*Contributed Paper*

# Local Participation in Natural Resource Monitoring: a Characterization of Approaches

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**Abstract:** *The monitoring of trends in the status of species or habitats is routine in developed countries, where it is funded by the state or large nongovernmental organizations and often involves large numbers of skilled amateur volunteers. Far less monitoring of natural resources takes place in developing countries, where state agencies have small budgets, there are fewer skilled professionals or amateurs, and socioeconomic conditions prevent development of a culture of volunteerism. The resulting lack of knowledge about trends in species and habitats presents a serious challenge for detecting, understanding, and reversing declines in natural resource values. International environmental agreements require signatories undertake systematic monitoring of their natural resources, but no system exists to guide the development and expansion of monitoring schemes. To help develop such a protocol, we suggest a typology of monitoring categories, defined by their degree of local participation, ranging from no local involvement with monitoring undertaken by professional researchers to an entirely local effort with monitoring undertaken by local people. We assessed the strengths and weaknesses of each monitoring category and the potential of each to be sustainable in developed or developing countries. Locally based monitoring is particularly relevant in developing countries, where it can lead to rapid decisions*

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*Paper submitted May 27, 2007; revised manuscript accepted May 27, 2008.*



*Conservation Biology*, Volume **, No. *, ***–***

DOI: 10.1111/j.1523-1739.2008.01063.x

*to solve the key threats affecting natural resources, can empower local communities to better manage their resources, and can refine sustainable-use strategies to improve local livelihoods. Nevertheless, we recognize that the accuracy and precision of the monitoring undertaken by local communities in different situations needs further study and field protocols need to be further developed to get the best from the unrealized potential of this approach. A challenge to conservation biologists is to identify and establish the monitoring system most relevant to a particular situation and to develop methods to integrate outputs from across the spectrum of monitoring schemes to produce wider indices of natural resources that capture the strengths of each.*

**Keywords:** biodiversity assessment, conservation, local stakeholders, monitoring schemes, natural resource management

Participación Local en el Monitoreo de Recursos Naturales: una Caracterización de Métodos

**Resumen:** *El monitoreo de tendencias en el estatus de especies o hábitats es rutinario en los países desarrollados, donde es financiado por el estado o por grandes organizaciones no gubernamentales y a menudo involucra a grandes números de voluntarios amateurs competentes. El monitoreo de recursos naturales es menos intenso en los países en desarrollo, donde las agencias estatales tienen presupuestos pequeños, hay menos profesionales o amateurs competentes y las condiciones socioeconómicas limitan el desarrollo de una cultura de voluntariado. La consecuente falta de conocimientos sobre las tendencias de las especies y los hábitats presenta un serio reto para la detección, entendimiento y reversión de las declinaciones de los recursos naturales. Los tratados ambientales internacionales requieren que los signatarios realicen monitoreos sistemáticos de sus recursos naturales, pero no existe un sistema para guiar el desarrollo y la expansión de los esquemas de monitoreo. Para ayudar al desarrollo de tal protocolo, sugerimos una tipología de categorías de monitoreo, definidas por el nivel de participación local, desde ningún involucramiento local con el monitoreo realizado por investigadores profesionales hasta un esfuerzo completamente local con el monitoreo llevado a cabo por habitantes locales. Evaluamos las fortalezas y debilidades de cada categoría de monitoreo, así como su sustentabilidad potencial en países desarrollados o en desarrollo. El monitoreo basado localmente es particularmente relevante en los países en desarrollo, donde puede llevar a decisiones rápidas para resolver amenazas clave sobre sus recursos naturales, puede facultar a las comunidades locales para un mejor manejo de sus recursos naturales y puede refinar las estrategias de uso sustentable para mejorar la forma de vida local. Sin embargo, reconocemos que la precisión y exactitud del monitoreo llevado a cabo por comunidades locales en situaciones diferentes requiere de mayor estudio y los protocolos de campo requieren de mayor desarrollo para obtener lo mejor del potencial de este método. Un reto para los biólogos de la conservación es la identificación y establecimiento del sistema de monitoreo más relevante para la situación particular, así como el desarrollo de métodos para integrar los resultados de una gama de esquemas de monitoreo para producir índices de recursos naturales más amplios que capturen las fortalezas de cada uno.*

**Palabras Clave:** conservación, evaluación de la biodiversidad, esquemas de monitoreo, intereses locales, manejo de recursos naturales

## Introduction

Monitoring has been defined as “the systematic measurement of variables and processes over time” and “assumes that there is a specific reason for that collection of data, such as ensuring that standards are being met” (Spellerberg 2005). Monitoring of natural resources has become increasingly important, and various international agreements, such as the Millennium Development Goals and the national legislative frameworks of many countries, rely on an adequate knowledge of trends in species and habitats to make informed policy decisions. Despite legal frameworks and an obvious need, however, monitoring often receives low priority because it can be difficult and expensive to coordinate. Thus, monitoring of the impacts of conservation policy intervention falls well behind that of most other policy fields (Ferraro & Pattanayak 2006; Donald et al. 2007).

