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A quick guide to video-tracking birds

Lucas A. Bluff and Christian Rutz*

Department of Zoology, University of Oxford, South Parks Road, Oxford OX1 3PS, UK
**Author for correspondence* (*christian.rutz@zoo.ox.ac.uk*).

Video tracking is a powerful new tool for studying natural undisturbed behaviour in a wide range of birds, mammals and reptiles. Using integrated animal-borne video tags, video footage and positional data are recorded simultaneously from wild free-ranging animals. At the analysis stage, video scenes are linked to radio fixes, yielding an animal's eye view of resource use and social interactions along a known movement trajectory. Here, we provide a brief description of our basic equipment and field techniques to enable other researchers to start their own video-tracking studies.

Keywords:
animal-borne video and environmental data collection system (AVED); biotelemetry; habitat use; home range; New Caledonian crow; very high frequency (VHF) wildlife radio tracking

1. INTRODUCTION

Video cameras are now small enough to deploy onboard many terrestrial species, permitting an animal's eye view of the environment (Rutz *et al.* 2007). Continuing miniaturization opens new frontiers for research, but the use of animal-borne cameras as a research tool is currently under-exploited, mainly because there are no commercial suppliers of tags or receivers (Moll *et al.* 2007; Rutz & Bluff 2008). In this paper, we describe basic equipment and field techniques for 'video tracking'—the simultaneous recording of video and positional data from free-ranging subjects by means of integrated animal-borne video tags (Rutz *et al.* 2007; Rutz & Bluff 2008). While video tracking is suitable for a wide range of birds, mammals and reptiles, we will focus most closely on flying birds, as their light bodies and aerial lifestyle present particular technological challenges.

2. EQUIPMENT, DATA COLLECTION AND ANALYSIS

(a) *Integrated video tags*

Although the final design will be application specific, a basic integrated video tag comprises video camera, video transmitter, microphone (optional), battery, timer chip and a small, very high frequency (VHF) radio tag for positional tracking (figure 1*a*; for a three-dimensional animation, see video 1 of the electronic supplementary material). Assembled 'spy bugs', featuring battery-powered video cameras with 2.4 GHz transmission, are readily available from internet sources. Stripping these units of excess packaging is the cheapest and easiest means of obtaining a 'bare-bones' tag, or of familiarizing oneself with the technology. Most researchers, however, will require light weight, custom-built tags with superior video resolution, transmission range and battery life. We provide detailed information on component selection and tag construction in the electronic supplementary material.

An integrated VHF radio tag is essential for capturing video footage (see §2*d*), enables recovery of shed tags and provides positional data for linking video-recorded behaviour to certain habitat patches within an animal's home range (Rutz & Bluff 2008). We strongly recommend the use of a timer chip, which delays video transmission for a nominated period (manufactured by Ron Joyce; contact via British Technical Films, UK). A delay of approximately 24–48 hours will allow the animal to habituate to the video tag before filming begins, and video shoots can be scheduled to coincide with periods of high activity (e.g. early morning). Longer intervals are possible but come at the cost of reduced transmission time due to battery depletion. Packaging of electronics for deployment on wild subjects requires particular attention (minimizing size, weight and adverse effects; optimizing camera view and durability), and we offer guidance in the electronic supplementary material.

(b) *Mounting integrated video tags on birds*

The welfare of the animal is of paramount importance when selecting video-tag mounting positions. Where possible, researchers should adopt standard techniques and mass guidelines for conventional VHF radio tags (e.g. Kenward 2001). In the interest of subject welfare and for optimal tag construction, prototypes must be tested with captive subjects first, followed by further field trials.

A backpack-mounted video tag with a laterally oriented camera allows the analysis of wing dynamics during flight, whereas a tail-mounted tag with a forward-facing camera permits the recording of foraging behaviour, social interactions and physiological parameters (e.g. breathing and defecation rates). Our tail-mounting technique (Rutz *et al.* 2007; see video 1 and text in the electronic supplementary material) achieves a good camera angle on medium-sized birds and exploits the natural 'release mechanism' offered by bird feathers. For our fieldwork, we specifically targeted the moulting season of our study species to ensure that tags are shed within days or weeks after deployment (Rutz *et al.* 2007). This approach led to successful tag drop-off in all of the 15 cases where we resighted crows 6–12 months after fitting them with video tags ($n=22$ tagged crows; see the electronic supplementary material).

