on changes over time. The method has been adapted to work in a variety of habitats, from forests through grasslands to coral reefs and rivers (e.g. Obura et al. 2002; Gaidet et al. 2003 and papers by Townsend et al. 2005 and Uychiaoco et al. 2005 (this issue)). The locally-based transect method can be undertaken on foot, in canoes along rivers or while swimming over coral reefs. As with the patrol method, the key to embedding the method at local level is to make it as simple as possible.

Species lists

The third set of these methods is a way to measure abundance changes in wildlife species, and involves an assessment of the presence/absence of species on lists summarising all the species encountered during a defined period of time in the field such as a day or an hour (Roberts et al. 2005 (this issue)). If enough lists are compiled then the proportion of times that a particular species is recorded can be used as proxy measure of abundance (e.g. Pomeroy 1992; Bibby et al. 2000). This method is somewhat more technically demanding than the others, but has been used successfully in two of the present case studies (Bennun et al. 2005; Hockley et al. 2005 (this issue)).

Photography

The fourth type of method consists of simple fixed-point photography from a suitable vantage point on the ground. Human memory can be subjective and may also not be able to capture details of changes over time. Photography is an affordable method in many parts of the developing world (e.g. van Rijsoort and Jinfeng 2005 (this issue)). This method can tell if the size of important habitats is declining and why. In some cases, e.g. in the savanna woodland habitats of eastern and southern Africa, such a method might also provide some information on large mammal changes, but in general this is not the case and the method is not generally suitable for providing information on changes in abundance of animals within an area. In very poor communities, such as many parts of tropical Africa, this method might also be too expensive to be sustained over the long term.

Village group discussions

The fifth of these methods involves village group discussions. Monitoring by a small number of particularly knowledgeable forest product gatherers, hunters or fishers can provide relevant information that can be triangulated by some of the more quantitative methods such as patrol records and transect methods. The results are discussed among the group members, regularly presented at village meetings, and thereby brought to the attention of many people in order to seek their suggestions and endorsement for management decisions that will lead to conservation actions at the local level (e.g. Danielsen et al. 2000; Steinmetz 2000; Obura et al. 2002 and papers by Poulsen and Luanglath 2005; Topp-Jørgensen et al. 2005; van Rijsoort and Jinfeng 2005 (this issue)). This is an important element of locally-based monitoring as it feeds immediately back to decision-making bodies at the most effective and operational level – that of the resource users themselves.

These broad classes of methods are non-exclusive and several of our case studies use more than one (Table 2). In most cases the schemes are specific to local areas, but in Ghana, Namibia and the Philippines they have been adopted nationally (Brashares and Sam 2005; Danielsen et al. 2005; Stuart-Hill et al. 2005), and elements of the scheme in Tanzania are now also being adopted nationally (Topp-Jørgensen et al. 2005). In addition, one paper illustrates the extension of locally-based methods to a range of sites across the world (Bennun et al. 2005). As well as demonstrating the range of possible techniques, this diversity of case studies enables us to examine the merits of locally-based monitoring with respect to each of the issues raised in the Introduction.

Key issues

Cost

The costs of the monitoring schemes vary widely between our case studies due to variations in the objectives of the schemes themselves, and differences in costs between countries (Table 1). Costs also vary with the intensity of data collection (e.g. density of field sites and frequency of data collection), accessibility of the area, density of government staff at the field level, and type of participation of the stakeholders (Table 1). These variations make the costs of the monitoring schemes difficult to compare. However, all the locally-based monitoring systems examined here have some cost, in addition to the time put into monitoring which is not then available for farming or other economic activities. The present levels of recurrent costs (excluding depreciation of equipment) range from 0.01 USD/ha/yr in Kenya and Namibia to over 10 USD/ha/yr in rivers and coral reefs of Ecuador and the Philippines (where censuses require the use of boats). The median cost of all schemes examined was 0.08 USD/ha/yr.

How do these costs compare with those of professional monitoring, and direct management? The costs of monitoring by professional scientists vary widely but as an example the programme for monitoring a protected area in Uganda cost USD 120,000 in 2001, or 3.6 USD/ha/yr (A. McNeilage *in litt*.). Other field activities required for managing conservation areas (such as law enforcement or resource management) also vary widely in cost. However, some approximate figures are informative. The costs of effectively managing protected areas in developing regions characterised by high human population density and high endemism run at very roughly 10 USD/ha/yr (Balmford et al. 2003a), dropping to 0.2 USD/ha/yr in extensive wilderness areas. However, the great majority of these costs are not currently met, either by governments or external agencies (Balmford and Whitten 2003). For example, our experience with the forest sector in Tanzania is that around 0.02–0.04 USD/ha/yr is actually available from the government Forest and Beekeeping Division for management activities in the most biologically valuable and pressurised forest areas in the country – and significantly less than this for lower priority areas. Hence locally-based monitoring can be expensive relative to the funds available for management in such countries. However, this is not necessarily the case – the median funding available for management across the range of examples presented in Table 1 is ~1.7 USD/ha/yr, or ~20 times the median cost of locally-based monitoring. Moreover, locally-based monitoring appears to be consistently cheap relative to the costs of effective management, and of professional monitoring.

Three other important points on cost emerge from our case studies. First, in seeking to calculate the costs of monitoring we have been struck by the difficulty of separating monitoring from management – in the context of these locally-based schemes the two activities are often undertaken as one (for example via patrols or village meetings). Monitoring is supposed to inform management, but in some cases it is management in its own right, as, for example, the simple presence of people showing an interest in an area generally has an unquantified but real benefit in terms of reducing threats. Hence the expenditure on the locally-based monitoring schemes summarised in Table 1 usually delivers important benefits besides monitoring *per se* (see sections below on local constituencies and decision-making).

Second, locally-based monitoring carries the potential disadvantage that the costs of monitoring can sometimes be borne disproportionately by the local communities themselves. This can be particularly problematic where the benefits they derive from such monitoring are less than the costs (e.g. Hockley et al. 2005; Topp-Jørgensen et al. 2005 (this issue)). This problem can be compounded by situations where the more powerful members of the local society capture the benefits and the poorer members are coerced into doing the monitoring work. It is important that when monitoring schemes are being established the magnitude and distribution of local costs are given careful consideration. If a conservation initiative has simply offloaded the costs of monitoring onto the local communities without associated benefits, this is probably not sustainable (see section below on sustainability).