Most of the literature on methods of natural resource monitoring covers an externally driven approach in which professional researchers from outside the study area set up, run, and analyze the results from a monitoring programme that has been funded by a remote agency (e.g., Goldsmith 1991; Sutherland 1996; Thompson et al. 1998; Bibby et al. 2000; Spellerberg 2005). This approach has been criticized for being expensive to sustain over time and reliant on skills that are not endemic (Sheil 2001). Linking monitoring to the decisions of local people may help make monitoring more relevant locally and hence sustainable (Danielsen et al. 2005*a*). In developed countries this has been facilitated by citizen-scientist programs, in which professional scientists develop a coordinated network of volunteers, many of whom may have no specific scientific training, who undertake research-related tasks such as observation, measurement, or computation (e.g., Greenwood 2007). Elsewhere, landowners who control a particularly valuable natural resource (habitat or species) often have a strong interest in monitoring these using their own resources so that they can make management decisions related to harvesting the resource (e.g., monitoring linked to shooting of Red Grouse [*Lagopus lagopus*] in the United Kingdom [www.gct.org.uk]).

These solutions to enhancing natural resource monitoring are uncommon in developing countries, where there are few volunteers and only a small group of professional experts (Sheil 2001; Danielsen et al. 2005*a*). Developing country realities suggest the need for other forms of monitoring—approaches that are simple, cheap, and require few resources (Danielsen et al. 2005*a*).

Discussion of the relative benefits and disadvantages of professional-researcher-executed and locally based monitoring tends to focus on these 2 extremes (Gilchrist et al. 2005), but in reality these simply form the ends of a spectrum of possible monitoring protocols. If monitoring the planet's natural resources is to be guided, or indeed itself monitored, it is necessary to examine this gradient more closely. To stimulate a more nuanced debate, we suggest a typology of monitoring schemes determined on the basis of relative contributions of local stakeholders (community members, volunteers, or locally employed staff such as rangers) and professional researchers. We reviewed the characteristics of these categories and provide examples from around the world. Finally, we suggest how this typology could be used to select an appropriate monitoring scheme for different circumstances and management needs, because making indicators fit for a purpose (e.g., maximizing improvements to decision making given limited resources) is a recognized challenge of monitoring (Mace & Baillie 2007).

## Classification of Monitoring Schemes

We used the level of relative involvement of local stakeholders and professional scientists in monitoring to identify 5 categories of monitoring schemes (Table 1 and Supporting Information Fig. S.1) that between them span the full spectrum of monitoring protocols.

### Category 1. Externally Driven, Professionally Executed Monitoring

These schemes do not involve local stakeholders. Design of the scheme, analysis of the results, and management decisions derived from these analyses are all undertaken by professional scientists funded by external agencies. Many existing monitoring schemes, particularly those organized by government agencies or global schemes funded by international organizations, fall into this category (e.g., forest-inventory plots, remote sensing of forest cover) (Table 1).

### Category 2. Externally Driven Monitoring with Local Data Collectors

This category of monitoring scheme involves local stakeholders only in data collection. The design, analysis, and interpretation of the monitoring results are undertaken by professional researchers—generally far from the site. In developed countries, participants are often volunteers who donate their time freely (e.g., to monitor water and air quality, vegetation, weather, and the populations of birds, amphibians, fishes, invertebrates, and invasive species) (Table 1). Commercially exploited wildlife populations are also monitored by volunteers through, for example, fisheries statistics, hunter records, and angler–diary programs. These citizen science schemes often involve hundreds or thousands of volunteers (e.g., Gibbons et al. 2007) whose efforts are embedded within a strong organizational infrastructure that provides sophisticated professional support and feedback to the participating volunteers. In developing countries, there are fewer examples of volunteer monitoring. Nevertheless, local stakeholders in developing countries may be involved in this category of scheme by being paid to collect data as rangers working in protected areas, as staff on scientific expeditions, as staff assisting volunteer tourists to do monitoring work, or within hunter- or fisher-monitoring schemes (Table 1). We provide one detailed example of a category 2 scheme in Zambia.

### Category 3. Collaborative Monitoring with External Data Interpretation

This category of monitoring scheme involves local people in data collection and management-oriented decision making, but the design of the scheme and the data analysis are undertaken by external scientists. Local people may either be paid for their time or contribute their time freely. Because analysis of category 3 data is not undertaken by local people, it may not incorporate local-stakeholder perspectives. This is significantly different from categories 4 and 5, in which local people are also involved in carrying out the analysis on which subsequent decision making is based. Category 3 monitoring schemes exist in the developed and developing world (Table 1). We provide a detailed example of a category-3 scheme in Madagascar.

