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Evaluation of six digital camera models for the use in capture-recapture sampling of Eurasian Lynx *(Lynx lynx)*

Evaluierung von sechs Fotofallenmodellen hinsichtlich der Eignung für Fang-Wiederfang Methoden beim Eurasischen Luchs (Lynx lynx)

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Abstract

Digital outdoor cameras are increasingly used in wildlife research because they allow species inventories, population estimates, and behavior or activity observations. Which camera model is suitable and practical depends on environmental conditions, focus species and specific scientific questions posed. Here we focused on testing cameras appropriate for elusive species that can be identified visually owing to individual coat patterns. Specifically the camera should be adequate for calculating the minimum population of Eurasian Lynx (Lynx lynx) *during a systematic monitoring with camera traps. Therefore we tested six digital camera models with regard to trigger speed and the image quality necessary for visual identification of pacing lynx on trails. The decision if a camera model is adequate for the scientific goal was regulated due to priority levels under laboratory conditions.*

Only one camera model proved to be suitable for camera-trap monitoring. Our practical camera test can be used to evaluate newer models of digital cameras as they become available. This application opens an avenue for a non-invasive population monitoring of rare and elusive species in a low mountain range area.

Keywords: *camera-trap monitoring, camera test, non-invasive monitoring,* Lynx lynx

Zusammenfassung

Digitale Fotofallen werden weltweit in der Wildtierforschung eingesetzt. Die Einsatzgebiete sind vielfältig, sie reichen von Artenbestandsaufnahmen und Populationsschätzungen über die Verhaltensforschung bis hin zu Aktivitätsanalysen. Das jeweilig eingesetzte Kameramodell muss an die Aufnahmesituation und die Zielsetzung der Analyse angepasst sein.

Das Ziel unseres Fotofallentests war es, ein Modell zu finden, welches für die visuelle Identifizierung von Fellmustern des Eurasischen Luchses geeignet ist. Die Fotofalle soll in einem systematischen Monitoring für die minimale Anzahl der im Gebiet vorkommenden Luchse und deren Populationsschätzung mit Fang-Wiederfang Methoden eingesetzt werden können. Bei dem Test von sechs Fotofallenmodellen, fiel das Hauptaugenmerk auf die Auslösegeschwindigkeit und die Bildqualität welche die nötigen Faktoren für die Sicherstellung der visuellen Identifikation von schreitenden Luchsen am Wildwechsel darstellen.

Zur Entscheidungsfindung der Eignung eines Fotofallenmodells für die Fragestellung definierten wir Prioritätslevel unter Laborbedingungen. Es stellte sich heraus, dass nur ein Fotofallenmodell die Ansprüche erfüllte. Der praktische Fotofallentest kann für neuerscheinende Fotofallenmodelle adaptiert werden. Diese Anwendung eröffnet die Möglichkeit für ein nicht invasives Monitoring in Mittelgebirgslandschaften.

Schlüsselworte: Fotofallenmonitoring, Kameratest, nicht invasives Monitoring, *Lynx lynx*

1 Introduction

Currently, radio-telemetry and camera trapping are the methods of choice to gather information on the space-time data behaviour of animals (Garrote et al. 2010). But camera trap monitoring is a non-invasive method and more cost effective than radio- telemetry (Gil-Sánchez et al. 2011).

Remote cameras have proven to be useful in wildlife studies (Cutler & Swann 1999, Karanth & Nichols 1998, Marnewick et al. 2008, Soisalo & Cavalcanti 2006). Modern digital cameras have, in comparison to the past, extended features, can operate over much longer periods of time than analog cameras, are portable and handy, and offer high trigger speeds. The cameras can be used for general species detection, species inventories, wildlife crossing surveys behavioral studies and estimation of population abundances and densities (Cutler & Swann 1999). Also for studies of animal behavior and activity patterns, camera traps have been used (Akbaba & Ayaş 2012).

