Environmental Management (2012) 50:707–720
DOI 10.1007/s00267-012-9909-3

Biodiversity Monitoring at the Tonle Sap Lake of Cambodia: A Comparative Assessment of Local Methods

Sophat Seak · Dietrich Schmidt-Vogt · Gopal B. Thapa

Received: 5 March 2011 / Accepted: 22 June 2012 / Published online: 29 July 2012

Abstract This paper assesses local biodiversity monitoring methods practiced in the Tonle Sap Lake of Cambodia. For the assessment we used the following criteria: methodological rigor, perceived cost, ease of use (user friendliness), compatibility with existing activities, and effectiveness of intervention. Constraints and opportunities for execution of the methods were also considered. Information was collected by use of: (1) key informant interview, (2) focus group discussion, and (3) researcher's observation. The monitoring methods for fish, birds, reptiles, mammals and vegetation practiced in the research area have their unique characteristics of generating data on biodiversity and biological resources. Most of the methods, however, serve the purpose of monitoring biological resources rather than biodiversity. There is potential that the information gained through local monitoring methods can provide input for long-term management and strategic planning. In order to realize this potential, the local monitoring methods should be better integrated with each other, adjusted to existing norms and regulations, and institutionalized within community-based organization structures.

Keywords Local biodiversity monitoring · Community-based monitoring · Biological resource monitoring · Biodiversity monitoring · Tonle Sap

S. Seak
Department of Environmental Science, Royal University of Phnom Penh, Room 112, Building A, Campus I Toul Kok, Phnom Penh, Cambodia

S. Seak (✉)
Natural Resource Management, Asian Institute of Technology, Km 41, Paholyothin Road, Klang Luang, Bangkok, Pathumthani 12120, Thailand
e-mail: sophat.seak@ait.ac.th

D. Schmidt-Vogt
Centre for Mountain Ecosystem Studies, Kunming Institute of Botany, Chinese Academy of Sciences, Kunming, China

G. B. Thapa
Regional and Rural Development Planning, Asian Institute of Technology, Bangkok, Pathumthani, Thailand

Introduction

Biodiversity monitoring can be a useful tool for biodiversity conservation and sustainable resource management, as it is capable of systematically generating data on change or condition of biodiversity and natural resources (Margolius and Salafsky 1998; NORDECO and DENR 2001). The data generated can be utilized for interventions to protect and manage populations and habitats (Danielsen and others 2005a, 2003; Teder and others 2006). By generating time-series data, biodiversity monitoring can play a very important role to inform policy/decision makers and society regarding the current status of biodiversity (Stork and others 1996; Vreugdenhil and others 2003). Monitoring can also provide an enabling atmosphere of collaboration among professional experts, resource managers and local communities (Sekercioglu 2011). Biodiversity monitoring can be undertaken in several forms. These include: scientist monitoring (Alzinga and others 2001), government ranger or official monitoring (Gray and Kalpers 2005), and community based monitoring (Danielsen and others 2000, 2005a).

Scientist monitoring is often conducted for selected species or populations according to availability of funds or interest of donors and government authorities (Alzinga and others 2001; Bani and others 2006; Joseph and others 2006). It involves sophisticated sampling design with

replicates, control sets, and construction of indicators as well as advanced data analysis techniques, including the application of species diversity indices (Feinsinger 2001; Kéry and Schmidt 2004; McGeoch and others 2006; Katzner and others 2007). In addition, monitoring conducted by scientists requires a comprehensive level of skills and a great deal of resources and time investment for operations (Sutherland 1996; Danielsen and others 2005a; Lindenmayer and Likens 2010) and for translating monitoring data into management actions (at least from 1 to 3 years) (Danielsen and others 2010). Moreover, actions have little impact at local or village level, but rather at regional and international scales. Biodiversity monitoring by government rangers or officials is often conducted with technical and financial assistance of NGOs and academic institutions who provide a lead in monitoring method design, data collection, analysis and interpretation, and who provide hands-on training to rangers and officials. The interventions are usually limited to areas where rangers and officials are deployed (Gray and Kalpers 2005; Danielsen and others 2005b, 2008).

There is a growing recognition among conservationists, resource managers and scientists that community based monitoring may be an alternative or supplement to other forms of monitoring (Oldekop and others 2011; Sekercioglu 2011; Mortensen and Jensen 2012), especially in developing countries where both technical and financial resources are relatively limited, and where the approach has already been successfully applied (Yoccoz and others 2003; Danielsen and others 2005a, 2008, 2010; Lawrence and Paudel 2006). Community-based monitoring was found to be better adapted to local contexts, and less costly than scientist-led methods (Steinmetz 2000; Gaidet and others 2003; Uychiaoco and others 2005; Rijsoort and Jinfeng 2005; Gaidet-Drapier and others 2006). It has also been stated that data collected by community-based monitoring can be made available for decision making in a matter of days (Obura and others 2002; Danielsen and others 2005a, 2010; Noss and others 2005; Steinmetz and others 2006).

In Tonle Sap Lake of Cambodia, community-based conservation of biodiversity has been practiced since the past decade (Gray and others 2007) involving all three types of monitoring: monitoring by scientists, by government rangers and officials, and by local communities (Seak and others 2011). Scientist-led monitoring is supported by the US-based NGO Wildlife Conservation Society (WCS). Ranger and official-based monitoring is carried out by government agencies [Ministry of Environment (MoE) and Fisheries Administration (FiA)] with WCS providing technical support for design and data analysis. Community-based monitoring received technical support by government rangers and officials during the start-up phase, and by NGOs and academic experts after communities were officially established and became operational in the 2000s (Seak and others 2011).

In a previous paper (Seak and others 2011) we investigated and discussed the three monitoring systems—state-managed, NGO-managed and community-based—by focussing on three monitoring methods: patrol, community meeting and surveillance. This paper focusses only on local methods applied in the context of community-based monitoring, which were not included in the first paper. Monitoring by local communities on Tonle Sap Lake is classified into categories 3 and 4 of Danielsen and others (2008). It is aimed at protecting the lake's biodiversity and biological resources, which are declining chiefly due to overfishing, to the conversion of flooded forest to agricultural land and settlement purposes (Campbell and others 2006), and to invasive alien species (Lim and others 2004; Neou and Lane 2002). Community-based monitoring at Tonle Sap Lake involves a number of locally-developed methods, which are believed to inherently emanate from local ecological knowledge of distinct features of biodiversity (species). It is uncertain as to what extent community-based monitoring schemes could provide the comprehensive model and good practices of long term monitoring outcomes for the sake of biodiversity conservation. Though several studies have addressed the issue of accuracy of data produced by the community-based monitoring (Gilchrist and others 2005; Oldekop and others 2011; Mortensen and Jensen 2012), no study has so far been carried out to document and to systematically assess local monitoring methods practiced by communities around Tonle Sap Lake. This paper aims to assess community-based monitoring of biodiversity and biological resources on the basis of the following criteria: methodological rigor, perceived cost, ease of use (user friendliness), compatibility with existing activities, and effectiveness of intervention.