### Category 4. Collaborative Monitoring with Local Data Interpretation

Locally based monitoring schemes involve local stakeholders in data collection, interpretation or analysis, and management decision making, although external

**Table 1. Role of local and professional researchers in the different categories of natural resource monitoring schemes.**

| *Category of monitoring* | *Primary data gathers* | *Primary users of data* | *Examples of monitoring schemes** |
|---|---|---|---|
| 1. Externally driven, professionally executed | professional researchers | professional researchers | forest inventory plots (Condit 1998; www.teaminitiative.org), remote sensing of forest cover (Mayaux et al. 2005), water-quality monitoring (www.gemswater.org/), water-flow assessments (Morishita et al. 2004), and World Database of Protected Areas (www.unep-wcmc.org/protected_areas/) |
| 2. Externally driven with local data collectors | professional researchers, local people | professional researchers | volunteers monitoring of water/air quality (Savan et al. 2003), vegetation (Brandon et al. 2003), weather and climate change (www.on.ec.gc.ca/canwarn/), mammals (Toms & Newson 2006), birds (Gregory et al. 2005; Greenwood 2007), amphibians (http://armi.usgs.gov), fish (Schmitt & Sullivan 1996), invertebrates (www.bugwise.net.au/involved; Roy et al. 2007), and invasive species (Boudreau & Yan 2004); fisher, angler, and hunter records schemes (Ericsson & Wallin 1999; Bray & Schramm 2001; Pauly & Watson 2005); data collection by paid local people in the Arctic (e.g., observing caribou *Rangifer tarandus* from helicopter in Greenland; Cuyler et al. 2002); in developing countries data collection by paid local people on scientific expeditions or at field observatories (e.g., Sangalaki marine turtle breeding station, Indonesia; www.bestari.org); ranger-based monitoring in Ghana (Brashares & Sam 2005); volunteer tourist monitoring of coral reefs (Mumby et al. 1995; Darwall & Dulvy 1996); experimental fisher/hunter records schemes (Marks 1994; Ticheler et al. 1998) |
| 3. Collaborative monitoring with external data interpretation | local people with professional researcher advice | local people and professional researchers | community-based monitoring of wetlands in Madagascar (Andrianandrasana et al. 2005) and BirdLife International's Important Bird Areas in Kenya (Bennun et al. 2005); bicycle transects of large mammals in Zimbabwe (Gaidet et al. 2003); hunter self-monitoring in the Bolivian Chaco (Noss et al. 2005); in developed countries, hunter-records schemes such as wildlife triangle monitoring in Russia and Finland (Lindén et al. 1996) |
| 4. Collaborative monitoring with local data interpretation | local people with professional researcher advice | local people | ranger and community-based monitoring of resource use and wildlife in China (Rijsoort & Jinfeng 2005), Laos (Poulsen & Luanglath 2005), the Philippines (Danielsen et al. 2005b; Uychiaoco et al. 2005), East Africa (Obura et al. 2002; Topp-Jørgensen et al. 2005), Namibia (Stuart-Hill et al. 2005), and Ecuador (Becker et al. 2005; Townsend et al. 2005); in developed countries, monitoring by volunteer wardens at nature reserves and by amateur naturalists (the Neighbourhood Nestwatch scheme; Evans et al. 2005) |
| 5. Autonomous local monitoring | local people | local people | customary conservation regimes in the Canadian Arctic (Ferguson et al. 1998; Moller et al. 2004), Indonesia (Mantjoro 1996), Laos (Baird 1999), Mexico (LaRochelle & Berkes 2003), Mongolia (Fernandez-Gimenez 2000), New Zealand (Moller et al. 2004), and the Pacific Islands (Johannes 1978, 1998); in developed countries, also fishing and hunter clubs monitoring of, for example, moose (*Alces alces*), bears (*Ursus* spp.), trout and salmon (*Salmo* spp.) |

**See Supporting Information for literature cited.*

scientists may provide advice and training. The original data collected by local people remain in the area being monitored, which helps create local ownership of the scheme and its results, but copies of the data may be sent to professional researchers for in-depth or larger-scale analysis. Examples of category 4 schemes in developed countries include volunteer wardens at nature reserves collecting data, using them as the basis for local management decisions, and providing them to national schemes for larger-scale analyses. Developing countries also have examples of this category of monitoring scheme, including community-based monitoring schemes operating in protected areas or community-managed areas (Table 1). Nevertheless, many of these are still at the pilot stage and still externally supported. We provide a detailed case example of a category 4 scheme from the Philippines.