They have been successfully used to study especially elusive animal species that can be individually recognized by their individual coat patterns on the high-quality images, e.g., tigers (Karanth 1995, Karanth & Nichols 1998, Karanth et al. 2004) ocelots (Trolle & Kéry 2003) and jaguars (Silver et al. 2004).

The demand for digital outdoor cameras has led to their fast development and a large variety of models on the market. The choice of camera depends on the defined scientific question.

Our objective was to find an adequate camera-trap to be set on trails and to establish a practical and repeatable test for new camera models as they become available. In a controlled laboratory test, we tested six digital camera models for their suitability in recognizing individuals of pacing Eurasian Lynx (*Lynx lynx*) on trails. Therefore we focused on image quality and trigger speed. The selected camera was subsequently used in a photographic capture-recapture study to estimate the population size of lynx.

2 Materials and methods

2.1 Camera models

We tested six digital camera models (Tab. 1) in winter 2008/2009. The chosen brands and models were either recommended by other scientists and/ or because of a detailed internet search. The camera systems chosen fulfilled the following requirements: apparently good picture quality according to the manufacturer data, trigger speed ≤ 1 sec, availability for the timeframe of the test (shortage of supply, waiting periods), < $ 800, low maintenance (no extra accessories necessary), and < 5 kg weight (including batteries). We tested one camera of each model because we assumed that the quality within a sold charge of cameras is homogenous. Differences will be much bigger between several charges. Furthermore we assured to test a typical representative of each model.

2.2 Controlled laboratory test

In order to evaluate the different camera models for the visual identification of lynx individuals (Laass 1999, Thüler 2002), we defined three groups of requirements and ranked them according to our needs in the study: 1 (highest priority): detailed high-quality image showing defined contour of lynx coat markings, especially under night conditions, i. e., the light conditions under which crepuscular and nocturnal species are usually observed, and adequacy of trigger speed for imaging a pacing lynx, which was fulfilled if the motive appeared in the centre of the image; 2 (medium priority) reliability of triggering and user friendliness, and reliable range of the sensor to find out the optimum distance between two opposing camera traps per site; and 3 (lowest priority) lowest price of adequate models. Camera models that did not fulfill the requirements of the first priority were classified as inadequate.

The digital cameras were tested under controlled laboratory conditions in a depot hall. A cable wire was stretched across the room. Each end of the wire was attached to a crank to pull the object, a lynx hide, installed on the wire through the depot (Fig. 1). The object was attached to a wooden slat positioned on the cable wire. The lynx hide, with a small spotted coat pattern typical marking for the lynx in the area, was moved at a speed of 3–4 km h^{-1}. This was the observed speed of a pacing lynx in an enclosure, which we determined by measuring the time needed for the lynx to cover a specific distance. A white 6 × 10 m plastic tarp was suspended in the background to simulate snow as the best period to conduct photographic capture-recapture sampling is winter time (increased capture probability, Laass 1999).

The six camera models were installed separately on a moveable stand constructed from a polished wooden pole. For each test, one camera model on a stand was placed at one position, covering distances from 1–8 m from the center of the wire at 1-m intervals.

Each camera model was tested under both day and night conditions. Daylight was simulated using a 500-W halogen spotlight in addition to the ambient depot illumination and the light entering the depot from the open gates. The spotlight was placed directly next to the camera stand to illuminate the object from the same distance (Fig. 1). Night was simulated in absolute darkness, i. e., with closed gates and no artificial light.

Each camera has a passive infrared sensor trigger, which detects the temperature gradient between a temperate source and the non-temperate environment. Therefore the lynx hide contained a hot water bottle filled with hot water (around 80 °C). Although the isolation of the bottle reduced the temperature of the water, the emitted infrared radiation was at least as high as that of a real lynx with a body temperature between 38 °C and 39 °C (Göltenboth & Baronetzky-Mercier 1995). The hot water inside the bottle was replaced each time a new camera model was tested to ensure the same conditions. The reliable range of the sensors was determined by examining the largest distance where the camera still triggered on a reliable basis.

2.3 Test classifications

We chose classification levels to guarantee repeatability of the camera test.