Backpack-mounting techniques permit greater tag mass but are more suited to species where recapture is probable, as designing safe and reliable release mechanisms for small harnesses remains challenging (Kenward 2001). For both backpack- and tail-mounted video tags, coverage of cameras and antennae by feathers should be minimized, observing species-specific constraints imposed by flight performance and ability to habituate to tags.

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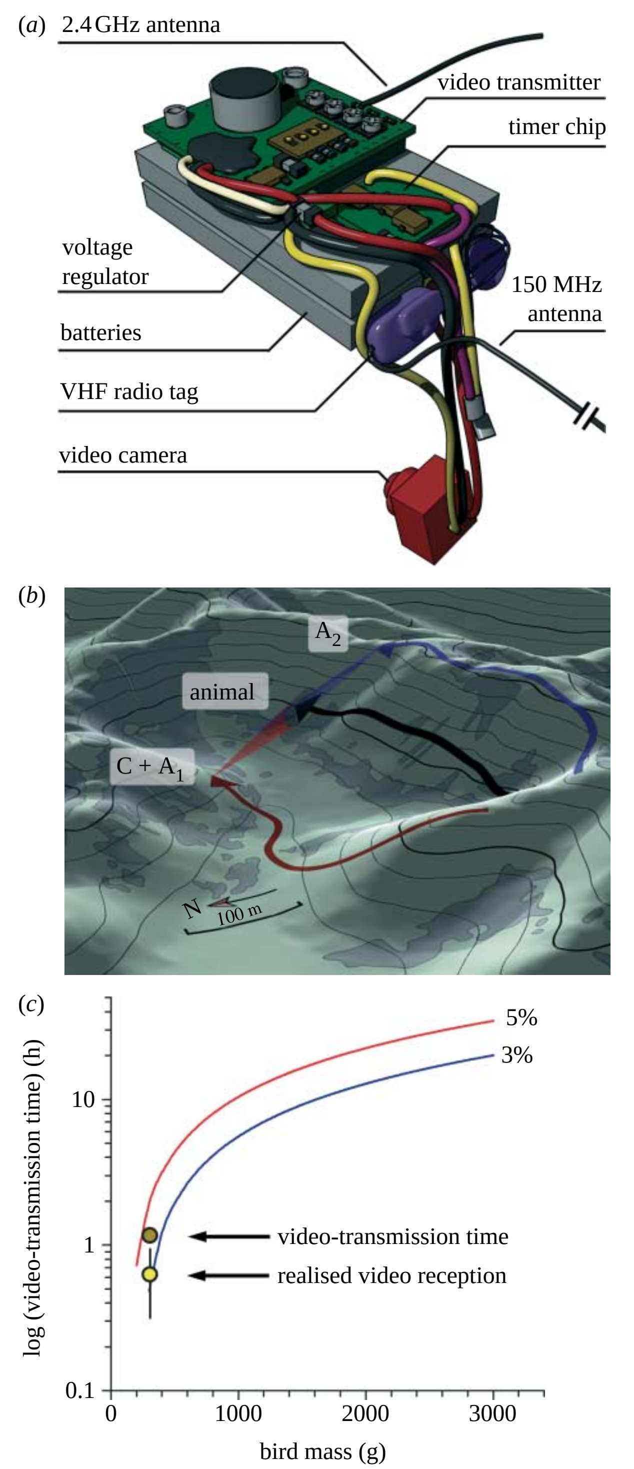