### Category 5. Autonomous Local Monitoring

In this category the whole monitoring process—from design, to data collection, to analysis, and finally to use of data for management decisions—is carried out autonomously by local stakeholders. There is no direct involvement of external agencies, except possibly to help advocate the continued relevance of such schemes. In developed countries category 5 schemes include natural resource monitoring among indigenous groups in New Zealand and the Canadian Arctic (Table 1) and on privately owned land managed by hunting and fishing clubs, where careful monitoring of high-value species takes place (e.g., trout and salmon [*Salmo* spp.] and bears [*Ursus* spp.]). In developing countries many customary systems of natural resource management rely on a locally evolved monitoring scheme to ensure that the valued attributes are maintained. Examples include Laotian freshwater fisheries, the Indonesian *sasi* system, and Pacific reef tenure (Table 1). Because many of these schemes are informal and exist within traditional societies that are located far from research institutions, there is little scientific documentation of the results (Berkes 1999).

The continuum of monitoring approaches mirrors the devolution of management responsibility in different approaches to natural resource management. The most locally based monitoring schemes (category 5) are typically part of "traditional" or "customary" systems of conservation management, and management responsibility might always have been at that level. The second-most locally based scheme (category 4) is equivalent to community-based natural resource management, in which management decisions and other rights have been devolved to the community. Monitoring schemes within category 3 and partly in category 2 mirror some of the more collaborative schemes in natural resource management, for example, systems such as joint forest management in which management rights and responsibilities have not been devolved but there is a sharing of management costs and benefits. Finally, the least locally based of the monitoring schemes (category 1 and partly category 2) parallel those conservation approaches that do not involve local people and in which the majority of decisions are made by remote government agencies or nongovernmental organization (NGOs).

## Characteristics of Monitoring-Scheme Categories

We assessed the different categories of monitoring against the following criteria: costs to local stakeholders; costs to others; requirement for local expertise; requirement for external expertise; accuracy and precision; promptness of decision making; potential for enhancing local stakeholder capacity; and capacity to inform national and international monitoring schemes (Tables 2 & 3). To some extent, these criteria follow from how we categorized the monitoring schemes; hence, we focused only on the most pertinent points that separate monitoring schemes from each other.

### Cost to Local Stakeholders

Costs to local people vary considerably across categories of monitoring schemes and generally increase with category number (Table 2). In category 1 schemes local people are not involved and hence do not incur costs. In category 2 schemes the costs to local volunteers can be considerable because people have to commit themselves to a program of regular visits, often at set times. For example, it has been estimated that in the United Kingdom, volunteers spend around 1.6 million h each year contributing to bird surveys, work that would cost at least $40 million to undertake professionally (http://www.bto.org/news/news2006/jul-aug/20_million_contribution.htm). Where local people participate in category 2 schemes in developing countries, they are usually paid for their time. Category 3 and 4 schemes have extensive involvement of local people who are not usually paid for their time, although materials and transport may be supplied. In category 5 schemes local people bear all the costs.

### Cost to Others

Costs to nonlocal stakeholders also vary considerably across monitoring schemes. Category 1 schemes have high costs for salaries of professional researchers, with an example cost from Bwindi Impenetrable National Park in Uganda of \$3.6 $ha^{-1}$ $year^{-1}$ (Danielsen et al. 2005*a*). Costs of a category-2 scheme in a developing country are \$0.06 $ha^{-1}$ $year^{-1}$, category-3 schemes range from \$0.01 to \$0.13 $ha^{-1}$ $year^{-1}$, and category-4 schemes have a median cost from 7 examples of \$0.05 $ha^{-1}$ $year^{-1}$ (Danielsen et al. 2005*a*). There are no external costs for category 5 monitoring schemes.

**Table 2. Variation in 8 characteristics across the 5 different categories of natural resource monitoring schemes.**

| | *Characteristic*[a] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Monitoring category*[b] | *cost to local stakeholders* | *cost to others (outsiders)* | *requirement for local expertise* | *requirement for external expertise* | *accuracy and precision* | *promptness of decision making* | *potential for enhancing local stakeholder capacity* | *capacity to inform national and international monitoring schemes* |
| Category 1 | * | *** | * | *** | ***[c] | *[d] | * | *** |
| Category 2 | ** | ** | ** | *** | *** | * | * | *** |
| Category 3 | ** | ** | ** | *** | *** | * | ** | *** |
| Category 4 | *** | *-***[e] | *** | **-***[f] | ** | *** | *** | ** |
| Category 5 | *** | * | *** | * | * | *** | *** | * |

