1

Camera trapping for animal monitoring and management: a review of applications

Don E. Swann and Nic Perkins

Abstract

Camera traps are being used throughout the world to address a wide range of issues in wildlife management and to address both research and management questions that cannot be easily answered with other methods. In addition to detecting rare species and providing answers to practical management questions, camera traps have a potentially large role in assessing global changes in biodiversity of mammals. The quality of camera traps is continuing to improve, and field and analytical techniques are also moving rapidly forward. This paper reviews the current state of camera trapping in wildlife ecology with a focus on new and emerging applications in management and monitoring. Recent papers, including many in this volume, indicate that camera traps have the potential to be a powerful new tool in areas of animal ecology where they have not previously been widely used, such as estimation abundance, sampling of small animals, and establishing conservation priorities based on regional monitoring. In addition, the use of camera traps by citizen scientists and environmental educators continues to grow and become more integrated with more traditional scientific studies.

Introduction

Cameras that record images of wild animals when humans are not present have a long history in ecology, but their use dramatically increased with the introduction of commercial infrared-triggered cameras in the early 1990s. Today, the term 'camera trap' typically refers to cameras units that are triggered by the movement of an animal within a detection area, although the term also can describe cameras set to take photos at set time intervals. Nearly all camera traps used in current wildlife applications are small (the size of a shoebox or smaller), consist of only one piece, shoot digital still or video images, and are passively triggered using an infrared light source. Nevertheless, a dazzling array of commercial camera traps and optional features are available (Rovero *et al*. 2013; Swann *et al*. 2004, 2011; <http://www.trailcampro.com>), and these can be further modified by researchers.

Camera traps have been applied to nearly every aspect of vertebrate ecology, including to study nest ecology, research activity patterns and behaviour, document rare species or events, and estimate state variables such as species richness, occupancy, abundance (Cutler and Swann 1999; Kucera and Barrett 2011). Data recorded by camera traps typically consist of an image (e.g. Plate 1.1), series of images, or video of an individual or group of animals within the area of detection covered by the camera trap, as well as other information such as the date, time, and location of the photograph. Because most individuals in the image can be identified to species, the trap thus records the presence of that species at that place and time. Other information, such as behavioural data (e.g. Meek *et al*. 2012) or events such as predation or feeding (e.g. Zimmerman *et al*. 2011) can also be recorded. In some cases individual animals can be identified either through tags previously affixed by researchers or by unique natural marks. Some data gathered by physical trapping techniques, such as reproductive condition and genetic data, cannot usually be obtained by camera traps, but camera trap data are often combined with other techniques such as radio-telemetry (e.g. Larrucea *et al*. 2007) and genetics (e.g. Janečka *et al.* 2011).

Despite the limits of the data that can be gathered by camera traps, experience during the past two decades indicates why they are powerful tools for addressing conservation of populations of native species, especially mammals. First, camera traps provide basic knowledge of the distribution of mammals (their presence in a certain place), which is essential for conservation on both the local and regional scale, but often previously lacking for the many species that are nocturnal, avoid humans, and seek cover. Second, they are relatively inexpensive, which means they can be deployed very efficiently to increase sample sizes over wide areas (De Bondi *et al*. 2010). And third, camera traps are relatively non-invasive and safe for both humans and animals. From a practical point of view, it is obviously much easier to sample populations of very large mammals with camera traps than with live traps.

As a result, camera trapping has been truly significant for wildlife management and conservation throughout the world. Camera traps have documented species that are new to science, or occur in areas where they were thought to be locally extinct or not previously known to exist (e.g. Sangay *et al*., Chapter 10). Kucera and Barrett (2011) list several recent examples, including a new species of striped rabbit (*Nesolagus timminsi*) in South-east Asia (Surridge *et al*. 1999), a range extension for the Sulawesi palm civet (*Macrogalidia musschenbroekii*) (Lee *et al*. 2003) and the documentation of the wolverine (*Gulo gulo*) in California for the first time since 1922 (Moriarty *et al.* 2009). Camera traps also have been used to reliably estimate, for the first time, the abundance of the tiger (*Panthera tigris*; Karanth and Nichols 1998) and other species where individuals can be readily recognised based on their spot pattern. After many years of debate and poor information on the number of species of mammals present in natural areas, camera traps are now producing reliable estimates of species richness and other community measures (Tobler *et al*. 2008; O'Brien *et al*. 2011) that are not based on poor-quality observational data or generalised range maps (e.g. Newmark 1995; Parks and Harcourt 2002).