Third, the costs of locally-based monitoring are likely to vary over time. In the majority of our case-studies the start-up cost for the monitoring system has been large and paid for by external agencies. As examples, the Philippine ranger- and community-based scheme cost around 1 million USD to establish and institutionalize in 17 protected areas (A.E. Jensen *in litt.*), and in Laos and Tanzania, comparable systems each cost over 100,000 USD to establish even though they built on the tools developed in the Philippines (E. Topp-Jørgensen and M. K. Poulsen *in litt.*). However, once it has been established and people are trained and deriving sufficient benefits to sustain the process, locally-based monitoring typically becomes considerably cheaper and new sites can be added at little cost. The Ghana ranger-based monitoring system operated for more than 30 years with monitoring incorporated within the jobs of the rangers and with salaries paid by government and only sporadic external funding (Brashares and Sam 2005 (this issue)). Once established, volunteer-based monitoring systems can also be fairly cheap (Mumby et al. 1995; Darwall and Dulvey 1996; Engel and Voshell 2002; Greenwood 2003; Roberts et al. 2005 (this issue)).

Sustainability

The definition of 'sustainable' that we use here is that it will be possible to continue the activities indefinitely at a level that ensures the objectives of the monitoring are fulfilled. In some cases (e.g. where valuable resources are rapidly disappearing), sustainability may not be crucial, and locally-based monitoring may nevertheless prove a useful tool for improving management of the area in the short term (Becker et al. 2005 (this issue)). However in general, it is clearly desirable that any scheme that is started is financially and institutionally sustainable. We have tried to assess the case studies in terms of their likely sustainability. We have also drawn out some general principles that are more likely to make the monitoring effort sustainable in the longer run.

Four of our case study examples of formalized, long-running locally-based monitoring schemes were initiated with foreign government or NGO involvement. The fact that they are now being sustained without such support provides evidence that the operational costs of locally-based monitoring in developing countries can be met when the external support ceases – as in both case studies from the Philippines, in the Laos 'village logbook', and in the Ghana example (Brashares and Sam 2005; Danielsen et al. 2005; Poulsen and Luanglath 2005; Uychiaoco et al. 2005 (this issue)). Funding to continue those schemes which have sustained themselves without support from foreign governments or NGOs has come from either the local communities or the national government. Even in these four cases, however, some small additional external inputs could almost certainly have enhanced the impact of the schemes. For example, ongoing analysis of the data collected by rangers in Ghana over the past 33 years could have prompted changes in the management regime of the reserves; instead, analysis was only retrospective and came too late for many of the reserves' large mammal populations (Brashares et al. 2001). Likewise, a little support now to strengthen training in data analysis and participatory approaches in the Philippines could improve the quality of the scaling-up process across the country.

The remaining nine ongoing monitoring schemes in this special issue are either in the early stage of implementation and their ability to sustain themselves still needs to be seen (Stuart-Hill et al. 2005; Topp-Jørgensen et al. 2005; van Rijsoort and Jinfeng 2005 (this issue)), or they currently depend on NGO input for operations and it is not known if they would persist if these inputs were terminated (Andrianandrasana et al. 2005; Becker et al. 2005; Bennun et al. 2005; Gray and Kalpers 2005; Noss et al. 2005; Townsend et al. 2005 (this issue)).

Our case studies highlight six principles that appear important in enhancing the chances of a locally-based monitoring scheme becoming sustainable without continued external support:

1. Locally-based monitoring has to address benefit flows which the community derives from the habitat or population being monitored. These are most often harvested goods, but could include indirect use benefits such as water supply (Becker et al. 2005 (this issue)), or non-use benefits such as aesthetic values (Bennun et al. 2005; Roberts et al. 2005; Topp-Jørgensen et al. 2005 (this issue)). Those benefits which are only tangible over larger scales (such as the downstream effect of water supply) are perhaps better addressed by government or NGO monitoring.
2. Second, it is not enough that the scheme addresses locally relevant benefit flows. The benefits to local people participating in monitoring should also *exceed* the costs (Topp-Jørgensen et al. 2005 (this issue)). On the one hand the benefits of the monitoring (in terms of decreased risk of stock collapse, for example) are typically only a fraction of the gross benefits derived from the population or habitat (Hockley et al. 2005 (this issue)). On the other

hand, monitoring itself can impose significant costs, in terms of time as well as resources, which may in some cases exceed its benefits (for a detailed analysis see Hockley et al. 2005). Against this, it is worth noting that there often are a number of important social benefits of monitoring – ranging from enhanced *de facto* rights to land and resources, to local status, pride in an area, and potentially enhanced training opportunities.

3. Third, monitoring schemes must pay attention to ensuring that conflicts and politics between government managers and communities do not constrain the involvement of local stakeholders in the monitoring process.
4. Monitoring should build on existing traditional institutions and other management structures as much as possible. Where the locally-based monitoring strategy has been developed in collaboration with government agencies, for example in the Iringa District of Tanzania (Topp-Jørgensen et al. 2005 (this issue)), then the measures are also likely to fit with local government systems. In many cases these measures will be simplified as local governments also have low technical capacity (few computers, poorly trained and motivated staff, etc.), enhancing the potential for synergies between locally-based monitoring and the needs of local government.
5. It is crucial to institutionalise the work at a suite of levels, from the relevant policies of the country down to the job descriptions of different government officers (Bennun et al. 2005; Poulsen and Luanglath 2005 (this issue)). In our case examples, effective institutionalisation of the monitoring has taken place in the Ghanaian protected area system of ranger-based monitoring (Brashares and Sam 2005 (this issue)). More recently, the Philippines has made locally-based monitoring a requirement for all 290+ protected areas, even though many staff have received no training in relevant methods.
6. Sustainability is enhanced where the data are stored, analysed, and remain accessible locally, even if this means there is some loss of quality. In only a few of our case examples was the data analysis performed away from the area in question – even though this is often the norm for monitoring systems established in western countries. This process of local data storage and analysis has been assisted by the decentralization process ongoing in most case study countries. It might also in turn help address one of the fundamental issues facing conservationists working in developing countries – where the capacity of government to absorb funding or new ideas is limited by the small number of qualified staff and their demanding working conditions. By involving communities and government agents at the field level the available pool of actors in the conservation arena is greatly expanded.