Research Methods

Study Area

The study site is situated in Boeng Tonle Chhmar Core Area (BTC), part of the Tonle Sap Lake of Cambodia, which was designated as UNESCO World Biosphere Reserve in the year 2000 (Fig. 1). The lake is influenced by the hydrological pattern of the Mekong river, which causes seasonal reverse flows of the Tonle Sap River and huge fluctuations in the size and depth of the Tonle Sap Lake. Lake hydrology is one of the causes of the wide range of exceptionally reproductive habitats for aquatic fauna and flora (Lamberts 2006). The lake is characterized by a high

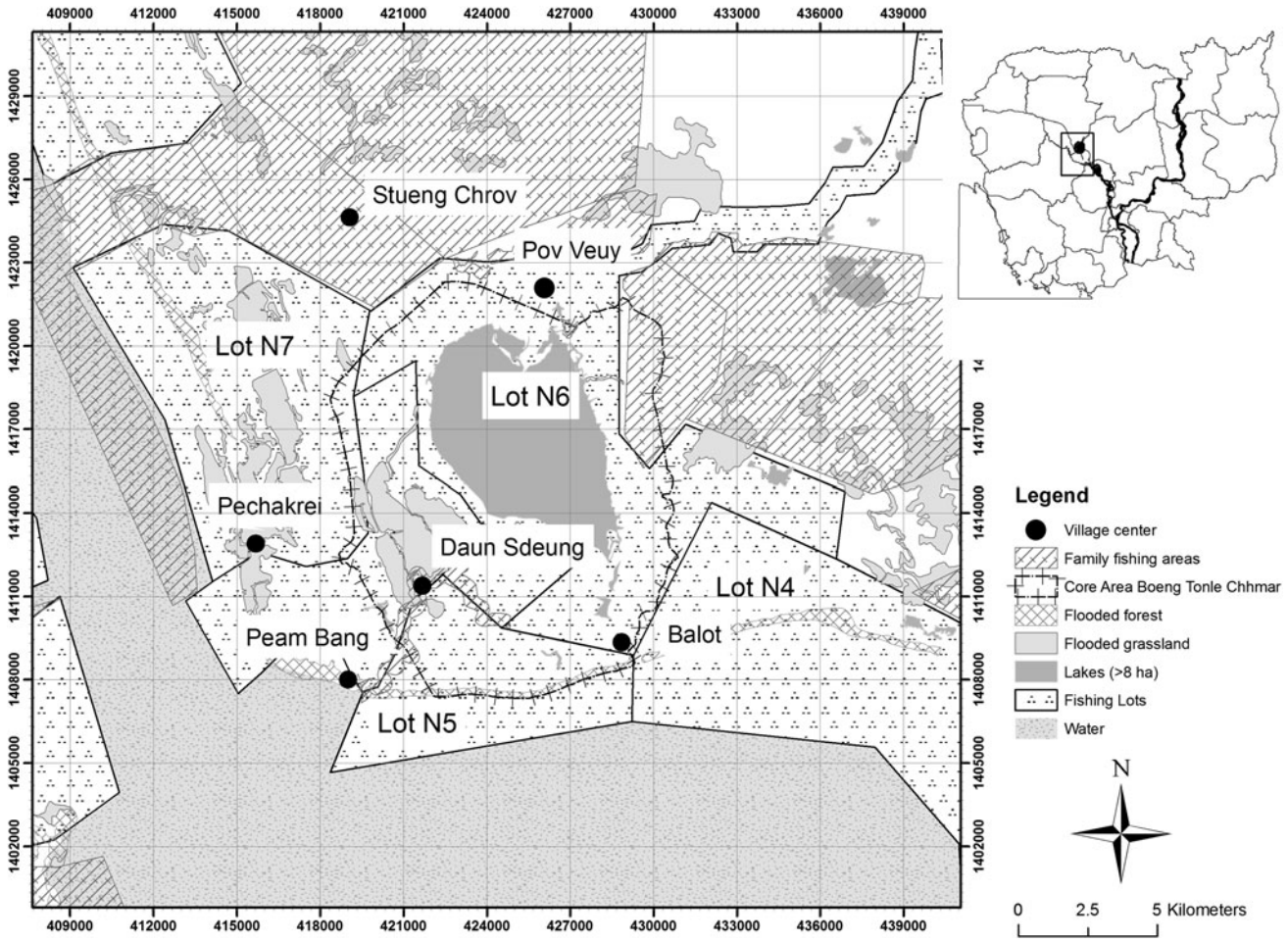

Fig. 1 Boeng Tonle Chhmar core area: flooded forest cover, different management zones (core area, commercial fishing lots, community fishing ground) and village centres. The map was modified from Seak and others (2011)

biodiversity of fish (149 species), reptiles (Siamese crocodile, nearly extinct), birds (11 globally threatened and 6 nearly threatened species), mammals and plants of approximately 200 species (Campbell and others 2006). The lake provides direct economic benefit to about 1.2 million people residing in the floodplain and indirect benefit to several million people in the country (Matsui and others 2005). In terms of direct benefit, the lake's capture fisheries yield an annual production of between 180,000–250,000 tonnes (van Zalinge 2002; Lamberts 2001). Because of its economic significance for the livelihoods of the surrounding population, the lake biodiversity is at severe risk due to overharvesting and other unsustainable practices. We selected BTC, one of the three core areas of the Tonle Sap biosphere reserve, as our study site for the following reasons: it is representative of Tonle Sap Lake in terms of being rich in biodiversity; it is intensively used by fishing communities; community-based monitoring is being practised by community fisheries and in community managed protected areas.

The study site in BTC core area is Peam Bang commune of Stuong district, Kampong Thom province, which covers an area of 14,560 ha (MOE and others 2002). The BTC study site has three overlapping management regimes, and is at the same time a core area of the Biosphere Reserve, a Ramsar site, and the site of four commercial fishing lots (lots 4, 5, 6 and 7). Because of the abundance of its fisheries, BTC has attracted many people, including seasonal fishers who migrate from the uplands of Kampong Thom, Kampong Chhnang, Pursat and Siem Reap provinces to this area. As of early 2009, the area consisted of four registered villages: Peam Bang; Pov Veuy; Daun Sdeung; and Balot with a total permanent population of some 2,500 persons (494 households). During the fishing season (November–May), the population may triple.

Community-based natural resource management in the form of community fisheries and community-managed protected areas was established in each village of BTC since 2001 after the Royal Government of Cambodia undertook the fishery reform of early 2000, which included the release

of more than 50 % of commercial fishing ground for community management after chronic conflict between commercial fishing concessionaires for nearly a decade. The community fisheries and community-managed protected areas were supported by rangers and fisheries officers under the control of the Ministry of Environment (MOE) and of the Ministry of Agriculture Forestry and Fisheries (MAFF), respectively. Peam Bang, Daun Sdeung and Pov Vuey villages were accorded community fisheries, while Balot village was accredited as Community-Managed Protected Area. The function and organization of community fisheries are governed by the Fishery Law (adopted in 2007) and Sub-decree of Community Fisheries Management (adopted in 2005) (FiA 2008). Community-Managed Protected Areas, on the other hand, are under the Law on Protected Area Management (MOE 2008). Each community must produce by-laws and regulations outlining specific roles and responsibilities, and submit them to the line agencies (MAFF or MOE) for formal approval. Monitoring is also stipulated in the by-laws and regulations.

Data Collection and Analysis

The study used both qualitative and quantitative techniques, applying the following tools in a step-wise process: (1) key informant interviews; (2) focus group discussions; and (3) researcher observation.