As demonstrated at the First International Camera Trapping Colloquium in Wildlife Management and Research, new developments in camera trapping are arriving at a staggering pace. Camera traps themselves are rapidly evolving, becoming faster, cheaper, more resilient, and more versatile (Meek 2011). Researchers are developing new techniques for deploying them, including using vertical mounts (Swann *et al*. 2004; Welbourne, Chapter 20). More researchers are aware that detectability is always < 1 in camera studies (Kéry 2011) and are becoming more adept and sophisticated at analysing camera trap data using occupancy and other methods (O'Connell and Bailey 2011). They are rapidly improving methods for managing data, including extracting data directly from photos, eliminating the need for data entry, and even developing methods for using pattern recognition to identify animals automatically (Falzon *et al*., Chapter 28). And of course, they are improving methods for sharing data through the internet and cell phone applications.

What is truly exciting about camera trapping in the modern era is that the explosive adoption of this technology, in synergy with improvements in camera trap quality, wildlife data analysis, and information management, is resulting in novel applications in wildlife conservation around the world. It is a testament to the rapid advances in camera trapping that several important developments in camera trapping have occurred since the very recent publication of a major book on the subject, *Camera Traps in Animal Ecology* (O'Connell and Bailey 2011). The goal of this paper is to provide a short summary of some of these applications and explore their potential for creating ground-breaking developments in the coming years.

Estimating animal abundance and density

Camera traps are often used to provide an index of abundance (also called relative abundance), such as the number of photos of a species per trap night. However, indices typically provide biased estimates of abundance (Anderson 2001), which in camera trapping is primarily due to spatial variability and detectability (O'Brien 2011). Many users of camera traps assume that the number of photographs per unit time is an accurate reflection of the number of individual animals present. However, this assumption may not be valid because many factors may influence the number of photographs, including attraction to the camera trap, trap shyness, use of or type of attractant, weather, ability of the camera trap to detect an animal when present, and others. Several recent studies (see Karanth *et al*. 2011) have followed Karanth (1995), who used camera traps and individual natural markings to estimate tiger abundance and density using capture–recapture models. However, this approach does not work for species without features that allow them to be individually recognised. The recent work by Marcus Rowcliffe and colleaques (Rowcliffe *et al*. 2008, 2011) is thus truly important for camera trap researchers, as it presents an opportunity to estimate density by modelling the underlying process of the encounter between the camera trap and the animal. Their random encounter model (REM) relies on characteristics of the camera trap (the distance and angle with which it detects animals) and the characteristics of animals that can be determined from videos taken at the camera sites, including its size and speed.

One of the complications of using the REM has to do with the difficulty of accurately estimating the area of the detection zone. Although this problem has been addressed using distance sampling techniques by Rowcliffe *et al*. (2011), papers presented in this volume (e.g. Welbourne, Chapter 20) suggest that another approach may be to mount cameras vertically (facing down at the ground), so as to more precisely control the area of detection. This approach may not be appropriate for larger animals in tropical areas where a large amount of vegetation is present, but might work in less vegetated areas and for smaller mammals in most habitats.

Studying small animals

Another interesting new direction for camera trapping is in studies of smaller animals, including mammals such as insectivores, rodents, and small marsupials, as well as birds and herpetofauna (e.g. Welbourne, Chapter 20). Camera traps have been used in small mammal research for some time, but typically to determine temporal patterns (e.g. Pearson 1959). Recent work on small mammals with more accurate new commercial traps, particularly in Australia with Reconyx™ brand traps that pick up smaller heat signatures (e.g. Meek *et al.* 2012; Weerakoon *et al*., Chapter 29), allow researchers to estimate variables such as abundance (where individual animals are marked or have identifiable patterns), species richness, and occupancy that previously required the use of live traps. The work by Rowcliffe *et al*. (2008, 2011) applies to estimating density of small mammal abundance, which has the potential to replace live trapping for many studies, especially if combined with vertical camera mounts on a network grid of small mammal sensors at random locations with no bait. A paper presented at the First International Camera Trapping Colloquium in Wildlife Management and Research by Falzon *et al*. (Chapter 28) presented a method for automated species identification that allows for removal of the consistent background image in photos and use of visual algorithms to identify individual species. Although this approach is still in early stages of development, it is expected to grow and have important implications for monitoring not only abundance and density using the REM, but also species richness and occupancy. Further, because infrared triggered cameras may always have imperfect detectability, it seems conceivable that in the future constant photo or video surveillance of a series of unbaited, random plots would produce the potential for higher detection rates and very accurate estimation of small mammal populations, as well as populations of herpetofauna and ground birds.