In conclusion, for locally-based monitoring to become sustainable the key is to keep it as simple and locally appropriate as possible. Ideally these schemes should be developed at a slow pace, paying sufficient attention to capacity-building, and using equipment which can be maintained locally with minimal recurrent costs (using toponyms instead of GPS; bicycles instead of motorbikes; ring-binders instead of electronic databases; hand-drawing skills instead of GIS, and so on). There is often pressure, mainly from external funding agencies (Rodríguez et al. 2003) and top government officials, to use more sophisticated technologies, but if the locally-based systems are to be sustainable, these pressures are best resisted.

Likewise, there is a need to move beyond the notion that local stakeholders are too unorganised or ignorant to sustain monitoring efforts without external assistance. If sufficient incentives are in place and capacity has been well developed, there is no reason to believe that local stakeholders cannot undertake extensive responsibilities. In some areas, local people have carried out monitoring of natural resources for centuries, sustained by themselves, as an integral part of their land management. In some sub-Saharan African countries, for example, restrictions on the use of certain animals and the maintenance of sacred forest patches require some degree of local monitoring to ensure that the valued attributes are maintained. However, it is very often the case that these informal schemes are overlooked by government staff and scientists.

Ability to detect true trends

While locally-based monitoring has the potential to generate data sustainably and at low cost, many scientists remain concerned about its ability – compared with professional methods – to detect changes in populations, habitats, or patterns of resource use (e.g. Penrose and Call 1995; Brandon et al. 2003; Rodríguez 2003). Unfortunately, studies to date have been too few, and their results too inconsistent, for firm conclusions to be drawn.

We were able to find only 16 published tests comparing the performance of locally-based and professional methods: 12 from temperate regions (four terrestrial, six freshwater, and two marine), and only four (two terrestrial, two marine) from developing countries (see Table 3). Between them these tests provide cautious support for the idea that locally-based methods can identify underlying temporal or spatial variation in biological resources, but a number of important concerns emerge repeatedly. Compared with professionally-derived data, results from locally-based monitoring often have higher variance (Barrett et al. 2002; Genet and Sargent 2003), with the size or abundance of organisms sometimes being consistently under- or over-estimated (McLaren and Cadman 1999; Bray and Schramm 2001), and with mis-identification of more difficult taxa quite common (Brandon et al. 2003; Genet and Sargent 2003). Likewise, several studies caution that analysis of locally-derived data can sometimes be overly simplistic (Ericsson and Wallin 1999; Engel and Voshell 2002). However, most authors consider that these difficulties can in principle be addressed, through improved training of data collectors (Mumby et al. 1995; Darwall and Dulvy 1996; Bailenson et al. 2002; Barrett et al. 2002; Brandon et al. 2003; Janzen 2004), continued support from professional scientists (Barrett et al. 2002; Greenwood 2003), and more careful data analysis (Ericsson and Wallin 1999; Engel and Voshell 2002; Greenwood 2003; see also below).

Table 3. Summary of published comparisons of the performance of locally-based monitoring and professional monitoring.

Study and country	Biome	Who does locally-based monitoring?	Attribute(s) being monitored	Assessment of performance of locally-based vs professional monitoring
Developed countries				
Ericsson and Wallin 1999; Sweden	Terrestrial	Hunters	Moose *Alces alces* density	After appropriate calibration hunter observations predicted temporal and spatial trends in density
McLaren and Cadman 1999; Canada	Terrestrial	Volunteers	Bird species identity and abundance	Novices underestimated numbers of most bird species but improved with experience
Brandon et al. 2003; USA	Terrestrial	Volunteers	Habitat quality of forests	Volunteer identification of difficult trees and counts of abundant shrubs poor but could be addressed through better training
Greenwood 2003; UK	Terrestrial	Volunteers	Abundance of breeding birds	Ongoing input from professional scientists into survey design and data analysis guarantees quality and ensures high-level use of results
Bray and Schramm 2001; USA	Freshwater	Anglers	Catch per unit effort and size of sport fish	Angler data on catch per unit effort and length generally not correlated with professional, and give very limited coverage of certain species
Hoyer et al. 2001; USA	Freshwater	Volunteers	Species richness and abundance of aquatic birds	Volunteer data on species richness and abundance accurately matched those collected by professional biologists
Fore et al. 2001; USA	Freshwater	Volunteers	Species richness and dominance of benthic communities	After training results of volunteer surveys matched those of professional biologists
Engel and Voshell 2002; USA	Freshwater	Volunteers	Ecological condition, from benthic community structure	Initial volunteer protocol consistently overrated ecological condition, but volunteer measures using modified sampling and analysis protocols closely matched professional measures
Genet and Sargent 2003; USA	Freshwater	Volunteers	Anuran species identity and abundance, from calls	Volunteer estimates of abundance showed high variability, with some species misidentified
Boudreau and Yan 2004; Canada	Freshwater	Volunteers	Spread of invading water flea	No difference in detection by volunteers and professional biologists
Schmitt and Sullivan 1996; USA	Marine	Volunteers	Fish species identity and abundance	Results consistent with those of previous professional studies
Barrett et al. 2002; Australia	Marine	Volunteers	Identity, size and abundance of harvested species	Volunteer data on species identities and sizes were more variable and less reliable than those of professional biologists, but training and data amalgamation could improve usefulness
Developing countries				
Hellier et al. 1999; Mexico	Terrestrial	Local communities	Forest cover and abundance of harvested species	Some contradiction with professionally-derived data on vegetation change
Noss 1999; Central African Republic	Terrestrial	Hunters	Abundance and density of game species	For 2 out of 4 species hunter-based method could generate only abundance indices, not density estimates
Mumby et al. 1995; Belize	Marine	Volunteers	Abundance of reef organisms; substrate composition	Accuracy and consistency of volunteer data varied with habitat type and taxon and were lower in deeper water, but did not increase with experience
Darwall and Dulvy 1996; Tanzania	Marine	Volunteers	Fish species identity and abundance	Precision increased sharply with experience

The general shortage of tests is reflected in the present issue. Only two of our case studies compare findings between locally-based and professional monitoring; no others included parallel use of both types of methods. Uychiaoco et al. (2005) report that out of four community-collected measures of reef benthic cover and fish abundance, only one was correlated with the equivalent data collected by biologists, with local people's measures of fish abundance being far more variable than those of professional scientists. In contrast, Roberts et al. (2005 (this issue)) find that annual variation in the proportion of days on which different bird species are caught during mist-netting at a reserve (which they suggest might be indicative of proportional recording on amateur birdwatchers' day lists) could predict local and even national temporal trends in species' abundance.