[a] *Key: *, low; **, intermediate; ***, high.*
[b] *Monitoring categories are defined in the text.*
[c] *Especially in developing countries, local people may be needed for locating and identifying (e.g., tracks of) wildlife species.*
[d] *An exception is remote-sensing schemes that detect, for example, forest fire in near real time and potentially may allow for almost immediate decision making.*
[e] *Recurrent costs to nonlocals low, set-up and training costs to nonlocals high.*
[f] *Recurrent requirement for nonlocal expertise intermediate; during set up/training requirement for nonlocal expertise high.*

### Requirement for Local Expertise

Because the categories are defined by their degree of local participation, it follows that requirements for local participation vary across categories. There is no local involvement in category 1 schemes, but the need for local expertise is substantial in other categories (Table 2). The volunteers or locally employed people involved with category 2 schemes often need to have considerable species-identification expertise and must keep records and follow a prescribed method with procedural rigor. In category 3 schemes significant biological expertise is also required, but there is an additional need to make decisions on the basis of the results of monitoring. In category 4 and 5 schemes there is a need for a high level of local expertise in selecting relevant methods, interpreting data, and making management decisions. The need for local social and community-relations expertise is also significant in these categories.

### Requirement for External Expertise

The requirement for external expertise is particularly high in the category 1 schemes and may slowly decline from category 2 to 4 schemes. By definition, there is no external involvement in category 5 schemes. Across the schemes, there may be a change in the balance of types of expertise between those focused on natural sciences and those that require participatory social-anthropological and facilitation skills, but socioeconomic literacy is required at every stage if the scheme is to be efficient and sustainable. In category 4 schemes the level of external engagement in day-to-day implementation declines dramatically, but significant external expertise may be required before the scheme can function independently.

### Accuracy and Precision

For all categories of monitoring scheme, careful consideration of likely biases in the sampling strategy and survey methods, and thorough training of data gatherers and data interpreters will improve accuracy and the precision (Yoccoz et al. 2001, 2003; Nichols & Williams 2006; Holck 2007). Category 1 schemes often aim for a high level of accuracy and precision and may explicitly consider the power of the study to detect trends of interest (Hatch 2003; Maxwell & Jennings 2005). Category 2 schemes are vulnerable to bias due to the spatial or temporal coverage of monitoring, a lack of experienced observers, methods changing over time, and results reflecting observer perceptions (Bibby et al. 2000; Danielsen et al. 2005*a*), although methods exist to circumvent such biases (Greenwood 2007). There is hardly any literature on the degree of accuracy or precision of category 3 through 5 monitoring approaches (but see Uychiaoco et al. 2005). Overall, accuracy and precision probably decline from category 1 to 5 schemes (Table 2), but there is a need for scientific assessment of this assertion within carefully designed comparisons.

### Promptness of Decision Making

The speed of decision making is predicted to rise progressively through category 1 to 5 schemes (Table 2). Different categories of monitoring schemes tend to lead to decisions made at different scales that address different categories of threats and result in different types of actions (Danielsen et al. 2005*a*). Only one empirical study has addressed the speed with which conservation-management decisions have been made as a consequence of locally based monitoring (Danielsen et al. 2005*b*). The rapid decision making possible in category 4 and 5

**Table 3. Potential ways to avoid the pattern of variation in 8 characteristics across the 5 categories[a] of natural resource monitoring schemes, and proposed questions for those who will conduct monitoring to answer in the design phase.[b]**

| *Characteristic* | | | | | | | |
|---|---|---|---|---|---|---|---|
| *cost to local stakeholders* | *cost to others (outsiders)* | *requirement of local expertise* | *requirement of external expertise* | *accuracy and precision* | *promptness of decision making* | *potential for enhancing local stakeholder capacity* | *capacity to inform national and international monitoring schemes* |
| Careful design may reduce costs of categories 3 and 4. | Careful design may reduce costs of categories 1, 2, 3, and 4. | Need unavoidable? | Careful design may reduce need in categories 1, 2, and 3. | Careful design may reduce need in categories 1, 2, 3, and 4. | Promptness may require supportive environment to maximize benefits of categories 3, 4, and 5. | Enhancement may require supportive environment to maximize benefits of categories 4 and 5. | With appropriate design and support, category-4 schemes could still feed up. |
| Are there local stakeholders who might benefit from being involved with monitoring? Are there local stakeholders involved with management, or are they excluded from being involved in some way? | What external resources are available? Are they sustainable over time? | What is local capacity (or scope for training) like? | What is availability of external expertise? | What is need for accuracy and precision? | What is need for immediacy and speed of decision making? | What is need for local empowerment? | What is need for global data from this scheme? |

[a] *Categories are defined in the text.*
[b] *The way to avoid variation is listed first under each characteristic and questions follow.*

schemes requires a supportive policy and legal environment (Table 3). If local stakeholders have little control over resources, it is unlikely their monitoring will lead to prompt decision making.