Finally, camera traps have typically been used in studies of mammals and birds, and only occasionally used in studies of reptiles and amphibians. Dustin Welbourne's presentation at the Colloquium (Welbourne, Chapter 20) is interesting not only because it focuses on herpetofauna, but is potentially ground-breaking in its approach to inventory and monitoring of this taxonomic group. Even more than small mammals, reptiles and amphibians are very difficult to detect due to their small size and (as ectotherms) lack of a heat signature. Many species are rare, cryptic, and active only during specific windows of heat and humidity. Herpetologists have traditionally used a variety of methods to estimate population parameters, including observations and times searches (Visual Encounter Surveys, or VES), pitfall traps, hoop traps, and other methods. Welbourne's work suggests that a more efficient and less invasive approach may be to use camera traps, mounted vertically over plates that can be naturally warmed to a different temperature than the surrounding substrate, in conjunction with drift fences. It remains to be seen whether this technique can be modified to sample the range of terrestrial reptiles and amphibians with different types of movement and habitat use (e.g. sand-dwelling, rock-dwelling, aquatic and aboreal). In addition, it may be possible to eliminate drift fences if capture rates are high enough. As with small mammals, this technique can further developed with the use of species recognition software and non-infrared triggered cameras that run continuously.

Applied management

While large conservation issues, such as preserving the biological diversity of our planet, require a large scale vision (Wilson and Peter 1988), most actual conservation happens locally. Every day, throughout the world, wildlife managers strive to reduce the impacts of introduced predators, develop structures to prevent threatened species from being killed by cars, create artificial water resources to replace lost natural sources, build gates on caves to protect bats, and engage in many other types of hands-on conservation efforts.

The basic type of data collected by camera traps – the image or images of an animal in a certain place at a certain time – has been very useful for addressing local wildlife management questions for some time, and continues to be very useful. Recent published papers around the world expand the uses of camera traps to topics as diverse as assessing the value of artificial water sources (Krausman *et al.* 2006); comparing different types of forestry practices on mammal communities (Samejima *et al.* 2012); assessing effects of human presence on large carnivore populations (Muhly *et al.* 2011); assessing effects of predator control on prey species populations (Salo *et al.* 2010); evaluating the potential for expansion of the wild boar population in Switzerland (Wu *et al.* 2011); and many others. Case studies at the colloquium that used camera traps for applied management applications included addressing the effectiveness of different types of baits for decreasing introduced carnivores while preserving native species (Antos and Yuen, Chapter 2; Moseby and Read, Chapter 14; Bengsen, Chapter 31); quantifying the use of water holes by introduced camels and their interactions with water availability and native animals (Ninti One Ltd 2013); whether and how native mammals use glide poles and other structures to successfully cross roadways (Taylor and Goldingay, Chapter 22); and identifying the predators of the New Zealand kea

(*Nestor notabilis*, B. Barrett pers. comm.). In addition, camera traps are being used in some truly innovative management applications, such as to identify Tasmanian devils (*Sarcophilus harrisii*) with devil facial tumour disease and track the spread of this disease (Thalmann *et al*., Chapter 3).

The main trend in using camera traps in applied management studies is that camera traps are rapidly becoming more affordable and reliable. Many wildlife managers, especially in developing countries, have lacked effective methods for determining whether their conservation actions are indeed effective. The potential for obtaining larger numbers of camera traps make it easier not only to capture data that may provide insight into a particular management issue, but also to implement studies with a higher sample size, thus providing results that allow for greater inference.

Monitoring of animal communities at local, regional and international scales

Knowledge of the number of species occurring in a particular place, either locally as in a national park, or regionally or even globally, is essential for managing and conserving biodiversity, but the poor state of this knowledge remains one of the greatest hindrances to conservation (O'Brien *et al*. 2011). Because funding for conserving biodiversity are always less than what is needed, establishing conservation priorities is one of the most vexing problems in conservation biology (Isaac *et al*. 2007). Three-quarters of all species-based conservation projects are specifically aimed at charismatic megafauna (Leader-Williams and Dublin 2000). While part of the problem is the nature of the public's attention, the lack of information on many species is also an issue.