The definitions were the following:

1 Reliable coverage:

The reliable range of the sensors was determined by examining the largest distance where the camera still triggered on a reliable basis. This means to determine the maximum distance from the camera to the object that triggers the camera, without any extra support

2 Image quality (at daytime & at nighttime):

1 - **excellent** image definition, is characterized by precise recognition of coat markings, optimal for individual recognition.

2 - **good** image definition, means that clear distinctions of the coat markings is possible, good for individual recognition.

3 - sufficient image definition, means that the coat markings are still recognizable, merely enough for individual recognition.

4 - **inadequate** image definition, no individual recognition possible.

3 Adequacy of trigger speed:

For the use of camera traps on trails, a fast trigger speed is very important to get the animal in the centre of the image. Otherwise there is a possible loss of crucial information such as for example the coat markings on the inner legs.

Yes - motive centred on the image on more than 80 % of the images,

No - motive not centred on the images.

4 Installation:

The installation of the camera should be simple, quick and flexible. The minimum equipment accounts for a tension belt plus an appliance to lock the camera. Additional time and financial costs due to deficient accessory is not conductive.

1 - valuable accessory, conceptual, uncomplicated;

2 - no or deficient accessory, complicated

5 User friendliness:

Systematic camera trap monitoring often needs several controllers because of the effort. Thus a model with self-explanatory applications is of advance. Additionally the manual should be well structured, with explanatory illustrations and legends in comprehensible English language.

1 - application easy to understand, coherent manual;

2 - application understandable with the manual;

3 - application, menu, and legends non transparent even with manual

6 Reliability of triggering:

1 - reliable, if three images out of three tests per meter were triggered

2 - unreliable, if less than three images of three test per meter were triggered

7 Adequacy:

1 - high-quality image, adequate trigger speed, and at least satisfactory reliability, user friendliness, sensor range, and low cost;

2 - quality of image and trigger speed are partially adequate, and reliability, user friendliness, sensor range, and low cost are satisfactory;

3 - poor-quality image, inadequate trigger speed

2.4 Uncontrolled field test

We installed the cameras in a lynx enclosure for the most contiguous comparison to the questioning possible. The cameras were built up in a distance of 3 m to the fence and 3 m apart from the next model in October 2008. The two adult lynx were photographed pacing on the trail for 3 days.

3 Results

The six models of digital cameras differed considerably in trigger speed, image quality and reliability (Tab. 2).

The concentricity of the photographed object is highly influenced by the trigger speed (Pollock et al. 1984) and also by the apex angle of the motion sensor because a narrow concentration gap requires a small apex angle. A trigger speed > 0.3 s is not adequate for high-quality images at a distance < 6 m.

A fast trigger speed combined with a small apex angle ensures that the object is located at the center of the image. In our tests, the Reconyx models with infrared flash had a larger angle, i. e., a wider concentration gap, than the Cuddeback Capture™ model with white flash. The larger angle of the Reconyx models arises from the camera being able to record a continuous observation due to extended features.

Overall, the Cuddeback Capture™ was superior to the other five camera models tested. The image quality under night conditions was excellent. The exposure time was short because of the white flash, which resulted in fixed images with a very fine image resolution. Consequently, the patterns of the small-spotted lynx hide used could be distinguished without deformation, and therefore, the images could be used for visual identification of individuals. During day time conditions the image quality was still good in the controlled laboratory test. In uncontrolled field tests, moving objects were often diffuse which is caused by a long exposure time. Also the object sometimes appeared transparent and the background shined through. Since this did not occur in the controlled laboratory test, we did not consider this as a misoperation, but rather caused by poor illumination in the field. Another advantage of this camera model was the fast trigger speed of 0.3 s. The moving object was always centered on the image, so the model can be used for the lynx on trails. The triggering of this model was very reliable. Since several field technicians will be involved in the camera-trap monitoring, user friendliness of the camera is essential to keep the failure potential low. The operating instructions of the Cuddeback Capture™ are simple and easy to understand. A rotary control ensures the clear programming of time and date. Two images can be made with a delay of 0.5, 1, 5, 15, and 30 min. The distance from the camera to the object that triggers the camera was 7 m (test until 8 m), and not the 15 m stated by the producer. The Cuddeback Capture™ was the least expensive model tested (Tab. 1). The lower price makes it possible to purchase more cameras for replacement or larger studies.