### Potential for Enhancing Local Stakeholder Capacity

The potential for enhancing local capacity increases from category 1 through 5 with the increasing involvement of local stakeholders (Table 2). Category-1 schemes contribute little or nothing to local capacity building. Category 2 schemes may improve capacity of volunteers or park rangers and help change attitudes among local community members. Category 3 and 4 schemes can empower local stakeholders and improve collaboration with management authorities by improving use of indigenous knowledge, strengthening community-based resource management systems, and providing more-transparent, accountable, and inclusive decision making (e.g., Andrianandrasana et al. 2005). The potential of category 3 and 4 schemes to enhance local capacity is maximized when leadership of these schemes is established locally rather than transferred to national or international organizations. Category 5 schemes constitute a fully internalized, local management system, and hence in principle provide the greatest local control over monitoring and decision making in natural resource management. Nevertheless, category 5 schemes do not necessarily address existing inequalities within local communities (e.g., exclusion of the poorest or gender imbalances), and hence can exclude the community members who depend the most on exploitation of natural resources. Moreover, because such schemes are undertaken without the involvement of external stakeholders, they may not improve collaboration between communities and, for example, government authorities or private business.

### Capacity to Inform National and International Monitoring Schemes

The ability of monitoring schemes to integrate with other schemes to generate wider indices of natural resources probably declines progressively from category 1 through 5 schemes (Table 2). Category 1, 2, and 3 schemes may, if well designed, fairly easily feed data into larger-scale schemes (e.g., category-1 international schemes include water-quality monitoring [www.gemswater.org/] and a database on the world's parks [www.unep-wcmc.org/protected_areas/] and their management effectiveness [Stolton et al. 2003]).

Many category 2 volunteer schemes are designed for large-scale use (e.g., the Marine Trophic Index [Pauly & Watson 2005] and Internet-based bird-recording schemes [Roberts et al. 2005]). National category 2 bird monitoring schemes across Europe have been combined to produce an international monitoring index of common birds, even though the various national schemes use different recording methods (Gregory et al. 2005). Among category 3 schemes, BirdLife International's Important Bird Area monitoring scheme provides data from the local level for both national and international analysis (Bennun et al. 2005).

Data from category 4 schemes are beginning to be aggregated for national-level analysis in Tanzania (Blomley et al. 2008), Namibia (Stuart-Hill et al. 2005), and the Philippines (Danielsen et al. 2005*b*). These initiatives, although promising, are still in their infancy. Some category 4 data are also used in global schemes (e.g., World Wide Fund for Nature's Living Planet Index [Loh et al. 2005]). We know of no category 5 schemes that are contributing data to larger-scale analyses. This is unsurprising because the schemes are fully self-determined, the variables monitored are often locally defined (e.g., presence of particular species, flow of rivers), and there is little communication with external agencies.

Category 2 through 4 schemes seem particularly well suited for collecting data on some important attributes that are difficult to monitor at a national or global level with professionally executed monitoring schemes. Examples include ecosystem goods and services delivered at the local scale and the condition of certain habitats, like fragmented forests and wetlands, whose loss proceeds primarily via degradation rather than wholesale conversion.

## Examples of Locally Based Monitoring Schemes in Developing Countries

Monitoring that involves local stakeholders is already well established in many developed countries (e.g., volunteer bird-recording schemes). Nevertheless, we believe the locally based monitoring concept has great unexplored potential in developing countries, where funds and expertise are limited and people are more dependent on natural resources. Here we provide examples of category 2 through 4 monitoring schemes from developing countries.

### Category 2 Scheme: Fisher Data Collection in the Bangweulu Swamps, Zambia

The Zambian government has collected fisheries statistics in Lake Bangweulu for many years. The methods of this category-1 monitoring scheme are similar to those proposed by the United Nations Development Programme/Food and Agriculture Organization Fisheries Division in the 1970s. The frequency and consistency has varied greatly, depending on availability of finance and workers; thus, the data are too few or unreliable to allow much meaningful analysis (Ticheler et al. 1998).

To solve this problem, 12 literate professional fishers living in the swamps were selected to carry out part of the sampling in parallel with the monthly experimental gill-net surveys by scientists. Some used their own gear, whereas others were issued experimental gill nets, but the fish caught belonged to the fishers, and they were free to fish when and where they wanted as long as some basic information was recorded. The information collected was kept to a minimum and made as simple as possible. For each catch, only data on the time of fishing, fishing method, and locality were recorded. Each individual fish caught was recorded by species, mesh size in which it was caught, and the length to the nearest centimeter. Fishing effort that resulted in no catches was also recorded. Fishers were paid a fixed monthly wage for sampling and an additional sampling bonus for persistent and good-quality data, and data collected were passed to government officials during monthly supervisory visits.