Key informant interviews were held in the second half of 2008 with 66 key informants selected through purposive sampling to represent five groups of stakeholders. Eight informants were the chiefs and vice chiefs of the four villages, providing information on biodiversity conservation, and the administrative structure of community-based organizations. Twenty-two participants, which included the heads of community fisheries/managed protected areas, were selected from the four villages and interviewed concerning monitoring methods, decision making, enforcement, by-laws and regulations, and community operation. Twenty-two elderly people (older fishers) were interviewed on traditional monitoring methods and interventions. Ten rangers and four fisheries officers were chosen for discussion on the general status of biodiversity conservation, their technical assistance for community organizations, law enforcement and monitoring methods in the study site of BTC. Moreover, each group of stakeholders was carefully consulted about monitoring tools and techniques for specific species and places, as well as about labour, time, and cost involved in the application of each method, about opportunities and constraints of the respective monitoring methods, local conditions, history of study site, ethnicity, population, assessment criteria and sustainability of local methods.

Focus group discussions were held in March 2009 with the primary purpose of comparative assessment of each monitoring methods following the analysis of results from key informant interviews to classify the local monitoring methods and types of decision making. To carry out this exercise, group meetings were held in each village with the three stakeholder groups combined: village heads and vice heads, active community members, and elderly people. Discussions with rangers and fisheries officers were organized separately in order to avoid bias of their assessment.

Researcher's observations were used to verify data gathered and to detect hidden data on the state of biodiversity, habitat, use, fishing gear, participation, and suppression (intervention) that respondents were afraid to disclose during interviews and group discussions. For this purpose, during four separate visits in September and November 2008, and March–April 2009, we spent time with villagers from each community, participating in their fishing, hunting, patrolling activities, and decision-making processes in order to explore additional monitoring methods and interventions.

Criteria for the Evaluation of Monitoring Methods

For the assessment of local monitoring methods, we used and adopted the five evaluation criteria developed by Seak and others (2011) with minor modifications to fit with the characteristics of local methods. These five criteria are: (1) methodology rigor; (2) perceived cost; (3) ease to use (user friendliness); (4) compatibility with existing activity; and (5) effectiveness of interventions (Table 1). In addition,

Table 1 Definition of criteria for the assessment of local monitoring methods in Tonle Sap Lake, Cambodia

Types of criteria	Justification
Methodology rigor	The level to which a monitoring method is perceived as having a rigorous enough methodology to generate relatively accurate and precise data
Perceived financial cost	The level to which a monitoring method is perceived as requiring a certain array of cost to implement
Ease of use	The level to which a monitoring method is perceived as being complicated or easy to understand and apply with regard to capacity and skill of local community
Compatibility with existing activities	The level to which a monitoring method is perceived as being consistent with existing local practices, livelihood activities, and the needs of potential enhancement
Effectiveness of intervention	The level to which a monitoring method is perceived as being able to produce effective measures for intervention, leading to efficient decision making at local scale

Source adopted from Seak and others (2011)

the five criteria were reviewed with key informants of the study area and on the basis of the available literature (Hartanto and others 2002; Danielsen and others 2000). With respect to assessment, the weighted score system of Seak and others (2011) was employed as a basis for evaluating each method through separate focus group discussions with the three key groups of stakeholders mentioned above.

A weighted score of 0 means no influence, 1 means low influence, 2 medium influence, and 3 high influence. Each group was asked to score each method and provide reasons of scores given. The average scores of each method were summarized based on the results obtained by each group assessment. The average scores of each method were then consulted with the respective leaders of each group of stakeholders for consensus and to validate whether the average scores reflect the situation and practices in the study area.

Results

While local monitoring methods have been applied by local communities in BTC since a long time, active community members were trained in some of the methods (catch of fish, reptile, and mammal; transect count, nest count; observation; estimation of bird flock; and transect walk for vegetation) presented below by experts from the Royal University of Phnom Penh, Cambodia and the Asian Institute of Technology, Thailand during 2006–2007 as part of a research project on natural resource management in BTC with funding support of USEPAM/Danida (University Support to Environmental Planning and Management Project/Danish Agency for International Development). The training included data collection design, simple analysis, and translation of monitoring results into appropriate decision-making (interventions). In addition to that, since the establishment of communities in 2001, members of these communities were selected and trained by rangers (for community-managed protected area) and fisheries officers (for community fisheries) in basic patrol, community meeting and surveillance techniques for monitoring biodiversity and biological resources in BTC (Seak and others 2011).

Local Monitoring Methods for Fish

There are several methods to monitor fish according to the various fish species. Fish in Tonle Sap Lake are categorized into white fish and scaled round fish.

Fish Catch

Local fishers can follow the trend of fishery resources in their localities through daily observation of the fish catch. Fishery biologists as well as ecologists use fish catch in the so-called "Fish catch record" method, where Catch per Unit of Effort (CPUE) is applied for an assessment of fishery biology, production and ecological behavior. For this purpose, catch record sheets are prepared and analysed by experts and by fishers who were trained to record their daily catch data. For local monitoring purposes a less sophisticated 'Fish catch method' that relies on existing methods of grading the fish catch and on fishers' memory can be employed. On Tonle Sap Lake, local fishers sell their catch to the village middleman after each fishing trip. Their fish catch is graded according to species and weight, and divided into fish with commercial value and by catch. In addition to species and weight, fishers are able to recall size of species, duration of fishing, location of fishing, and types of gear used to capture fish. The size of each fish species can be measured by visual estimation using finger span.

Transect Count by Boat

Besides the fish catch method, the annual trend of snakehead population can be detected from visual observation of the abundance of their fingerlings. Snakehead species are locally categorized as round-scaled fish. Several species of snakehead are reported in Cambodia (Rainboth 1996). The common species in BTC are: snakehead (local name: Trey raws, scientific name: *Channa marulius*); black snakehead (Trey raws, *Channa melasoma*); giant snakehead (Trey diep (juvenile) and Trey Chhdaur (adult), *Channa micropeltes*); and chevron snakehead (Trey phtuok (juvenile) and Trey raws (adult), *Channa striata*).

The transect count method includes counting the number of schools (cohorts) of fish fingerlings by boat along transects during the hatching season (June–August). Transects can be laid out by boat along any location of the stream or in natural ponds or flooded shrubland (locally called "Prey sbart"). Fingerling count should preferably be conducted at 8–9 am when the fingerlings forage in schools. The data from the count by boat transect can help to estimate species abundance and annual production of the current year.

The same method can be applied to detect the trend of clown featherback (Trey kray, *Chitala ornate*), and of species belonging to the white fish category (referred to as white-scaled fish in the family Cyprinidae), i.e. *Henicorhynchus* sp. *and Thynnichthys thynnoides* (locally called Trey riel and Trey linh, respectively) which play an important role in the Great Lake ecosystem and in fish catches. *Dangila* sp. (carp), and *Probarbus* sp. (barb) are also important. These species hatch during July–September. The hatchlings can be seen at 7–8 a.m. in schools. Boat transects are usually conducted along channels with flooded vegetation and good water quality.

Observation of Breath/Bubble

This method is specifically employed for monitoring Trey pra kchau (Mekong catfish, *Panguasius bocourti*), which is widespread in the Mekong river system, including Tonle Sap Lake, and commands a high market value. Fishers are able to identify the breath of this species from bubbles rising to the surface that can be used as a proxy indicator to determine species abundance ahead of the catch season. More bubbles indicate more yield. Bubbles can be observed during the breeding season July–September at any time of the day.