Two other case studies use power analysis to examine how far spatially and temporally intensive sampling regimes could be pared-down yet still detect key trends with a statistically acceptable degree of confidence. Both reveal that the lower limits to worthwhile sampling effort are surprisingly high. Thus using data from harvested crayfish populations in Madagascar, Hockley et al. (2005 (this issue)) report that a single village would have to invest at least 300 person-days per year in monitoring to have an 80% probability of detecting a population decreasing by 20% over 5 years. This may be a worst case scenario however. Using Ghanaian ranger-based wildlife data, Brashares and Sam (2005, this issue) show that survey efforts could be decreased by 25–50% before their ability to detect trends in the abundance of large mammals and hunters was substantially reduced. The Ghana study also provides some evidence that a high spatial intensity of sampling may be more important than high temporal intensity.

Taken together, the literature, the case studies, and our symposium discussion support four general conclusions about the relative ability of locally-based monitoring to detect changes in biological resources:

1. Further quantitative comparisons of the findings of locally-based and professional monitoring are badly needed, especially in developing countries, and in circumstances where data-gatherers have received little or no formal scientific education (cf. Table 3). We are not suggesting that every locally-based scheme needs to be calibrated against a professional method – this would be logistically impractical, unaffordable, and would imply widespread distrust of local communities. However we do suggest that all methods (Table 2) need careful and well-documented checking against broadly accepted techniques, across a range of local contexts (see also Engel and Voshell 2002). Unless this costly and time-demanding task is done, there will always be the concern that, however well intentioned, management interventions derived from local monitoring might in some cases be directed towards inappropriate targets.
2. Locally-based methods are in general more vulnerable than professional techniques to various sources of bias, which decrease their accuracy (defined as the closeness of the resulting measures to their true values; Table 4a). Key

Table 4. Key potential constraints to the accuracy and precision of locally-based and professional monitoring of biological diversity and resource use.

	Locally-based monitoring	Professional monitoring
(a) Constraints to accuracy		
Lack of measurement experience	2	1
Conflict of interest	3	1
Inconsistent use of methods, across time or observers	3	1
"Fossilized" perceptions	1–2	0
Unrepresentative spatial or temporal spread of sampling effort	1–3	1
Poor identification, field or language skills	1–3	1–3
(b) Constraints to precision		
Small sample size	3	2
Poor temporal or spatial spread of sampling effort	1–3	1
Physical loss of data	2	1
Inconsistent use of methods, across time or observers	3	1

0 = not a problem; 1 = limited problem; 2 = potentially important problem; 3 = serious constraint.

potential problems include a lack of measurement experience on the part of observers (which often leads to over-estimates of abundance and size – e.g. Uychiaoco et al. 2005 (this issue)); potential conflicts of interest (with recorders perhaps inadvertently providing data which are biased towards managers' preconceptions); a tendency, in the absence of careful documentation, for methods to drift over time, or for results to reflect long-term ('fossilized') perceptions more than current trends (e.g. Andrianandrasana et al. 2005 (this issue)); and the potential for the spatial or temporal coverage of monitoring to be unrepresentative of the entire system of interest.

3. Besides accuracy, the utility of monitoring is limited by the precision of the results (that is, the closeness of repeated measures of the same quantity to each other; Table 4b). Sources of low precision (leading to high variance around the estimated true value of the attribute of interest) include small sample sizes; overly thin or patchy temporal or spatial deployment of sampling effort; the physical loss of data; and the inconsistent application of methods, either through time or across observers. These problems can affect all sample-based monitoring, but are likely to be a particular problem where financial or professional human resources are tightly limited.
4. Accuracy, precision, and overall usefulness are all best addressed by careful planning. A guide for developing systematic monitoring, adapted for the community-, ranger- or volunteer-based context, is provided in Box 1 (adapted from Royal Society 2003; Green et al. 2005). Important steps that in our experience are all too often ignored include (i) broad consultation right at the outset, with all key stakeholders to jointly determine the aims of the monitoring programme, coupled with ongoing checking that the monitoring addresses their concerns; (ii) explicit consideration during the design

stages of likely biases, and of how best to deploy sampling effort to enhance precision; (iii) thorough training of data gatherers; and (iv) establishment of mechanisms for feeding results directly into management.

Provided that these principles of effective monitoring are addressed then in our view there is no reason that locally-based methods should yield results that are in any way inferior or less reliable than those derived by professional monitoring (see also Yoccoz et al. 2003). Rather than being seen as "quick and dirty", if properly designed such approaches have the potential instead to be low cost, rapid, and locally relevant. In reality, in many areas the alternative to local schemes would be no monitoring at all.

Decision-making and action

The purpose of management-oriented monitoring is to influence decision-making and action on the ground. Without this, there is little reason for carrying out the monitoring. We have tried to assess the case studies provided in this issue in terms of their ability to influence decision-making. We have also tried to give a general characterization of the decisions and actions that arise from locally-based monitoring.

The case studies provide evidence that in the schemes examined a large number of conservation and natural resource management decisions are taken on the basis of local monitoring. Quantitative data from cases in Tanzania and the Philippines suggests that these decisions are highly relevant from a biodiversity conservation perspective because a large proportion of the decisions taken addressed the most serious threats to the biodiversity of the sites and led to change in local policies with potentially long-term impacts (Danielsen et al. 2005 and in prep.; Topp-Jørgensen et al. 2005 (this issue)). For instance, patrol records and village group discussions prompted a village head to issue a village ordinance banning electro fishing to protect the freshwater fish resources (NORDECO and DENR 2001). Likewise, based on data from transects and village group discussions, an indigenous Obo Bagobo chieftain issued a byelaw on a closed season for hunting Philippine warty pig *Sus philippensis*. Similarly, the management council of a protected area decided to develop a pasture management plan for communal lands with local goat keepers after observing signs of serious erosion on photos from fixed point photography.