There are many challenges to tracking of the status of different taxonomic groups, ranging from the sheer number of species to the complexities of their life cycles. The challenge of monitoring animals typically detected by camera traps, particularly medium and large mammals, is that they are often rare, nocturnal, and avoid humans. However, camera traps have proven to be very useful in overcoming these issues. Thus the greatest current challenge may be to organise researchers to deploy cameras in a systematic way and share the data so the information can be most useful for monitoring trends over time and establishing conservation priorities. Because the focus is on entire communities, such an approach requires a randomised study design with unbaited camera traps. On a local level, an increasing number of such programs in national parks and other reserves are beginning to monitor communities in this way.

Even more exciting is the development of programs that monitor the status of communities on larger geographic scales. A primary example of this is the Terrestrial Ecology Assessment and Monitoring (TEAM) network (Ahumada *et al*. 2011; Jansen *et al*., Chapter 24), which, in an international partnership at 16 sites across the globe, collects data useful for conservation of tropical forest mammals. TEAM has developed a detailed, standard protocol and data storage and sharing methods that allow for comparisons of species richness, diversity, and evenness among sites. In addition, programs like the Wildlife Picture Index (WPI) (O'Brien *et al*. 2010; Townsend *et al*., Chapter 5) combine camera traps with occupancy analysis and generalised additive models to allow conservationists to monitor trends in biodiversity over time. The success of approaches such as TEAM and WPI suggest that similar standardised approaches can accomplish important conservation work across a variety of regional and national scales, and deserve to be implemented more widely.

Citizen science and education

Two final developments in applications of camera traps in monitoring and management are the growing use of camera traps in education and the establishment of citizen science networks that involve non-scientists in collecting important scientific data (e.g. Griffiths and Lewis, Chapter 9; Thomas, Chapter 8 volume). There is considerable overlap between these two areas. In a recent major event at Saguaro National Park in Arizona, the 2011 BioBlitz, students learned to use and deploy camera traps in

Fig. 1.1. Camera trapping as education: students at Saguaro National Park, USA, set a camera trap as part of 2011 BioBlitz.

an effort to both document mammals and learn more about their habits and conservation needs, and the park posted most of the photos gathered during and after the event (Fig. 1.1 and Plate 1.2; <http://saguwildcams.shutterfly.com>). Photos from camera traps are being used the world over to excite people about the wildlife around them that usually remains unseen. These images are often quite powerful and have great potential for promoting conservation among citizens who might otherwise not be interested.

The primary user of camera traps in many countries, and particularly the United States, is by hunters. In the USA, the value of hunter-collected data in the documentation of rare and threatened cannot be underestimated. Where we live in Arizona, USA, for example, camera traps set by hunters have provided some of the best recent records of rare tropical cats such as jaguars and ocelots. Networks of camera traps maintained by volunteers are proving to be valuable for conservation in some areas (e.g. Erb *et al*. 2012). The effort to tap into the larger pool of existing camera trap data (which can be easily found by making a Google search of Flickr and camera traps, for example) includes eMammal (<http://www.facebook.com/eMammal>; <http://www.nwf.org/News-and-Magazines/National-Wildlife/Animals/Archives/2012/Camera-Traps-and-Conservation.aspx>), which is being developed as an international archive of wildlife photos by the Smithsonian Institute. At the same time, some caution is in order. Camera traps are a neutral way to detect animals, and can be used just as easily as a tool to detect and kill wildlife as to detect and conserve them. As researchers share information, it is important to recognise that the potential downsides of sharing the secrets of wildlife.

Conclusion

What makes camera trapping unique among the many methods used by wildlife ecologists is that it is, in a sense, both a science and an art. It is a science in that camera traps can produce data that are useful for addressing questions about our world works. But the same process produces images that can be 'appreciated primarily for their beauty or emotional power', which is how the Oxford Dictionary (<http://oxforddictionaries.com/definition/english/art>) defines art. As Dustin Welbourne recently wrote, 'the raw data collected with cameras and recorders can be experienced. It is visceral and tangible to our senses, and even seasoned researchers are often excited to '"see"' what has been detected' (Welbourne 2012b). It is important for scientists and managers that the art function of photos produced by camera traps does not become a substitute for the science function; that is, no matter how excellent and interesting a camera trap images are, they cannot replace the requirement of having clear objectives, strong study design, and efficient and accurate methods for managing photo data.

At the same time, the art value of camera traps has a place in conservation biology that is significant and not likely to go away soon. It is this dynamic between science and art that would seem to ensure that the value and creative uses of camera traps are likely to continue to grow, as today's camera traps merge with newer technologies in ways that may rapidly change the definition of the term. The challenge for conservation biologists is to harness this creativity with sound science in ways that will help the Earth's many magnificent creatures survive until the next generation.