Transect Estimate by Paddle

The transect estimate by paddle is employed for a rapid assessment of the fish stock in a particular channel or pond before a fisherman decides to buy a contract from fishing lot owners or a government agency, or before setting out to fish in an area. The special paddle that is used for this purpose is believed to be imbued by the spirit of the area. Successful estimation of yield depends upon respect paid to the spirit.

The paddle is made of the wood of a local timber species: Sralao (*Lagerstroemia calyculata Lythraceae*). Paddle specification is: 2.5 m total length, flat dimension 1 m × 5 mm × 9 cm and 0.5 m is handle. The paddle is used as a sensor when being dipped into the water during rowing for identifying fish species and estimating their abundance. Fish species are identified according to how and where they touch the paddle and as to whether slime remains attached to the paddle after the impact. Trey chhlang (*Mystus nemurus*) hits the paddle strongly, leaving slime at its surface. Trey kanchos chhnoht (*Mystus atrifasciatus*) and Trey kanchos bay (*Mystus albolineatus*) hit the paddle gently at its lower end, leaving behind some jelly as well. Trey chkoak tituy (*Albulichthys albuloides*), Trey chkoak ploeung (*Cycloscheilichthys furcatus*) and Trey brama *(Boesemania microlepis)* hit the paddle strongly two times intermittently but leave no jelly on the paddle. Trey kes (*Micronema* sp.) and Trey ta aun (*Ompok* sp.) hit the paddle gently at its mid-section (up to handle of paddle) coating it with jelly from the middle up to the water surface. Abundances are estimated by inserting the paddle at ten meter intervals. The best time for this type of estimate is April prior to the celebration of Khmer New Year day when the water in Tonle Sap Lake starts receding and when fish collect in deep pools.

Local Monitoring Methods for Birds

Nest Count

BTC is one of the Important Bird Areas (IBA) in Tonle Sap Biosphere (Seng and others 2003). Owing to the abundance of fish and the availability of favourable habitat, the area hosts important reproductive and feeding grounds that attract many bird species. One of the bird species that commonly make their nest in BTC IBA is the fish eagle. Fish eagle nests are mostly found on Deum raing (*Barringtonia acutangula)* trees. In order to detect the population trend of this species, local communities count the number of fish eagle nests. The count can be integrated with fishers' livelihood activity (counting nests while fishing).

The method is applied to other species as well, for example to egret (locally called Kok, *Bubulcus ibis*), during June-July. The bird chicks can be more easily observed in July-August (flooding period) than in the dry season when travel is difficult due to the dense thorny shrub. This method is practiced by communities as part of the requirement to record biological resources in their localities under the registered community status.

Transect Count of Bird Flocks

At BTC IBA, flocks of bird species are counted during foraging, especially along the shoreline during transect walks or boat transects. Transects are done along channels and the shoreline of BTC when the water recedes. The count or observation by transect walk or boat is also carried out from March to May between 8 a.m. and 3 p.m. Flocks can be counted with the naked eye. Bird species that can be counted by this method include cormorants (*Phalacrocorax* spp.), darters (*Anhinga melanogaster*), pelicans (*Pelecanus* spp.*),* storks (*Mycteria* spp., *Ciconia* spp., and *Ephippiorhynchus asiaticus*), and lesser and greater adjutants (*Leptoptilos javanicus, Leptoptilos dubius*). Local fishers stated that more birds feed where more fish dwells and that the method can therefore be used as a proxy indicator to assess fish production as well as species abundance.

Measurement of Bird Feeding Areas

Fishermen measure or estimate the area along the shoreline where bird flocks feed. Knowing the area where bird species feed can help to determine presence/absence visually. It also helps to estimate the population of the bird species. For instance, if in year 1 an area where birds feed extends 1 km, and if in year 2 that area is only 0.7 km long, a decline in the population of that bird species can be inferred. In order to make this method more precise photographs of birds feeding at different locations can be taken at different times of the year.

Local Monitoring Methods for Reptiles

As the study area consists of mostly aquatic environment, local knowledge for monitoring of fishery resources is

better developed than for monitoring of other animal groups. In the case of reptiles, local monitoring methods have been developed only for species of commercial value such as water snake, python and tortoise. Here, we only discuss those species with conservation significance for the country and the world.

Snake and Tortoise Catch

Pos pralit (watersnake) has a high market value for export as a food item and for crocodile farming. Their population is monitored through catch observation similar to fish. Water snakes can be captured with gillnet of 2.5–3.0 cm mesh size. Some fishers use gillnets solely for capturing water snakes, while others collect them as by-catch of fishing. The best time of the year for capturing this species is in June at any daytime, at the shoreline of the Great Lake, or in channels or natural ponds/pools that are the common habitat of this species.

Tortoises, which are used for traditional medicine and protected under national law, are captured by Lorp tul, a cylindrical bamboo trap measuring 1.25 × 0.8 m. The trap is operated at each end of a bamboo fence (Pruol), which guides tortoises into the traps. These traps are set in shrubland and the best time for capture is around January–March. According to local fishers, two species of tortoise, namely Asian box turtle (*Cuora amboinensis*) and Malayan snail-eating turtle (*Malayemys subtrijuga)* are caught by this method. Using the catch record can do monitoring.

Transect Count of Tortoises by Breath Detection and Nest Count

Tortoises are harvested by fishers in BTC, especially northeast of Pov Veuy village at the border of Kampong Thom and Siem Reap provinces. Local fishers suggested two methods to detect tortoise: transect detection of breath, and nest count. Local people detect tortoises by observing its breath as indicated by bubbles. This method can be used to catch the tortoises or to identify that tortoises are in a specific location. The count of nests depends on local fishers' knowledge of tortoise habitat and place to reproduce. For monitoring purposes, the number of eggs can be established by community count. In the BTC study site, an elevated location about 200 m downstream away from Pov Veuy village center (also a Buddhist temple) on Stuong River called "Toul Khmoach (ghost island)" is a good habitat for tortoises (Fig. 1).

Field Observation of Python

There are two local techniques to detect the presence of python in a specific location, or even to catch it. The first method is to infer the presence of a snake from monkeys calling (Kress, Kress!!!) over a bush where a python may be hidden. The second method is by observing pelicans, warblers (local name Chap) (*Acrocephalus* spp., *Locustella lanceolta*), striatted grassbirds (*Megalurus palustris*) and white-breasted water hen (*Amaurormis phoenicurus*) flying around and calling over a bush or location where a python is likely to stay. When the number of birds increases, fishers take this as a sure sign that a python is there. Calls differ according to bird species.

Local Monitoring Methods for Mammals

Field Observation and Diary

There are not many mammalian species in the study site, except macaque, langur and otters. Most of the area is covered by flooded forest which is not a favourable habitat for mammals. Commonly used methods to detect mammal species are field observation and diary. Otter is monitored along the Stuong River (Fig. 1) at Pov Veuy village by observing its waste (excreta or stool). To detect relative abundance of macaque and langur one can observe its population when they are feeding on trees along the shoreline of channels, rivers and ponds during the dry season. In the wet season, both species prefer to stay on big trees that are above the flood level, for security and for obtaining food. Fishers record the number of individuals while fishing and note it down in their diary.

Boat Transect for Long-tailed Macaque and Silvered Langur

These two species can be observed while quietly rowing a boat to fishing grounds particularly in September when the flood water level is at its highest at any daytime in places with high trees along the shore. Local fishers reported that these two species have become rare largely due to illegal hunting for commercial purposes. During April to May, these two species can be observed in the morning and late afternoon, particularly in flooded forest on the shoreline of the Great Lake and along channels at Balot village.