There also seems to be evidence that community-based methods are more effective than methods without community participation in generating decisions (Danielsen et al. in prep.). In the case studies where monitoring did not lead to decision-making, this was because the feedback loop from data and analysis to decision-making had yet to be developed or institutionalised (Bennun et al. 2005; Brashares and Sam 2005; Roberts et al. 2005 (this issue)), or because the community members participating in the monitoring had not yet gained authority over the land and resources (Noss et al. 2005 (this issue)).

In general, the experience of the case studies suggests that locally-based monitoring and professional monitoring lead to substantially different kinds of decisions (Table 5). Decisions from locally-based monitoring are often taken promptly and at the local level (see also Kerr et al. 1994), in response to immediate threats to the environment. These decisions usually result in actions based on community rules and enforcement, such as local bylaws governing resource use (e.g. van Rijsoort and Jinfeng 2005 (this issue)). Such actions are aimed not only at protecting habitats and/or species but also at ensuring a continued supply of benefits for the local human communities. The decisions are often respected by the locals and the associated actions are relatively sustainable, both financially and organisationally, probably because they are nested within existing local institutions (Becker et al. 2005 (this issue)). This kind of monitoring generally provides fast and meaningful feedback to inform adaptive management.

In comparison monitoring by scientists may be slow in leading to decisions, but the scale of decision may be very different (Table 5). Professional monitoring has the potential to influence national and global policies and funding flows. Scientists often have better access than local communities to high-level decision-makers. For instance, results from locally-based monitoring are unlikely to persuade the US government to ratify the Kyoto Protocol, whereas findings from professional monitoring potentially could. Decisions from locally-based monitoring will generally not have impacts beyond the local scale unless the locally-based monitoring is embedded within or linked to a national or international scheme that feeds the data up to the levels at which governments, international agencies and multi-national corporations operate (see section below on tracking of larger-scale trends, and papers by Bennun et al. 2005 and Roberts et al. 2005 (this issue)). Several of our case studies did do this and it is noteworthy that in some, politicians and governments did pay attention (e.g., Andrianandrasana et al. 2005; Gray and Kalpers 2005 (this issue)). Unfortunately, in the only example we know in which national level aggregation of locally-based monitoring data has been institutionalised (the Philippines), the national work suffers from chronic underfunding and weak institutional support.

Why does locally-based monitoring lead to locally-based decision-making? Experience from the case studies suggests three reasons. Firstly, unlike monitoring by scientists, participatory monitoring encourages decision-making by providing an institution (e.g. village discussion groups composed of particularly knowledgeable villagers) or a forum (e.g. meetings between rangers and local residents) for regular discussion of local natural resource management. Monitoring provides a reason to discuss better ways of managing resources. Secondly, participatory monitoring provides local residents with otherwise rare opportunities for collaboration with government staff and for representation in local decision-making on natural resources. Understanding the local ways of thinking, and of making decisions, is therefore important for the success of local schemes. Thirdly, decision-making based on local monitoring is not swamped by government bureaucracy because many of the decisions are taken

Table 5. Comparison of locally-based and professional monitoring in terms of decision-making and action.

	Locally-based monitoring	Professional monitoring
Time from data sampling to decision-making?	Short	Long
Who uses the monitoring for decision-making?	Local villagers and government authorities at the field level (e.g. local authorities or protected area staff)[a]	Protected area management authorities, national governments, scientific advisors to governments and international NGOs
What are the decisions arising from monitoring usually taken in response to?	Immediate threats to the environment; perceived and/or obvious problems that residents and government field staff can see and grasp	Data-based trends in species abundance, species populations and habitat extent/ condition
What threats are addressed by the decisions arising from monitoring?	Immediate threats to the environment (e.g. forest degradation, overharvesting)	Immediate as well as root cause[b] threats to the environment
What actions do the decisions arising from monitoring result in?	Actions based on community rules and enforcement, aimed at protecting habitats or species or ensuring continued supply of benefits for the local human communities can inform higher-level decisions if data appropriately synthesized across studies	National park interventions, permit systems, policy changes in other sectors such as agriculture or transport
Are the actions likely to be sustainable?	Can be sustainable, especially if the actions are nested within existing local institutions[c]	Can be sustainable, if, e.g., governments sign and implement conventions[d]
Are the decisions arising from monitoring respected by local residents?	Decisions are often respected when existing village institutions are involved	The respect paid varies from place to place
Are the decisions arising from monitoring respected by government or private sector?	The respect paid depends on the context	The respect paid depends on the context
Contribution of decisions arising from monitoring to adaptive management?	Fast and meaningful feedback to the management level	Slow and commonly limited feedback to the management level

[a] Potentially also national government, if the monitoring is embedded within or linked to a system that rolls the data back to levels where national policy-makers can access and use it.

[b] E.g. climate change, energy policy, subsidies, international trade agreements.

[c] See Danielsen et al. 2005 (this issue).

[d] Assuming funds and political will are available to support their implementation.

promptly by the same people or institutions that collect the data (Danielsen et al. 2005 (this issue)).

Moving from decision-making to action, does locally-based monitoring in developing countries lead to improved management of natural resources? Obtaining evidence for this is constrained by the difficulty of measuring improved management by a standard scale across different habitats. Moreover, the true impact may only be discernible in the long term and most of the locally-based schemes underway are still young. In one of our cases, however, the main threat to biodiversity – wildlife hunting – was documented as being partly or fully reduced in a reserve as a result of actions resulting from locally-based monitoring (Topp-Jørgensen et al. 2005 (this issue)). In two other cases, locally-based monitoring led to successful lobbying for the gazetting of a new protected area (Becker et al. 2005; Townsend et al. 2005 (this issue)). There is, in general, substantial evidence from several of our cases to suggest that community-based monitoring rapidly leads to many relevant conservation management interventions. There is as yet, however, limited documentation of the long-term outcome of these interventions.

Local constituencies

We have tried to assess the benefits provided by the ranger- and community-based monitoring schemes in terms of building local constituencies and enhancing local capacity. The ranger-based monitoring schemes all contributed to empowering the rangers (Table 6). Ranger participation in monitoring increased their resource management capacity, field experience and naturalist skills, and their motivation and pride in their work (e.g. Gray and Kalpers 2005 (this issue)).