A disadvantage of the Cuddeback Capture™ is that the image was overexposed at a camera-to-object distance of < 1 m. Such images could not be used for visual identification. A second possible disadvantage of this camera is the white flash, which may be avoided by some species. In field tests, red deer and roe deer avoided camera sites after a few flash events, as evidenced by the tracks around the camera site and images of deer moving behind the opposing camera. Such avoidance by lynx was not observed during the test in the enclosure. A third possible disadvantage of the camera is the symptoms of wear and tear, even though the camera is overall solidly built. The rotary control wore out by turning it too fast and too hard. The entering ridge of the secure digital memory card lost the resistance that was noticed at the beginning of camera use. However, such wear and tear can be minimized if the camera is handled with care.

The five other digital camera models were inferior to the test winner, but differed in various aspects.

The Cuddeback Expert™ was overall only adequate for our purposes. The camera yielded an image quality sufficient for individual recognition when the white flash was used, but the trigger speed allows this model to be used only at a distance of > 3 m. The model was not user friendly. Even with the help of the manual, the wanted settings could only be found by testing several options. During the test, the settings often changed from the exposure mode to the test mode, in which no images can be made, thereby greatly risking data not being collected.

The Bushnell TrailScout™ was not adequate in our tests. The infrared images were overexposed, and the coat markings on the image were deformed. Also the white flash images at a camera-to-object distance up to 3 m were overexposed. At distance of ≥ 4 m, the image quality was good. The trigger speed was not sufficient below a distance of 4 m, the motive was not centered. This camera model was the most unreliable. The triggering did not always function. In field tests in the lynx enclosure, the other camera models pictured up to three times more animals under the same conditions. In the worst case, one out of four images taken by the Bushnell TrailScout™ was completely black.

The image quality of the Cuddeback Capture™ IR under night conditions was acceptable only up to a distance of 3 m. At larger distances the images became grainy and the object was almost not recognizable. Shortly after the camera test, the manufacturer recalled this model because of complaints about coverage and unacceptable image quality. A newer version of the camera, not available at the time of our test, now has 5 megapixels instead of the 3 megapixels.

Neither the Reconyx RC 45™ nor the Reconyx RC 60™ fared well in our test for the question posed. Although the trigger speed of 0.3 s was sufficient, the exposure time of these infrared cameras was relatively long. The image quality was not sufficient because the exact contours of the markings on the hide could not be distinguished. The cameras would be suitable for recognizing species, but not for visual identification of individuals of a species. These camera models are supposed to be adequate for prey sites and an overview at supplemental feedings. The cameras are able to take a series of images, which could be useful for examining the size and behavior of herds. The manuals require advanced English language knowledge. Therefore, the more non-native-English-speaking operators involved, the higher is the failure potential. The manufacturer offers additional software for the cameras, but we did not include the software options in the test.

4 Discussion

The first digital cameras available were not adequate for camera trapping because of their slow trigger speed and poor image quality. These attributes have developed rapidly owing to the high demand. Digital cameras, with their practically endless image recording, are in general now much more time and cost efficient than analog cameras.

However, as our study showed, the suitability of the digital cameras available today for camera-trap monitoring varies significantly, and testing the various models for the scientific question posed is crucial. New camera models with diverse and improved features are being continuously developed. Our camera test can be easily expanded to test these new models and features. For example, longer and reliable camera-to-object distances of up to 12 or 15 m might soon be possible. Our camera test could also be used to address other site-specific or object-specific questions, such as recording images under light conditions of dawn or dusk, or using different objects to test the differentiation of details in the images. In contrast to Fattebert & Zimmermann (2007), we chose to test each camera model separately to avoid mutual influences, such as brightening of images caused by the flash of the neighboring camera.