References

Ahumada JA, Silva CEF, Gajapersad K, Hallam C, Hurtado J, Martin E, McWilliam A, Mugerwa B, O'Brien T, Rovero F, Sheil D, Spironello WR, Winarni N, Andelman SJ (2011) Community structure and diversity of tropical forest mammals: data from a global camera trap network. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences* **366**, 2703–2711.

Anderson DR (2001) The need to get the basics right in wildlife field studies. *Wildlife Society Bulletin* **29**, 1294–1297.

Cutler TL, Swann DE (1999) Using remote photography in wildlife ecology: a review. *Wildlife Society Bulletin* **27**, 571–581.

De Bondi N, White JG, Stevens M, Cooke R (2010) A comparison of the effectiveness of camera trapping and live trapping for sampling terrestrial small-mammal communities. *Wildlife Research* **37**(6), 456–465.

Erb PL, McShea WJ, Guralnick RP (2012) Anthropogenic influences on macro-level mammal occupancy in the Appalachian Trail Corridor. *PLoS ONE* **7**(8), e42574.

Isaac NJB, Turvey ST, Collen B, Waterman C, Baillie JEM (2007) Mammals on the EDGE: conservation priorities based on threat and phylogeny *PLoS ONE* **2**(3), e296.

Janečka JE, Munkhtsog B, Jackson RM, Naranbaatar G, Mallon DP, Murphy WJ (2011) Comparison of noninvasive genetic and camera-trapping techniques for surveying snow leopards *Journal of Mammalogy* **92**, 771–783.

Karanth KU (1995) Estimating tiger *Panthera tigris* populations from camera-trap data using capture-recapture models. *Biological Conservation* **71**, 333–338.

Karanth KU, Nichols JD (1998) Estimation of tiger densities in India using photographic captures and recaptures. *Ecology* **79**(8), 2852–2862.

Karanth KU, Nichols JD, Kumar NS (2011) Estimating tiger abundance from camera trap data: field surveys and analytical issues. In AF O'Connell, JD Nichols and KU Karanth (Eds) *Camera Traps in Animal Ecology*. Pp. 97–118. (Springer Publishing, Tokyo).

Kéry M (2011) Species richness and community dynamics: a conceptual framework. In AF O'Connell, JD Nichols and KU Karanth (Eds) *Camera Traps in Animal Ecology*. Pp. 207–232 (Springer Publishing, Tokyo).

Krausman PR, Rosenstock SS, Cain JW, III(2006) Developed waters for wildlife: science, perception values, and controversy. *Wildlife Society Bulletin* **34**, 563–569.

Kucera TE, Barrett RH (2011) A history of camera trapping. In AF O'Connell, JD Nichols and KU Karanth (Eds) *Camera Traps in Animal Ecology*. Pp. 9–26. (Springer Publishing, Tokyo).

Larrucea ES, Brussard PF, Jaeger MM, Barrett RG (2007) Cameras, coyotes, and the assumption of equal detectability. *The Journal of Wildlife Management* **71**, 1682–1689.

Leader-Williams N, Dublin HT (2000) Charismatic megafauna as 'flagship species'. In A Entwistle and N Dunstone (Eds) *Priorities for the Conservation of Mammalian Diversity: Has the Panda had its Day?* Pp. 53–81. (Cambridge University Press Cambridge, England).

Lee RJ, Riley J, Hunowu I, Maneasa E (2003) The Sulawesi palm civet: expanded distribution of a little known endemic viverid. *Oryx* **37**, 378–381.

Meek PD (2011) Refining and improving the use of camera trap technology for wildlife management and research in Australia and New Zealand. Unpublished report to the Winston Churchill Memorial Trust of Australia. <http://www.rewildingfoundation.org/wp-content/uploads/2012/01/Meek-Final-Report-WCMT-2012.pdf>.

Meek PD, Zewe F, Falzon G (2012) Temporal activity patterns of the swamp rat (*Rattus lutreolus*) and other rodents in north-eastern New South Wales, Australia. *Australian Mammalogy* **34**, 223–233.

Muhly TB, Semeniuk C, Massolo A, Hickman L, Musiani M (2011) Human activity helps prey win the predator-prey space race. *PLoS ONE* **6**(3), e17050.

Newmark WD (1995) Extinction of mammal populations in western American national parks. *Conservation Biology* **9**, 512–526.