Figure 1. Animal-borne video cameras for studying wild free-ranging birds. (*a*) Computer model of an integrated video tag, as used by Rutz *et al.* (2007) for wild New Caledonian crows. Video tags of this design can be built with a deployment mass of less than 14 g. To expose electronics, the tag is shown without its heat-shrink packaging. For a three-dimensional animation of the model and an illustration of the tag's mounting position on a bird, see video 1 of the electronic supplementary material. (*b*) Video tracking with actively transmitting tags requires two or more fieldworkers (see §2*d*). A 'controller' (C) uses VHF radio telemetry to estimate the animal's location and instructs assistants (A_1 and A_2) on where best to position video receivers. In this case, the controller moves together with A_1 (red arrow) and communicates via walkie-talkie with A_2 (blue arrow). The animal is 'shadowed' as it traverses the environment (black arrow), exploiting the local topography to maximize video reception (note how A_2 moves along the ridge) and avoid disturbance to the subject. The red and blue cones indicate how, towards the end of the video shoot, the two independent video receivers are pointed from different directions at the tagged animal. This is a schematic of the session shown in fig. 1*b* by Rutz *et al.* (2007). (*c*) Larger bird species can carry integrated video tags with heavier batteries, permitting longer video-transmission times. Transmission times are calculated for the basic tag design used by Rutz *et al.* (2007), assuming that tags are fitted with batteries to make total tag mass 3 (blue line) and 5% (red line) of the animal's body mass, respectively. Owing to intermittent signal loss, the amount of video footage recorded in the field is less than the total video-transmission time. Using tags that transmit for approximately 70 min (dark yellow circle), Rutz *et al.* (2007) obtained 38±5 min (mean±s.e.) of analysable footage per successful video shoot (n=12 birds; light yellow circle).

(c) *Video-tracking receivers*

Commercially available receivers typically feature pre-programmed channels and low-gain dipole antennae. A helical antenna mounted in a parabolic dish, paired with an analogue-tuning receiver (available from Jonathan Watts; British Technical Films, UK), should markedly improve reception under field conditions. Multi-element antennae provide increased gain but are probably too directional for most applications. Video recording is done by digital camcorders, or hard-drive recorders, with AV-input capacity. Recorders should store full-frame, minimally compressed video at high frame rates and, ideally, should not automatically screen out low-quality footage (as even this may contain valuable information). The choice between NTSC and PAL video standards is determined by the availability of suitable video-tag components. For species with small home ranges, a pre-deployed network of transceivers may allow the efficient relay of signals to the recording unit, but we have not explored this option ourselves.

(d) *Data collection in the field*

Field techniques will be largely determined by the flush distance of the study species and the degree to which the video signal is attenuated by the local habitat. Previous experience in radio tracking the species is invaluable. Transmission may be highly sensitive to the position and orientation of the transmitter antenna—a 2.4 GHz signal diffracts much less than VHF and is more severely impeded by vegetation. Fieldworkers should always strive to get as close as possible to direct-line-of-sight transmission. In forested terrain, this is best achieved by positioning receivers on elevated points, so that the video signal needs to penetrate only a comparatively thin layer of vegetation (figure 1*b*).

The use of redundant receivers will increase the total amount of unique footage recorded if receivers are placed at different vantage points (figure 1*b*). These independent recordings are subsequently merged (see §2*e*). We capture video footage with tracking teams consisting of one 'controller' who uses VHF radio telemetry to locate the animal and anticipate its further movements and 1–2 (or theoretically more) assistants who operate video receivers. The 'controller' instructs assistants via walkie-talkie on where best to position video receivers and how to orient parabolic antennae to maximize reception (figure 1*b*). Training sessions are necessary to achieve good coordination among trackers.

VHF radio tracking plays a key role in data collection. During the habituation period (see §2*a*), we conduct preparatory tracking to map the bird's ranging behaviour and explore features of the local topography that can be exploited during the forthcoming video shoot. On the day of the shoot, we use high-effort radio tracking to follow the subject continuously from dawn to dusk, including the period of video transmission (70 min with our tags). The bout before the camera triggers gives important information for coordinating tracker movements, while all three bouts combined (before–during–after) yield a movement trajectory to which video data can be linked at the analysis stage (Rutz *et al.* 2007). The VHF transmitter of our integrated video tags lasts long enough (approx. three weeks) to enable collection of radio fixes for conventional home-range and habitat-use analyses, and we suggest that researchers use this opportunity to collect additional data from their video-tagged subjects (Rutz & Bluff 2008).

(e) *Data analysis*

Multiple-track video-editing software allows the construction of a single 'best' version of footage from independent receivers. For this purpose, recorders should be identical, with standardized settings. Keyframe-based compression is ill-suited to the jumpy nature of animal-borne video and should be avoided for initial recording or construction of files for scoring. While analysis will naturally depend on the research focus, most users will benefit from video-scoring software that synchronizes scoring keystrokes with individual video frames (e.g. www.jwatcher.ucla.edu). Scoring should be done from 'real-time' versions of footage, where breaks in transmission are included. If the start and end of each transmission period is scored, data can subsequently be filtered to include or exclude cases where transmission was interrupted during a behavioural event or sequence.