The 12 fishers collected length-frequency data for 1 year. Large quantities of reliable and cheap length-frequency data were collected, and they allowed for a full length–based stock assessment, including cohort analysis. Fishers collected nearly 400,000 individual fish records. On the basis of costs per individual fish record, data collected by the fishers were nearly 60% cheaper than data collected by scientists in the experimental gill-net surveys. Data from local fishers and government scientists were complementary. Fishers collected large quantities of reliable length-frequency data, but they did not assess sex ratios, and hence there was added value from the detailed government monitoring with stationary gill nets. In a large inaccessible area such as the Bangweulu swamps, involvement of local fishers in data collection was the most cost-effective way to complete an intensive assessment of the fishery.

### Category 3 Scheme: Participatory Ecological Monitoring of the Alaotra Wetlands in Madagascar

The Alaotra wetlands are the largest in Madagascar. They are shallow and highly productive and thus valuable for people and biodiversity, but are also vulnerable to degradation, particularly via sedimentation. Since 2001 Durrell Wildlife Conservation Trust, government, NGO technicians, and local communities collected data on key species (e.g., waterbirds and a locally endemic lemur), and on useful natural resources (Andrianandrasana et al. 2005). Monitoring teams at each site consisted of up to 17 people: 10 villagers and 7 technicians. Following a preparatory visit, participants were chosen at an initial meeting to which all community members were invited. Selection criteria included a good knowledge of the marshes, and literacy. Participants were paid around $2/day, which is less than an average earning from fishing. The monitoring teams facilitated group discussions with fishers and measured and identified fish caught by fishers. The monitoring teams also observed lemurs and waterbirds along fixed canoe transects and delimited burned marsh areas with geographic positioning systems. Durrell Wildlife technicians had university degrees, whereas other technicians had a secondary school education. Since 2002 the village participants, most of whom had primary school education, received training in data collection.

The monitoring has assisted wetland management by guiding amendments to and increasing respect for a regional fishing convention, raising awareness, catalyzing the transfer of marsh management to communities, and stimulating collaboration and good governance. Monitoring showed trends in natural resources management over time (e.g., changes in number of annual marsh fires) and provided valuable data on the fishery. Surveys also provided information on levels of hunting of water birds and lemurs and the area of lemur occupancy.

Overall, monitoring provided useful data for decision making and started the process of building local pride in the environment and the ability to analyze the monitoring data locally. Nevertheless, there was significant external input to the monitoring, including into data analysis and much of the interpretation.

### Category 4 Scheme: Community-Based Monitoring of Philippine Protected Areas

Until the 1990s most protected areas in the Philippines existed only on paper. In 1992 a new protected area act, the NIPAS Act, allowed for community participation in management of protected areas. In 1996 the World Bank and Danish aid (DANIDA) agreed to assist the Philippine government to operationalize the new act, and for 3 years they worked together to develop a simple community- and ranger-based scheme for monitoring in protected areas.

The scheme was intended to identify trends in important biodiversity assets and to use these trends to guide management action in protected areas. It also was intended to enhance participation of protected-area communities in management of the protected area (Danielsen et al. 2000). Data were collected by government rangers and volunteer community members. By allowing rangers to participate in field assessments, the scheme encouraged them to get into the field and improved their capacity for management. In each park monitoring focused on a list of 10–15 taxa and 5–10 signs of resource use, selected by local community members together with protected-area staff. Data were collected every 3 months. Data interpretation was undertaken locally by the protected-area staff and community members, and a small report was presented every quarter to the Management Council of each protected area. The report included the data set, a list of important observations of changes in species and resource use, and a list of proposed management interventions with a description of the issue identified, the location, and the proposed action to be taken by the protected-area council (Danielsen et al. 2005*b*).

Before this monitoring scheme was established, there was little collaboration between local people and park authorities, and park monitoring was restricted to assessments of the quantity of extracted timber (Danielsen et al. 2005*b*, 2007*b*). As a result of 2.5 years of operation of the scheme by 97 rangers and 350 community volunteers, 156 interventions were undertaken in terrestrial, marine, and freshwater ecosystems (Danielsen et al. 2005*b*). The majority of these interventions were meaningful and justified, 47% targeted the 3 most serious threats to biodiversity at the site, and 90% were implemented without external support. Many of the interventions were jointly undertaken by community members and the management authorities or consisted of local bylaws in support of park management. As a result of monitoring, schemes to regulate indigenous resource use were reestablished with government recognition in several parks. Monitoring led to more-diversified management responses on the part of the authorities, including a more socially acceptable and effective approach to enforcement. The scheme continues at most of the sites where it was established, even though DANIDA support ceased in 2001. The government has promoted the scheme as a standard management tool in protected areas and it has spread to new sites.