Our case studies on community-based monitoring schemes documented four major types of benefit in terms of building local constituencies:

1. The community-based schemes led to improved collaboration and communication between local stakeholders and government authorities. Quantitative data from the Philippines suggests that every third conservation management intervention generated by locally-based monitoring was collaborative between government and the members of the community. Related to this, some of the schemes also led to increased trust between the local stakeholders, and to more transparent, accountable and democratic decision-making, thereby fostering a sense of good governance (e.g. Andrianandrasana et al. 2005; van Rijsoort and Jinfeng 2005; Topp-Jørgensen et al. 2005 (this issue)).
2. The community-based schemes led to enhanced awareness and education, and change in attitude towards more environmentally sustainable natural resource management among the local participants (see also Kerr et al. 1994; Ticheler et al. 1998; Obura et al. 2002). For instance, in Tanzania, local involvement in monitoring provided the people with a direct and

Table 6. Key benefits of ongoing locally-based biodiversity monitoring schemes in terms of building local constituencies.

Case study[a]	Country	Who compiles data[b]	Empowerment of protected area staff	Improved collaboration and communication between local stakeholders and authorities	Enhanced awareness and change in attitude among locals	Increased compliance with laws	Strengthening of community-based resource management systems
van Rijsoort and Jinfeng 2005	China	R/C	+	+	+	+	+
Bennun et al. 2005	Kenya	C			+		
Poulsen and Luanglath 2005	Laos	R/C	+	+	+	+	+
Stuart-Hill et al. 2005	Namibia	C		+	+	+	+
Danielsen et al. 2005	Philippines	R/C	+	+	+	+	+
Topp-Jørgensen et al. 2005	Tanzania	C		+	+	+	+
Noss et al. 2005	Bolivia	C		+	+	+	+
Becker et al. 2005	Ecuador	C/V		+	+	+[c]	+
Brashares and Sam 2005	Ghana	R	+				
Gray and Kalpers 2005	Uganda, Rwanda, DRC	R	+				
Townsend et al. 2005	Ecuador	C		+	+	+	+
Andrianandrasana et al. 2005	Madagascar	C		+	+	+	+
Uychiaoco et al. 2005	Philippines	C		+	+	+	+

+ = benefit documented in this study.
[a] Source of information (this issue, and correspondence with the authors).
[b] C = community members; R = government rangers; V = volunteers (from abroad).
[c] Only compliance with local rules.

tangible link between personal income and resource conservation (Topp-Jørgensen et al. 2005 (this issue)). In Ecuador, participation in monitoring changed the attitude of many Cofán Indians in relation to turtle harvesting, from one of exploitation to one of managed harvesting and record-keeping (Townsend et al. 2005 (this issue)).

3. The community-based monitoring led to increased compliance with laws. The monitoring motivated the local stakeholders to agree on and then uphold resource-use regulations (see also Blyth et al. 2002). Among indigenous people in Bolivia, locally-derived monitoring data were considered to hold great weight in community discussions because 'outside experts were not blamed for inventing data' (Noss et al. 2005 (this issue)). Since local residents tend to comply with locally-agreed decisions, community-based monitoring may be more effective than professional monitoring in arresting over-exploitation and degradation of natural resources.
4. The community-based schemes translated local knowledge into biological or bureaucratic language, thereby strengthening existing community-based resource management systems and empowering local residents (see also Marks 1994; Ticheler et al. 1998). For instance, indigenous knowledge was absorbed into locally-based monitoring and used in a court case on oil contamination in Ecuador (Townsend et al. 2005 (this issue)). Likewise, experience from the Philippines suggests that, as a result of locally-based monitoring, indigenous resource-use regulation schemes were being re-inforced through local government recognition. In addition, indigenous people became increasingly recognized as resource co-managers.

Experience from our cases and from the few published studies of other community-based schemes in developing countries, we were able to find (Marks 1994; Ticheler et al. 1998; Steinmetz 2000; Obura et al. 2002) suggests that the four above-mentioned benefits are almost universal outcomes of community-based monitoring schemes on sites where the methods can be implemented (see Table 6).

One further benefit was reported in the community-based monitoring case studies in Madagascar and the Philippines, where the monitoring led to a more socially acceptable and effective approach to enforcement (Andrianandrasana et al. 2005; Danielsen et al. 2005 (this issue); and J. Durbin *in litt.)*. While scientists and government staff may be seen as representatives of an oppressive and interfering state, monitoring schemes where local people have direct access to decision-making are less likely to create antagonism. This may explain some of the success of the local schemes in building local constituencies.

Which particular monitoring method was most effective in strengthening the local constituencies? Data are limited but cross-method comparison in the Philippines provides evidence that the village group discussion method (Table 2) was strikingly more effective than the others in improving collaboration between stakeholders, motivating locals to participate in resource-use regulation, and empowering local stakeholders.

Tracking larger-scale trends

As well as providing data to inform local management decisions, locally-based monitoring has the potential to shed valuable light on changes in biodiversity and ecosystem services at national and even global scales. Papers in this special issue outline two systems currently in development – BirdLife's Important Bird Areas monitoring scheme, and Project Kagu – which have been explicitly designed to allow such upwards movement of data, and ultimately to permit global analyses (Bennun et al. 2005; Roberts et al. 2005 (this issue)). To the extent that systems like this can be implemented and replicated, important global monitoring gaps can be plugged, at relatively low cost, while at the same time increasing local people's input to higher-level decision-making.

Certain kinds of global and national data gaps seem particularly well-suited to input from local schemes (Table 7). In terms of trends in species and populations, the use of data from volunteer bird counts to address European Union farming policy demonstrates eloquently that appropriate analysis of locally-derived data can be of immense international value (Greenwood 2003; Gregory et al. 2005). Less ambitious schemes can also be useful, providing input into large-scale meta-analyses such as WWF's Living Planet Index of vertebrate population trends (Loh et al. 2005; see Figure 1); this is especially important given the paucity of tropical studies available for such analyses. Turning to habitats, while the extent of some biomes is most efficiently monitored top-down, via remote-sensing, for many others habitat loss proceeds primarily via degradation (and loss of content) rather than wholesale conversion. This is for instance the case in temperate and tropical grasslands, fragmented forest landscapes, freshwater (ponds, lakes, streams, rivers) and marine habitats such as inter-tidal areas, coral reefs and estuaries. Few large-scale programmes exist for tracking such changes in habitat condition, but new meta-analytical techniques mean that data from diverse small-scale studies can be usefully synthesized to elucidate regional and potentially even global patterns (Côté et al. 2005). Data from locally-based monitoring could also be aggregated to generate larger-scale overviews on threats (such as unregulated artisanal harvesting) operating at relatively small scales, and on the local impacts of management interventions.