Ninti One Ltd (2013) *Managing the Impacts of Feral Camels across Remote Australia. Final Report of the Australian Feral Camel Management Project.* (Ninti One Limited, Alice Springs).

O'Brien TG (2011) Abundance, density, and relative abundance: a conceptual framework. In AF O'Connell, JD Nichols and KU Karanth (Eds) *Camera Traps in Animal Ecology.* Pp. 71–96. (Springer Publishing, Tokyo).

O'Brien TG, Baille JE, Cuke M (2010) The wildlife picture index: monitoring top trophic levels. *Animal Conservation* **13**, 335–343.

O'Brien TG, Kinnaird MF, Wibisono HT (2011) Estimation of species richness of large vertebrates using camera traps: an example from an Indonesian rainforest. In AF O'Connell, JD Nichols and KU Karanth (Eds) *Camera Traps in Animal Ecology.* Pp. 233–252. (Springer Publishing, Tokyo).

O'Connell AF, Bailey LL (2011) Inference for occupancy and occupancy dynamics. In AF O'Connell, JD Nichols and KU Karanth (Eds) *Camera Traps in Animal Ecology*. Pp. 191–206. (Springer Publishing, Tokyo).

Parks SA, Harcourt AH (2002) Reserve size, local human density, and mammalian extinctions in U.S. protected areas. *Conservation Biology* **16**, 800–808.

Pearson OP (1959) A traffic survey of *Microtus-Reithrodontomys* runways. *Journal of Mammalogy* **40**, 169–180.

Rovero F, Zimmermann F, Berzi D, Meek P (2013) 'Which camera trap type and how many do I need?' A review of camera features and study designs for a range of wildlife research applications. *Hystrix* 24, 148–156 <http://www.italian-journal-of-mammalogy.it/article/view/6316/pdf>.

Rowcliffe JM, Field J, Turvey ST, Carbone C (2008) Estimating animal density using camera traps without the need for individual recognition. *Journal of Applied Ecology* **45**, 1228–1236.

Rowcliffe JM, Carbone C, Jansen PA, Kays R, Kranstauber B (2011) Quantifying the sensitivity of camera traps: an adapted distance sampling approach. *Methods in Ecology and Evolution* **2**, 464–476.

Salo P, Banks PR, Dickman CR, Korpimäki E (2010) Predator manipulation experiments: impacts on populations of terrestrial vertebrate prey. *Ecological Monographs* **80**, 531–546.

Samejima H, Ong R, Lagan P, Kitayama K (2012) Camera-trapping rates of mammals and birds in a Bornean tropical rainforest under sustainable forest management. *Forest Ecology and Management* **270**, 248–256.

Surridge AK, Timmins RJ, Hewitt GM, Bell DJ (1999) Striped rabbits in Southeast Asia. *Nature* **400**, 726.

Swann DE, Hass CC, Dalton DC, Wolf SA (2004) Infrared-triggered cameras for detecting wildlife: an evaluation and review. *Wildlife Society Bulletin* **32**, 357–365.

Swann DE, Kawanishi K, Palmer J (2011) Evaluating types and features of camera-traps in ecological studies: a guide for researchers. In AF O'Connell, JD Nichols and KU Karanth (Eds) *Camera Traps in Animal Ecology*. Pp. 27–43. (Springer Publishing, Tokyo).

Tobler MW, Carillo-Percastegui SE, Pitman RL, Mares R, Powell G (2008) An evaluation of camera traps for inventorying large- and medium-sized terrestrial rainforest mammals. *Animal Conservation* **11**, 169–178.

Welbourne D (2012b) Ready for my close-up: camera traps bring home the wild. *The Conversation*. <http://theconversation.edu.au/rready-for-my-closeup-camera-traps-bring-home-the-wild-9707>.

Wilson EO, Peter FM (Eds) (1988) *Biodiversity*. (National Academies Press, Washington).

Wu N, Abril C, Hinic V, Brodard I, Thur B, Fattebert J, Hussy D, Ryser-Degiorgis MP (2011) Free-ranging wild boar: a disease threat to domestic pigs in Switzerland? *Journal of Wildlife Diseases* **47**, 868–879.

Zimmerman F, Molinari-Jobin A, Ryser A, Breitenmoser-Wursten Ch, Presenti E, Breitenmoser U (2011) Status and distribution of the lynx (*Lynx lynx*) in the Swiss Alps 2005–2009. *Acta Biologica Slovenica* **54**, 74–84.