Capture of Otter by Trap

The number of otter can be monitored by the trap catch record method. The trap is made of bamboo or an iron frame with nylon net. The trap is placed on dead tree stumps where otters sleep and defecate. Dead fish is placed as bait inside a trap covered completely by tree leaves. The method is used for both hunting and monitoring and is frequently conducted in September at the flooded forest area around Pov Veuy village of BTC.

Local Monitoring Methods for Vegetation

The flooded forest vegetation in Tonle Sap Great Lake is classified into three types: gallery forest, shrubland and aquatic herbaceous plants (McDonald and others 1997).

Gallery forest type grows naturally on the lake shoreline, and on creek levees and river embankments. It generally consists of tall trees in various strata ranging from 7 to 15 m height and sometimes attaining over 1 m diameter at breast height (dbh). The dominant tree species are *Barringtonia acutangula* (local name Riang touch, Riang thom) and to a lesser extent *Xanthophyllum glaucum* (Taseng).

Shrub vegetation consists of semi-continuous, locally homogeneous stands of short trees and cover about 80 % of flooded forest in the Tonle Sap Great Lake. This type of vegetation is found in the backswamp areas behind the gallery forest and is dominated by extensive thickets of *Combretum trifoliatum* (Trah), *Brownlowia paludosa* (Ronea), *Ficus heterophulla* (Roleab), *Phragmites karka,* and *Vitex holoadenon,* with heights in excess of not more than 4 m and girth in between 10 and 20 cm. The last type of Tonle Sap floodplain vegetation is aquatic herbaceous vegetation, which includes floating and stationary herbs in open water (1–3 m tall).

Knowledge of local fishers on monitoring vegetation is not as extensive as that on monitoring animals. Fishers reported three methods for monitoring vegetation.

Transect Walk

Fishers commonly walk across shrublands and forests adjacent to their settlements for livelihood purposes (fishing, firewood collection, logging for construction of house and fishing gear). Local fishers are familiar with their environment for generations and able to identify the plant species, which they use for food as well as for construction materials for buildings and for fishing gear. The dry season (March–April) is the best time to conduct a transect walk across any location of flooded forest. Fishers identify plant species according to their local names along a transect line taking into account temporal and spatial variation. In addition to the identification and recording of plant species, the area of forest destroyed by fire is estimated. It is common in the area to use fire for the hunting of tortoises, snakes, and long-tailed macaques.

Positional Photography

This monitoring method is not like most of the others based on indigenous knowledge and traditional tools. However, during focus group discussions, local fishers reported that they take pictures of the forest area with cameras provided to each community by the Tonle Sap Sustainable Livelihood Project. The pictures are used for visual assessment of change of forest over the years such as the spread of invasive species like *Mimosa pigra*.

Discussion and Comparative Analysis of Local Monitoring Methods

Following the identification and description of local monitoring methods, we assessed and evaluated these methods comparatively according to criteria stated in Table 1. The comparative assessment is presented in Table 2. The assessment is meant to evaluate the local methods that have been practiced by communities in BTC assuming that these represent the practices of fishers all over Tonle Sap Lake.

Methodology Rigor

Many local methods for monitoring of fish have high methodology rigor. The fish catch method has high methodology rigor as fish catch is recorded daily and can thus provide a reliable trend of fishery resources. The data from the count by boat transect has high methodology rigor as it can help to estimate the species abundance and annual production. Breath detection of fish through observation of bubbles has medium methodology rigor as it cannot provide the precise estimate of population numbers. Transect estimation by the paddle, on the other hand, has a high methodology rigor as this method, when employed by an experienced and skillful observer, can estimate the number of species more precisely.

Three monitoring methods are used for birds, two of them with high methodology rigor. The nest count method can provide an accurate estimate of bird numbers and can also detect the trend of populations when practiced over time. Counting the number of birds or flocks during foraging by transect walk or boat transect has only medium methodology rigor as it cannot provide the exact estimate for the number of the birds. However, it can help to understand any change in the population as a whole. To measure an area where the bird species feed can give a more precise estimate of the number of birds and thus has high methodology rigor.

Three methods were used for monitoring reptile species. As in the case of fish species, the catch method has high methodology rigor. The transect method of breath detection and nest count of tortoises can also provide a good estimate of the number of tortoises and has high methodology rigor, as tortoises are large and therefore relatively easy to see and identify when compared with fish. The field observation method for python based on monkey call and bird flight cannot give a correct estimate of the number of python as it is a proxy indicator, and therefore has only medium methodology rigor.

Table 2 Comparison of local monitoring methods being practiced in Boeng Tonle Chhmar and Tonle Sap Lake, Cambodia

Types of monitoring methods	Methodology rigor	Perceived financial cost	Ease of use	Compatibility with existing activities	Effectiveness of intervention
Methods for fish					
Fish catch	***	**	**	*	***
Transect count: snakehead fingerling population	***	**	***	***	**
Observation of breath	**	**	***	***	**
Transect estimation by paddle	***	**	**	***	***
Methods for bird					
Nest count	***	**	***	**	***
Transect count (flock of bird species during feeding)	**	**	**	***	***
Measurement of an area where birds feed	***	**	**	*	***
Methods for reptile					
Catch	***	***	**	***	***
Transect count by breath and nest (lay eggs): tortoise	***	**	**	***	***
Field observation for python (by macaque or langur call and bird Pelican fly)	**	*	***	***	*
Methods for mammal					
Boat transect: for long tailed macaque and silvered langur	***	**	***	***	***
Capture by trap (Angkup for otter)	**	***	***	***	**
Methods for vegetation					
Transect walk: to observe status of vegetation	***	**	**	***	***
Positional photography	***	***	**	*	***

*** High, ** Medium, * Low

The monitoring method by boat transect for the long-tailed macaque and silvered langur can provide a good estimate of the number of these two species. This method was therefore assessed to be of high methodology rigor. The capture by trap method can provide an estimate of the number of otter but not a complete count. This method was therefore assessed to be of medium methodology rigor. Monitoring of vegetation by identifying and recording species and by estimating forest destruction has high methodology rigor. The positional photography method can provide a precise estimate and thus has also high methodology rigor.

Perceived Financial Cost

The perceived financial cost for monitoring fish was assessed at medium level. The cost involved in the fish catch method relates to the preparation of catch record sheets by experts, training the fishers to record their daily catch data, and analysis of the record by experts. As there is no direct cost for the time involvement of fishers, this method has medium level of cost. In transect count the associated cost includes the operational cost of the boat and food for the fishers involved. It is therefore assessed to be at medium level. The other two methods: observation of breath and transect estimation by paddle do not require any extra investment and are thus assessed at medium cost level.

Monitoring of birds is a voluntary activity which is done without sophisticated equipment. The cost involved in the net count method is mainly for food and record sheets and is assessed at medium level. The transect count includes operational cost for boat and is also assessed at medium level. Identification and measurement of places where birds feed has also been assessed at medium level of perceived associated cost.

The catch method to monitor water snake and tortoise species requires the use of gillnet and cylindrical bamboo trap. Because of these equipments and other additional expenses, this method requires high cost. The transect survey to observe the breath of tortoises requires only the operational cost for the boat and has been assessed at medium cost level. The field observation for the python has been assessed at low level of cost, as it is carried out along with other livelihood activities.