But perhaps the greatest scope for locally-derived inputs to large-scale measures of change is in tracking the delivery of goods and services from natural ecosystems. These form a prime focus of the Convention on Biological Diversity's 2010 target (UNEP 2002), yet are extremely hard to monitor using a top-down approach. We suggest that appropriate meta-analyses of locally-generated data on flows in benefits such as harvests of wild species, and reliable provision of clean water, offer the best opportunity for measuring global-level progress against the 2010 target for ecosystem services. Yet several steps must be taken in order for this considerable potential of locally-based data to be realised.

Table 7. Comparison of suitability of locally-based and professional monitoring in relation to what needs to be monitored, how the area is managed, what threatens it, and the availability of resources for monitoring.

		Locally-based monitoring	Professional monitoring
What needs to be monitored	Trends in species or populations	Yes, but some species not possible (cryptic)	Yes, but in practice often difficult
	Trends in extent or condition of habitats	Yes, especially condition	Yes, especially extent at large-scale, but remote-sensing not possible for some biomes
	Trends in ecosystem services	Yes, for those delivered at local scale	Very difficult for local-scale benefits; modelling and remote sensing can be applied to larger-scale benefits (e.g. carbon sequestration)
	Trends in threats	Yes, for those that operate locally (e.g. local overharvesting, habitat degradation)	Yes, mainly for those operating at large scales (e.g. habitat clearance, climate change)
	Trends in the impacts of management interventions	Yes, for those that operate locally	Yes, mainly for those that operate at large-scale
How the area is managed	Extent of local benefit-sharing	Local flow of benefits (e.g. resource harvesting) permitted	Any area
	Level at which management change is needed	Village or protected area	Government or protected area
What the threats are	Scale over which threats operate	Mainly local, some national	Mainly national or global
Availability of resources for monitoring	Financial resources for set-up and training	High	High
	Recurrent financial resources	Low	High

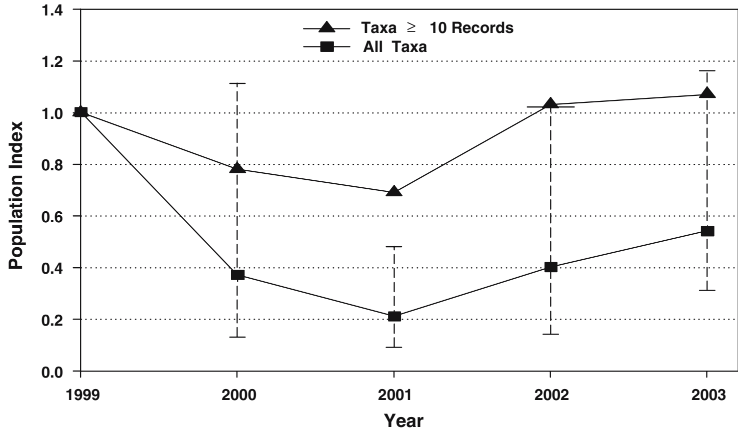

Figure 1. Example of the potential of locally-based monitoring of biodiversity in developing countries to provide input into larger-scale meta-analyses. The graphs show trends in population samples in forest ecosystems of Mindanao, the Philippines, using data from ranger-based transects. The figure is based on average trends in populations of 28 bird and 7 mammal taxa (■; including 95% confidence intervals obtained by a bootstrap method with 1000 replications) and only those taxa with 10 or more records (▲; 16 bird and 4 mammal species). To prepare the graphs, we used the analytical method of WWF's Living Planet Index described by Loh et al. (2005) on a set of data from Mt. Kitanglad Range (scheme described in Danielsen et al. 2000 and 2005 (this issue)). The Living Planet Index represents the average change within an entire collection of population samples over a given study period, giving equal weight to each species, whether common or rare, and to small and large populations (Kapos et al. 2004). The resulting trend line shows changes in species abundance and, by implication, the condition of the ecosystems in which they occur. Three potential biases of using these locally-derived transect data for generating species population trend indices emerge and need to be recognized (see also Kapos et al. 2004). Firstly, the sample size of most taxa was small, with 43% of the taxa being recorded in numbers less than 10. If the low-density forms were omitted from the analysis, the results would differ (see ▲). This bias is inherent to tropical forests where the numbers of low-density taxa are large. Secondly, the transects generated data on birds (80% of the 35 taxa) and mammals (20%), generally taxa at the upper trophic levels. No invertebrates were recorded. Cross-taxon species abundance patterns in tropical forests do not necessarily coincide. This bias is difficult to adjust for but needs to be taken into consideration when using the index. Thirdly, there is a geographic and habitat bias, because the index was only based on data from one site. Sensitivity analyses suggest that data from a minimum of around 45 populations instead of 35 would be needed (Kapos et al. 2004). This can be adjusted for by including data from a larger number of widely distributed sites. Fortunately, for heterogenous landscapes, many small samples provide a better sampling of the meta-community than few large samples (Wiens 1989; see also Brashares and Sam 2005 (this issue)).

Most importantly, for locally-based information to be useful at larger scales, monitoring schemes will need to be established in more sites and countries, and the resulting data must be as unbiased and precise as possible (see section on ability to detect true trends). Results can also only be synthesized where many programmes have monitored the same attributes (such as the rate of offtake of medicinal plants, or changes in condition of rangelands). They need not all use a single standardized technique – this would be difficult given the importance of

Box 1. Six steps for developing locally-based monitoring of biodiversity and resource use (modified from Royal Society 2003; Green et al. 2005).