## Criteria for Choosing a Monitoring Scheme

The context and the aims of the initiative will define which schemes are most appropriate (Table 3). Whatever category is chosen, adequate financial and human resources must be available over a suitable time frame if the monitoring is to be effective.

Category 1 schemes can be executed almost anywhere because they are largely externally driven. They are most suitable where highly technical monitoring across large scales demands high levels of professional expertise and where there is a guaranteed source of funding that will permit this form of technical monitoring to be sustained over time (Table 4).

Category 2 schemes can be used where there are skilled volunteers or funds to pay staff for collection of field data (Table 4). These types of schemes are ideal when large numbers of people are required to collect data across wide geographical areas and on a regular basis. This capitalizes on the strength of getting the most data possible, even if accuracy or precision of each individual data point may not be as high as that obtained by highly trained professionals.

Category 3 and 4 schemes depend on local people making significant investment in monitoring. External stakeholders should not try to get monitoring "on the

**Table 4. Criteria of importance for making decisions on which category of natural resource monitoring is most suitable for a given circumstance.**[a]

| Monitoring category[b] | *Highly accurate data required from the monitoring scheme* | *Government/NGOs have budgets for monitoring with their own staff* | *Professional scientists available* | *Volunteers easily available* | *Government extension/ranger staff available at local levels* | *Area remote and difficult for outsiders to access easily* | *Natural resources an important part of local livelihoods* | *Current management regimes allow local peoples' involvement (e.g., in parks and reserves)* | *Policy and legal environment supportive of community involvement in resource management* | *Empowering local people to make decisions about natural resource conservation an important objective of management* |
|---|---|---|---|---|---|---|---|---|---|---|
| Category 1 | *** | *** | *** | | | | | | | |
| Category 2 | *** | *** | *** | *** | * | ** | * | | ** | |
| Category 3 | ** | *** | *** | ** | ** | *** | *** | ** | ** | ** |
| Category 4 | ** | ** | ** | ** | ** | *** | *** | *** | *** | *** |
| Category 5 | * | | | ** | | *** | *** | *** | *** | *** |

[a]*Key: ***, very relevant; **, relevant; *, sometimes relevant; blank, not relevant.*
[b]*Monitoring categories are defined in the text.*

cheap" by expecting local people to bear costs. Unless there are real benefits felt locally, such monitoring will not be sustainable (Hockley et al. 2005). They are therefore most appropriate where local people have significant interests in natural resource use (Table 4). In these schemes local ownership, empowerment, and link to management decisions can be even more important than data quality, although management and empowerment benefits should not be used as an excuse for poor design. A balance is therefore needed between monitoring goals and the broader goals of seeing the results used and decisions taken about natural resource management.

Category 5 schemes by definition cannot be instigated from outside. These types of monitoring schemes can be highly effective when a valuable resource is being monitored by people with a large stake in knowing the status of that resource (Table 4). In other category 5 schemes, the design and implementation may result in data that scientists would consider inaccurate and imprecise.

## Need for Further Work

In some circumstances locally based monitoring has advantages over conventional monitoring (Danielsen et al. 2007*a*). It can build local capacity and relations between local people and the authorities, and can result in more-rapid management interventions. Nevertheless, the approach needs further development and verification. Systematic comparisons between professional and locally based monitoring approaches are needed, and there is a need to extend the focus of locally based monitoring from primarily biological monitoring to consider social measures (e.g., governance in natural resource management). Meta-analytical tools (Gurevitch et al. 2001) may offer opportunities for combining the results of locally based monitoring to draw general conclusions and to track larger-scale trends. For amalgamating results with meta-analysis, the main requirements are the use of a small number of methods, each well replicated, across a large number of schemes (Côte et al. 2005).

Finally, there is a need for larger-scale testing of locally based monitoring approaches tied to some of the local approaches to conservation management that are being promoted globally. Locally based monitoring may be the ideal way for communities to report to external agencies on progress with managing habitats, species, and flows of ecosystem services in community or comanaged conservation areas.

The world needs monitoring that makes a real contribution to improving natural resource management. It is therefore vital to improve the connection between the way conservation science is conducted and how it is applied.

## Acknowledgments

We thank C. Kremen and G. Meffe for encouragement, H. Andrianandrasana, J. Durbin, M. Gray, A. Jørgensen, K. Laidre, K. Pirhofer, and S. Wangchuk for valuable discussions, and 5 anonymous reviewers for comments. This work was supported in part by the Danish Council for Development Research (104.DAN.8.1203), Nordic Agency for Development and Ecology (NORDECO), and World Wildlife Fund-US.

## Supporting Information

A key to identify the category of a natural resource monitoring scheme and references cited in Table 1 are available as part of the on-line article. The author is responsible for the content and functionality of this material. Queries (other than absence of the material) should be directed to the corresponding author.

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