3. DISCUSSION

As with any other animal-mounted device, the suitability of video tags to both the study system and the research question must be appraised before attempting deployment (Kenward 2001). The fundamental concern is that of animal welfare; video tags must not exceed a reasonable proportion of the body mass of the subject or impede its movements (Moll *et al.* 2007; see text in the electronic supplementary material). Minimizing the impact of the tag on any aspect of the animal's natural behaviour is also in the researcher's interest, given that a key strength of video tracking is intrusion-free data collection.

The number of video tags that can be deployed is limited by money, time and manpower. Currently, the per-unit costs of self-assembled integrated video tags are approximately double that of commercial VHF radio tags. However, the transmission life of a video tag is orders of magnitude shorter than that of a radio tag of the same mass (figure 1*c*). Efficient video capture is more labour intensive than positional radio tracking alone, and the active transmission time is a small proportion of the total time required for each video shoot (e.g. tag construction; preparatory positional tracking). It should also be taken into account that some tags will fail, or some subjects may be inaccessible at the time of transmission. We suggest that a small number of trial deployments are used to estimate a realistic target sample size. In any case, we caution that, with current technology, video tracking is not suitable for one-off deployments, and success of any study will depend on achieving good sample sizes.

Trial deployments will also allow researchers to assess whether acceptable footage can be obtained from a distance without disturbing the subject. The successful transmission range of the video signal will be species and habitat specific and transmission may be intermittent, so it should be considered whether the resulting video data will be appropriate to the research question. For example, at the limits of transmission range, video-signal reception may be possible only when the subject is in an exposed position or remains motionless in a particular orientation—a systematic sampling bias that may be acceptable for some, but not all, projects. Camera resolution will rarely be an issue for behavioural studies, but the camera's field of view may be constrained by body parts depending on tag mounting (see §2*b*).

We developed our video-tracking technology for studying New Caledonian crows (*Corvus moneduloides*)—a species near the minimum body mass at which video tagging is currently feasible (we targeted large individuals for tagging, especially males; mean body mass was 302 g for $n=18$ birds fitted with tags of the final design; see figure 1*c*). The use of video tags on larger birds or terrestrial mammals will benefit considerably from additional tag mass. The most obvious improvements are increased transmission time by using larger batteries (figure 1*c*) and/or improved transmission range and reception quality by using more powerful video transmitters. While larger species will always permit more flexibility in video-tag configuration, technological advances will continue to expand the range of species that can be fitted with video tags.

We anticipate that video tracking will be of particular value to those researchers already employing VHF radio tracking (Rutz & Bluff 2008). Integrated video tags resolve the trade-off faced by many field biologists between non-disruptive tracking from a distance (e.g. to assess habitat preference; radio fixes) and approaching animals closely (e.g. to record detailed behaviour; video footage). In fact, detailed video recordings of social interactions and foraging behaviour may greatly facilitate interpretation of longer term radio-tracking data. Another immediate application for video tracking is the calibration of other animal-borne devices, such as posture- or heart-rate sensors (Moll *et al.* 2007; Rutz *et al.* 2007).

4. CONCLUDING REMARKS

Video tracking is a young research technique, and new users should be prepared to invest considerable time and other resources into its successful implementation. We believe, however, that its potential advantages by far outweigh current constraints and therefore encourage field biologists to take on the challenge to adapt and improve the techniques outlined in this primer. Continued technological advancement will not only improve tags of the basic video-transmission design we described here, but will provide alternative means of video-data collection. In our opinion, the next main goal will be the development of cheap, light-weight, solid-state video loggers for mass deployment. Such devices will require recovery for data download, but tag losses will be compensated for by increased sample size and uninterrupted video recordings.

The scope of video tracking for wildlife research is vast. It enables unprecedented, intimate glimpses into the lives of wild animals, and quantitative data collection in places and circumstances where other observation techniques fail. While strongly encouraging its wide adoption, we urge fellow researchers to use video tracking wisely—in systems that are insufficiently accessible with conventional techniques, such as VHF radio telemetry, and for addressing well-defined research questions. We look forward to the many new insights that video tracking will produce in the near future.

Our fieldwork was carried out with permissions from the Centre de Recherches sur la Biologie des Populations d'Oiseaux (France) and the Direction des Resources Naturelles (Province Sud, New Caledonia), and was in accordance with the University of Oxford's procedures for local ethical review.

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