1. Discuss within the responsible institutions and with interested stakeholders the need for, and the aims of, management-oriented monitoring. In particular, discuss:
   - Which aspects of biodiversity and resource use are you interested in?
   - What questions do you want the monitoring to answer?
   - What are you likely to do with the results?
   - When are the results of monitoring needed?
   - What level of precision and accuracy is required?
   - What incentives are required to ensure community, ranger or volunteer engagement?
2. Use existing knowledge, including that of villagers and local staff, to develop a model of the system, even if it is only conceptual. For example, the topic of interest may be the number of turtles than can be harvested sustainably from an area. This cannot be measured directly, but developing a simple model of how this relates to measurements that are feasible and realistic for community members, rangers or volunteers to conduct (such as the number of nesting females on a communal beach) makes the limitations of the assessment explicit.
3. Agree on an institutional framework for using the results of monitoring for adaptive management.
   - Agree on who takes decisions, and how monitoring results reach this body
   - Develop and agree on mandates and responsibilities of the involved parties
   - Wherever appropriate, the monitoring should be embedded within existing institutions
4. Develop a sampling strategy that specifies who measures what, how, where and when.
   - Discuss the usefulness, costs and difficulty of alternative measures, including any existing schemes underway
   - Identify which species, areas, or resource uses are to be monitored
   - Design a sampling strategy which pays explicit attention to potential sources of bias and in which the spatial and temporal deployment of sampling effort is appropriately stratified to maximise precision given available resources
   - Train data gatherers to follow a common protocol which is written down; if guidelines and training materials from other monitoring schemes are relevant, ask to use them, and adapt the materials to the local context
   - Agree on how and where to store data
   - Conduct a pilot study to test feasibility of data collection protocols; check with stakeholders whether the resulting data address their needs
5. Begin implementation on-the-ground. Important steps include:
   - Store data in its most disaggregated form and with details of exactly how it was collected
   - Record sampling effort, who collected the data, and precise locations of field study areas
   - Keep raw data for checking and re-interpretation
   - Ensure that checks are carried out to keep errors in recording and data storage at an acceptable level
   - Analyse the data, and feed results back to data gatherers
   - Wherever possible compare results with those of other locally-based or professional approaches
   - Provide results to decision-making body, and check they are fit-for-purpose
   - Ensure that data gatherers are aware of management decisions arising from their data
6. Discuss the results with the local/national stakeholders and revise the strategy for the monitoring accordingly.
   - Address sustainability issues such as post-project funding and recurrent training needs
   - Keep track of management interventions resulting from the monitoring
   - Make data available on open access database, if possible
   - Facilitate the development of national policy, guidelines or tools for monitoring.

the monitoring schemes being autonomous, and would preclude schemes from being responsive to local circumstances and needs. However, it is important that only a relatively small number of methods, each well replicated, is used across the set of studies to be analysed. Provided this is the case then meta-analytical techniques can be used to check (and if necessary adjust) for differences in results being due to differences in field methods (for a worked example see Côté et al. 2005).

Recommendations

Suitability of locally-based and professional approaches

The relative utility of locally-based and professional approaches is explored in Table 7. We argue that locally-based monitoring can generate cheap and locally meaningful data on the condition of habitats and the population sizes of larger and more obvious species. It can also provide evidence of changes in local ecosystem benefits such as reliable provision of clean water, as well as on local threats such as habitat degradation. Local methods are however unlikely to provide quantitative data on large-scale changes in habitat area, or on populations of cryptic species that are hard to identify or census reliably. Likewise, they are not suitable for examining large-scale ecosystem benefits such as carbon-sequestration or global-scale threats such as climate change.

Investments in monitoring should be carefully tailored according to the aims of the studies. Where changes, threats or interventions operate over large scales, or in complex fashions, locally-based methods are less likely to yield useful data and management solutions than professional approaches. But where the issues are relative small-scale and patterns of causality are likely to be relatively straightforward, locally-based methods can prove cheaper, more sustainable, and more effective than professional approaches.

Fertile ground for the development of locally based monitoring appears to be where local people are interested in monitoring attributes of interest that are under their direct control (benefits), or which they are concerned about such as threats (see Stuart-Hill et al. 2005 (this issue)). Monitoring attributes that are only of concern to outsiders are hard to sustain in a locally based scheme, and may therefore need to be undertaken by professional scientists.

Design

We recommend that scientists and managers who would like to establish systematic community-, ranger- or volunteer-based monitoring of biodiversity and resource use employ the steps outlined in Box 1. The monitoring should be kept as simple and locally appropriate as possible. Attention should be paid to capacity-building of data gatherers in field techniques, species identification skills, and how to make use of the data. The monitoring should be institutionalised within existing management structures at both local and national level and preferably be embedded within a scheme that feeds the data up to national or international levels. Unnecessary changes in the monitoring should be avoided and, if it has to change, efforts should be made to nest previous scheme within new scheme. Management interventions resulting from the monitoring should be tracked as a possible indication of the scheme's management impact and to provide direction.

Tasks ahead

The experiences from the case studies suggest that, if properly designed, locally-based monitoring can address several of the shortfalls of professional monitoring. Most importantly, local approaches have the potential to be low cost, rapid, locally relevant, and capable of building capacity among the local constituents. However, without rigorous validation studies, professional scientists will remain sceptical about the results of local monitoring schemes. We therefore recommend quantitative assessments of the ability of all locally-based methods (Table 2) to detect changes in populations, habitats, or the provision of goods and services.

We also recommend that scientists and managers explore the potential of amalgamating locally-based monitoring schemes to provide input into tracking larger-scale trends in the status of populations and habitats, the services they provide, and the threats they face. Our symposium suggested that one potentially powerful device for achieving these steps (and for supporting locally-based monitoring schemes more generally) could be the establishment of a dedicated website. This could host a catalogue of existing locally-based monitoring schemes, and act as a place where fieldworkers could access one another's experience and gain advice on how to collect, store and analyse data.

Establishment and maintenance of such a web-site should be complemented by regional workshops to exchange experiences, mutually agree on standards, and identify good practice. Disparate datasets could then be compatible enough for meta-analyses, in which case this initiative could act as a focal point for amalgamating results for analysis and subsequent input into national-, regional- and global-level measures such as those being developed for the 2010 target (UNEP 2004; Balmford et al. 2005; Convention on Biological Diversity 2005). We envisage that this initiative could simultaneously facilitate the development of a virtual community of local monitors, improve practice on the ground, and raise the profile of locally-based monitoring at national and international levels.

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