The perceived cost of boat transects for monitoring of long-tailed macaque and silvered langur is at medium level because of the operational cost for the boat. The capture of

otter by trap method needs high cost as fishers need additional operational cost for trap and boat. Vegetation monitoring by transect walk has been assessed at medium level of cost, while positional photography requires the use of a costly camera and was thus assessed at high level of cost.

Ease of Use (User Friendliness)

From among the local fish monitoring methods, the fish catch and transect estimation by paddle was ranked as medium ease to use. The fish catch requires developing the catch record sheet by the expert, training of fishers to record the daily catch data, and finally the analytical skill of experts to interpret the data. In case of transect estimation by paddle it requires the construction of a paddle with specific dimensions, and also the proper skill to operate the paddle. The two other methods were ranked as highly easy to use: the transect count to estimate snakehead fingerling population and observation of breath.

In case of monitoring methods for birds, the nest count method was ranked to be of high ease of use. However, the other two methods: transect count and measurement of the area where birds feed—are ranked to be of medium ease of use. In order to use the measurement method one should know the area and carry out measurement in different time periods.

The catch method to monitor water snake and tortoise species has been ranked to be of medium ease of use because the use of gillnet of different mesh size and cylindrical bamboo trap requires proper skill. The transect detection of breath and count of tortoise nests also needs proper skill and is therefore considered to be of medium ease to use. Field observation of python based on monkey call and bird flight can be done easily by any fisher and is thus ranked to be of high ease to use.

The monitoring methods for mammals—boat transect for monitoring long-tailed macaque and silvered langur, and capture of otter by trap—are easy to use as the specific habitats of these species are well-known to fishers.

The transect walk to observe the status of vegetation has been ranked as medium ease to use. This method needs the prior knowledge of plant species so that monitors can keep proper record during transect walk. In the case of positional photography, skills are needed to handle the camera and visually assess the change of forest year by year. Thus this method has also been ranked as medium ease to use.

Compatibility with Existing Activities

Among the fish monitoring methods, transect estimation by paddle method requires to prepare the paddle and skill to use the paddle properly. This method is integrated with local beliefs and was thus assessed as having high compatibility with their existing practices. The methods of transect count of snakehead fingerling population, and observation of breath were assessed to have high compatibility, because these methods have been practiced by local fishers for generations and are associated with their daily livelihood activities. The fish catch method requires the catch record sheet prepared by an outside expert and was thus assessed to be of low compatibility with existing activities.

The nest count method for birds was assessed to be of medium compatibility, as this method requires knowledge of bird species. The count or observation by transect walk or boat can be carried out alongside livelihood activities and requires the knowledge of specific bird species. This method was assessed to be of high compatibility with existing activities of local fishers, who are familiar with most bird species in the localities. The method 'measurement of areas where birds feed' was assessed to be of low compatibility as this method was not common in the past.

The catch method for reptiles was assessed as highly compatible as this method has been practiced by local people for a long time. Similarly, the field observation for python based on monkey call and bird flight is common practice and was therefore assessed as highly compatible. The transect count by breath and nest of tortoises was assessed as highly compatible because of the requirement for local knowledge and skill.

The boat transect for the monitoring of long-tailed macaque and silvered langur, and the capture of otter by trap were assessed to be highly compatible with local practices as fishers capture for food and sale. In the case of vegetation monitoring, the transect walk was assessed to be highly compatible as this method requires local knowledge of plant species. Positional photography, on the other hand, was assessed to be of low compatibility, as it requires sophisticated equipment.

Effectiveness of Intervention

Monitoring fish by the fish catch method is considered as a highly effective intervention. This method can identify the trend of fishery resources and fish biodiversity in any area. The transect count for snakehead fingerling population and the observation of breath methods were rated as having medium effectiveness for intervention. These methods provide the trends for the fisheries species and can be implemented directly by the community members for conservation purpose as mother snakeheads (broodstock) are protected from capture. The transect estimation by paddle is rated as having high effectiveness for intervention.

All the monitoring methods practiced locally for the monitoring of bird species are rated as highly effective for

Table 3 Kinds of monitoring outputs and management interventions from each local monitoring method in Tonle Sap Lake, Cambodia

Local monitoring methods	Examples of monitoring outputs	Management interventions (decision making)
Methods for Fish		
Fish catch	Fishers report low catch of fish, species, small size of fish captured, fishing effort and gear, sale incomes, and location of fishing ground	Increased awareness raising activities among the fishers in all villages, fishers are encouraged to respect fishing regulations on use of gear, non-access to closure area such as conservation zone and fish sanctuary, and species and sizes allowed to catch. Fishing lot owners are requested to allocate more space for community fishing ground. Because of demand and complaint by local fishers, Royal Government of Cambodia has issued the sub-decree to nullify commercial fishing concessions in Tonle Sap Lake (Royal Government of Cambodia 2012).
Transect count: snakehead fingerling population	Monitors record low abundance status, less number of species, and threat to the species with human-made factors	Fishers are encouraged to protect fingerlings by not capturing them as this is against fisheries law and community by-law and regulations. MAFF issued an ordinance (Prakas) to ban capture of fish fingerling and trash fish (Edwards 2008)
Observation of breath/ bubble of fish	Monitors record declining abundance status of fish species, and threat to the species	Similar as above. Proposed to designate strict conservation zone or fish sanctuary like 27 ha conservation zone of Balot Community-Managed Protected Area
Transect estimation by paddle	Fishers assess the stock and estimate catch of particular fish species in a location where they want to obtain fish contract. Report about declining catch in the area	Similar to above
All of above	Management teams of Community Fisheries and Community-Managed Protected Area use the data for various purposes to secure their operations and organization	Combined reports about illegal activities, decline of fisheries, and request to expand fishing ground to relevant government agencies via advocacy techniques. Establish internal rule and regulations for benefit sharing, and conflict resolution among the members. Diversified livelihood options such as green aquaculture, home garden, livestock husbandry with support of NGOs. Prepared appropriate plans for patrol and surveillance
Methods for bird		
Nest count	Monitors record number of bird nests, species, abundance status, habitat and threats	Strengthened awareness raising for community members to take part in conservation and protection, including reminding the ban of hunting birds as stipulated in applicable law. Demarcated the strict protection zone with no access (area closure)
Transect count (flock of bird species during feeding)	Monitors record number of flocks of bird species that are declining	Similar to above
Measurement of an area where birds feed	Monitors record the changes of area and locations where birds are foraging	Similar to above. Set up time slots for fishers to pass by the locations where birds are foraging. Commercial fishing lot owners help protect birds, leaving a certain location for birds to find fishes
Methods for reptile		
Catch	Fishers record varied production of water-snake and tortoise, hunting gear, and threat	Awareness raising, and law enforcement strengthened on use of appropriate gears and hunting target species allowed under the law
Transect count by breath and nest (lay eggs): tortoise	Monitors record changes of catch by species, and threats	Established conservation zone, as this species is not allowed to capture under current law
Field observation for python (by macaque or langur call and bird Pelican fly)	Monitors report the species presence and status, location and habitat, and threat	Awareness raising among the community members and outsiders for protection. Suppressed hunting activities on the spot

Table 3 continued

Local monitoring methods	Examples of monitoring outputs	Management interventions (decision making)
Methods for Mammal		
Boat transect: for long tailed macaque and silvered langur	Monitors record presence of these two species, location and habitat, and hunting incidents	Similar to above. Educated outsiders not to capture, as these species has highly commercial value. If the case is server, reported to rangers or fisheries officers for further action
Capture by trap (Angkup for otter)	Fishers report declining catch of otter, species, hunting gear, location and habitat, and time of hunting	Strengthened awareness raising, designated a certain location of habitat for conservation and protection
Methods for vegetation		
Transect walk: to observe status of vegetation	Fishers report the changed status of aquatic plant, species, use, and destruction and area under threat by fishing, wood fuel collection, fire, agriculture, and resettlement	Increased the awareness raising activities for protection of inundated forest. Increased the activities and area of replanting on area where flooded forest is destructed. Strengthened traditional rule of wood fuel collection by gathering dead wood and/or branches
Positional photography	Monitors record change of forest area, damage, loss of species, conversion to other land use types	Similar to above. Cracked down the claiming forest area for any land use purposes

intervention. Information produced by these methods can be more useful for key decision makers, NGOs and other donors who are capable of appropriate intervention to conserve fish biodiversity in the area. Similar is the case of the monitoring methods for reptiles. The information generated by catch and transect methods can be useful for the concerned stakeholders to implement the conservation activities. However, the field observation method for python cannot produce reliable data and was thus rated as having low effectiveness for intervention.

In the case of mammals, the boat transect for long-tailed macaque and silvered langur was considered to have high effectiveness for intervention as this method can provide reliable information for the trend of these species in the area. However, the capture of otter by trap was rated as having medium effectiveness for intervention because this method cannot provide complete information.

The two monitoring methods used for vegetation monitoring were rated as having high effectiveness for intervention. The transect walk method provides the record of floristic species, and estimation of forest area destroyed by hunting, fishing and fire. This information is very useful to formulate conservation plans in the community, as forest provides important habitat for aquatic life in the lake. The positional photography provides highly reliable visual assessment of change of forest by year and thus can also be very effective in forest conservation.

Conclusion and Recommendations

Monitoring by local communities at BTC involves a complex mix of methods. Methods differ from each other with respect to their main objective, i.e. whether they are applied mainly for monitoring use of biological resources or for monitoring conservation status of biodiversity, and with respect as to whether they are predominantly traditional, relying on local knowledge or utilizing modern techniques and equipment. Some of the traditional techniques have originally been developed for hunting, fishing and other ways of harvesting animals or plants and were later adapted for monitoring. While some methods are capable of producing accurate and reliable estimates, according to informants, others are capable of providing only superficial or cursory information. However, the overall impression is that even within a relatively confined area such as BTC, monitoring is carried out in a piecemeal and apparently haphazard fashion. Maintaining reliable and continuous records over years and exchanging information between communities seem to be particularly weak points of monitoring in this area (Table 3).

The inventory and comparative analysis of monitoring methods in BTC could provide the starting point for developing a more standardized, less fragmented and species-selective, more efficient, and more easily applicable monitoring system. Although this assessment was largely based on the analysis of perceptions by local communities, their evaluation reflected the daily livelihood activities into which monitoring is integrated. Since semi-aquatic ecosystems such as BTC are widespread in Cambodia, the new monitoring system could be applied on a much larger scale than BTC or even Tonle Sap Lake.

For developing such a monitoring system, methods reviewed in this paper can be selected according to how they have been evaluated by local people. Since community-based monitoring depends almost entirely on the willingness of local people to participate in such exercises, evaluation by local people can be a valid guiding principle for selecting monitoring methods.

In spite of the weaknesses and constraints that are inherent even in those methods that have been valued highly by local people, there is a great potential for improvement. This could be accomplished through: (1) standardization of methods with the assistance of experts, including design of data record sheets, enhancement of measurement units of relevant methods, and time interval for monitoring including a more conservation-oriented selection of species to be monitored and a stronger emphasis on monitoring biodiversity rather than biological resources; (2) requirement of producing regular reports on conditions of biodiversity by individual communities as required by current regulations; (3) exchange of data and local methods among and between communities and interested individuals; and (4) coordination and facilitation of appropriate backup support on technical and financial aspects to the community by concerned authorities, especially during the transitional period.

Furthermore, the encouragement of community-based monitoring should be based on existing practices and local context, indigenous ecological knowledge, and take into account the need to mainstream with livelihood activities. It is suggested that coaching and apprenticeship from outsiders in early stage of carrying out monitoring, analysis and interpretation of monitoring data be made available to communities so that regular reports can be produced and the local methods can be sustained over time.

Acknowledgments We acknowledge the funding support from USEPAM/DANIDA. We are also grateful; to Mekong Program on Water, Environment and Resilience (M-POWER) for an additional grant to support the field work; to Dr. Rajendra Shrestha and Prof. Henning Schroll for giving continuous advice while writing this paper; and to Dr. Ram Baskakoti, Dr. Richard Friend, Dr. Robert Arthur (World Fish Centre), and Dr. Robert Steinmetz (biologist of WWF Thailand) for providing valuable comments on the research methodology. Special thanks go to local community people in the study site, rangers, fishery officers and relevant stakeholders who have provided information and facilitation process during the field-work. We thank three anonymous peer-reviewers for giving excellent and concise comments to make this paper publishable.

References

Alzinga CL, Salzer DW, Willoughby JW, Gibbs JP (2001) Monitoring plant and animal populations. Blackwell Science, Inc., Malden

Bani L, Massimino D, Bottoni L, Massa R (2006) Multiscale method for selecting indicator species and priority conservation areas: a case study for broadleaved forests in Lombardy, Italy. Conservation Biology 20:512–526

Campbell IC, Poole C, Giesen W, Jorgensen JV (2006) Species diversity and ecology of Tonle Sap Great Lake, Cambodia. Aquatic Science 68:355–373

Danielsen F, Balete DS, Poulsen MK, Enghoff M, Nozawa CM, Jensen AE (2000) A simple system for monitoring biodiversity in protected areas of a developing country. Biodiversity and Conservation 9:1671–1705

Danielsen F, Mendoza MM, Alviola P, Balete DS, Enghoff M, Poulsen MK, Jensen AE (2003) Biodiversity monitoring in developing countries: what are we trying to achieve? Oryx 37:1–3

Danielsen F, Burgess ND, Balmford A (2005a) Monitoring matters: examining the potential of locally-based approaches. Biodiversity and Conservation 14:2507–2542

Danielsen F, Jensen AE, Alviola PA, Balete DS, Mendoza M, Tagtag A (2005b) Does monitoring matter? A quantitative assessment of management decisions from locally-based monitoring of protected areas. Biodiversity and Conservation 14:2633–2652

Danielsen F, Burgess ND, Balmford A, Donald PF, Funder M, Jones JPG, Alviola P, Balete DS, Blomley T, Brashares J, Child B, Enghoff M, Fjeldsa J, Holt S, Hubertz H, Jensen AE, Jensen PM, Massao J, Mendoza MM, Ngaga Y, Poulsen MK, Rueda R, Sam M, Skielboe T, Stuart-Hill G, Topp-Jørgensen E, Yonten D (2008) Local participation in natural resource monitoring: a characterization of approaches. Conservation Biology 23(1):31–42

Danielsen F, Burgess ND, Jensen PM, Pirhofer-Walzl K (2010) Environmental monitoring: the scale and speed of implementation varies according to the degree of people's involvement. Journal of Applied Ecology 47:1166–1168

Edwards P (2008) Cambodian Government ban on snakehead farming enforced. Aquaculture Asia Magazine 13(1):40–44

Feinsinger P (2001) Designing field studies for biodiversity conservation. Island Press, Washington

Gaidet N, Fritz H, Nyahuma C (2003) A participatory counting method to monitor populations of large mammals in non-protected areas: a case study of bicycle counts in the Zambezi Valley, Zimbabwe. Biodiversity and Conservation 12:1571–1585

Gaidet-Drapier N, Fritz H, Bourgarel M, Renaud PC, Poilecot P, Chardonnet (2006) Cost and efficiency of large mammal census techniques: comparison of methods for a participatory approach in a communal area, Zimbabwe. Biodiversity and Conservation 15:735–754

Gilchrist G, Mallory M, Merkel F (2005) Can local ecological knowledge contribute to wildlife management? Case study of migratory birds. Ecology and Society 10(1):1–12

Gray M, Kalpers J (2005) Ranger based monitoring in the Virunga–Bwindi region of East-Central Africa: a simple data collection tool for park management. Biodiversity and Conservation 14:2723–2741

Gray TNE, Hong C, Ro B, Collar NJ, Dolman PM (2007) Habitat preferences of a globally threatened bustard provide support for community-based conservation in Cambodia. Biological Conservation 138:341–350

Hartanto H, Lorenzo CMB, Frio AL (2002) Collective action and learning in developing a local monitoring system. International Forest Review 4(3):184–195

Joseph LN, Field SA, Wilcox C, Possingham HP (2006) Presence–absence versus abundance data for monitoring threatened species. Conservation Biology 20:1679–1687

Katzner T, Milner-Gulland EJ, Bragin E (2007) Using modelling to improve monitoring of structured populations: are we collecting the right data? Conservation Biology 21:241–252

Kéry M, Schmidt H (2004) Monitoring programs need to take into account imperfect species detectability. Basic and Applied Ecology 5:65–73

Lamberts D (2001) Tonle Sap fisheries: a case study on floodplain gillnet fisheries in Siem Reap, Cambodia. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand. RAP Publication 2001/11

Lamberts D (2006) The Tonle Sap Lake as a productive ecosystem. Water Resources Development 22:481–495

Lawrence A, Paudel K (2006) Adaptive value of participatory biodiversity monitoring in community forestry. Environmental Conservation 33:325–334

Lim S, Sour V, Sirita U (2004) The Mimosa pigra report: Issue paper No. 1, State of Environment Report. National Capacity Development Project, Royal Government of Cambodia. Phnom Penh, Cambodia

Lindenmayer DB, Likens GE (2010) The science and application of ecological monitoring. Biological Conservation 143:1317–1328

Margoluis R, Salafsky N (1998) Measures of success: designing, managing, and monitoring conservation and development project. Island Press, Washington, p 362

Matsui S, Kesinen M, Pech S, Nakamura M (2005) Tonle Sap: experience and lessons learned brief. http://www.iwlearn.net/publications/ll/laketonlesap_2005.pdf. Accessed 31 July 2009

McDonald A, Pech B, Phauk V, Leev B (1997) Plant communities of the Tonle Sap flood plain. Contribution to the nomination of the Tonle Sap as Biosphere Reserve for UNESCO's "Man in the biosphere program". UNESCO, Phnom Penh, Cambodia

McGeoch MA, Chown SL, Kalwij J (2006) A global indicator for biodiversity invasion. Conservation Biology 20:1635–1646

MOE [Ministry of Environment] (2008) Law on protected area management. Phnom Penh, Cambodia

MOE, DoF [Department of Fisheries], Wetlands International (2002) Management plan for the Boeng Chhmar Ramsar Site in Cambodia. Final draft, Phnom Penh, Cambodia

Mortensen LO, Jensen MB (2012) Methods in sustainable monitoring: plot sampling versus interviews. Biodiversity and Conservation 21:145–153

Neou B, Lane BD (2002) Natural resources management for human security in Cambodia's Tonle Sap biosphere reserve. Environmental Science and Policy 5:33–41

NORDECO [Nordic Agency for Development and Ecology], DENR [Department of Environment and Natural Resources] (2001) Biodiversity monitoring system manual for protected areas, 2nd edn. DENR, Minila, and NORDECO, Copenhagen

Noss AJ, Oetting I, Cuellar RL (2005) Hunter self-monitoring by the Isoseno-Guaran in the Bolivian Chaco. Biodiversity and Conservation 14:2679–2693

Obura DO, Wells S, Church J, Horrill C (2002) Monitoring of fish and fish catches by local fishers in Kenya and Tanzania. Marine and Freshwater Research 53:215–222

Oldekop JA, Bebbington AJ, Berdel F, Truelove NK, Wiersberg T, Preziosi RF (2011) Testing the accuracy of non-experts in biodiversity monitoring exercises using fern species richness in the Ecuadorian Amazon. Biodiversity and Conservation 20: 2615–2626

Rijsoort JV, Jinfeng Z (2005) Participatory resource monitoring as a means for promoting social change in Yunnan, China. Biodiversity and Conservation 14:2543–2573

Royal Government of Cambodia (RGC) (2012) Sub-decree 37 dated March 7, 2012 on cancelation of commercial fishing concession in Tonle Sap Lake. Phnom Penh, Cambodia

Seak S, Schmidt-Vogt D, Thapa GB (2011) A comparison between biodiversity monitoring systems to improve natural resource management in Tonle Sap Biosphere Reserve, Cambodia. International Journal of Biodiversity Science, Ecosystem Services & Management 7(4):258–272

Sekercioglu CH (2011) Promoting community-based bird monitoring in the tropics: conservation, research, environmental education, capacity-building, and local incomes. Biological Conservation. doi:10.1016/j.biocon2011.10.024

Steinmetz R (2000) Ecological surveys, monitoring and the involvement of local people in protected areas of Lao P.D.R. Evaluating Eden Series, Discussion paper No 13. IIED

Steinmetz R, Chutipong W, Seuaturien N (2006) Collaborating to conserve large mammals in Southeast Asia. Conservation Biology 20(5):1391–1401

Stork NE, Samways MJ, Eeley HAC (1996) Inventorying and monitoring biodiversity. Trends in Ecology and Evolution 11:39–40

Sutherland W (1996) In: Sutherland WJ (ed) Ecological census techniques: a handbook. Cambridge University Press, Cambridge

Teder T, Moora M, Roosaluste E, Zobel K, Pärtel M, Kõljalg U (2006) Monitoring of biological diversity: a common-ground approach. Conservation Biology 21:313–317

Uychiaoco AJ, Arceo1 HO, Green SJ, Cruz MTDL, Gaite PA, Alino PM (2005) Monitoring and evaluation of reef protected areas by local fishers in the Philippines: tightening the adaptive management cycle. Biodiversity and Conservation 14:2775–2794

Van Zalinge N (2002) Update on the status of the Cambodian inland capture fisheries sector with special reference to the Tonle Sap Great Lake. Catch and Culture 8:1–5

Vreugdenhil D, Terborgh J, Cleef AM, Sinitsyn M, Boere GD, Archaga VL (2003) Comprehensive protected areas system composition and monitoring. WICE, Shepherdstown

Yoccoz NG, Nichols JD, Boulinier T (2003) Monitoring of biological diversity—a response to Danielsen et al. Oryx 37:410