For field studies using camera-trap monitoring, the choice of camera trapping sites on a small scale must take the performance of the camera into consideration. For example, to avoid direct solar radiation, which leads to overexposure of the images, we will chose sites with canopy cover. Placement of the camera traps in shade furthermore leads to more camera flash images, which are of a higher quality, as shown in our test. We assume canopy cover to reduce the risk of drifting snow, which can cover the camera lens.

Another point to consider at the field sites is the placement of the cameras for the best possible images. At the speed of our test object, the best image quality of the test winner, the Cuddeback Capture™ , was reached at a camera-to object distance of 2–5 m, and the camera triggering was reliable up to 7 m. We therefore set the two camera traps 5–9 m apart to ensure high-quality images from at least one or even both camera traps of a lynx passing through the site. Even if the lynx passed within < 1 m to one camera, there is still a big chance that opposing camera, at ca. 4 or 8 m distances, would still be triggered. When using two opposing cameras, it is necessary to not set the cameras exactly facing each other. The long exposition time results in an interaction of the flashes. The flash of the opposing camera can cause overexposure of the image. So the cameras should be turned slightly away from each other. To estimate population abundances, the capture-recapture method calls for an equal capture probability per individual over the sites. The capture probability of an individual, however, can be affected by a change in behavior, such as trap shyness or trap happiness (Wegge et al. 2004), which could occur with camera-trap monitoring because of the white flash. Therefore, digital infrared cameras, which provide an image quality adequate for visual identification, should be used (Wegge, Pokheral et al. 2004) and developed further. Another area that has been developed but requires improvements is the ability to select the timeframe for the data acquisition. For example, if the data collected at a site indicate that the Eurasian Lynx, which is mainly a crepuscular species, visits the site only at specific time frames, energy and data-analysis time would be saved if specific time frame could be set on the camera. This is an option to save time and money which can be crucial for smaller projects with limited man power and financial support, but includes the risk of data loses.

For each scientific question posed, the most-suitable digital camera should be chosen. No digital camera model will be "perfect" for all kind of wildlife studies, but the models should be considered and tested based on the animal species (small vs. large animals, individually identifiable vs. not individually identifiable) under study, the environmental conditions of the study area (tropical forest vs. desert vs. high mountain ranges), and available financing.

5 Acknowledgements

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Tab. 1: Important features of the tested digital camera models.

Tab. 1: *Wichtige Eigenschaften der getesteten Fotofallenmodelle.*

Model	Year of launch	Suggested retail price	Trigger speed (s)	Resolution (megapix)	Image type	Flash type	Extra features	Range according to producer (m)
Bushnell® TrailScout™ 119935	2007	$ 349	< 1	5 or 7	Color or monochrome (adjustable)	Infrared or white flash	Choice of closure/ resolution, moon phases, laser pointer	13.5
Cuddeback® Capture™	2008	$ 199	0.3	3	Color (day and night)	White flash	-	15
Cuddeback® Capture IR™	2008	$ 249	0.3	3	Color (day), monochrome (night)	Infrared	-	8
Cuddeback® Expert™ C3300	2006	$ 349	0.75	3	Color (day and night)	Infrared or white flash	Video, battery indicator	12
Reconyx® RC 45 Rapidfire™	2007	$ 449	0.1	1.3	Monochrome (day and night)	Infrared	Rapid fire, °C indicator, battery indicator, moon phases	15–18
Reconyx® RC 60 Rapidfire™	2008	$ 599	0.2	3.1	Color (day) Monochrome (night)	Infrared	Rapid fire, °C indicator, battery indicator, moon phases, no glow	9–11

Tab. 2: Comparison of six digital camera models: Results (see test classifications for description of result levels).

Tab. 2: *Vergleich der sechs Fotofallenmodelle: Ergebnisse.*

Model	Reliable coverage1	Image quality2 (day)	Image quality2 (night)	Adequacy of trigger speed3	Instal-lation4	User friendli-ness5	Reliability of triggering6	Weaknesses	Ade-quacy7
Bushnell® TrailScout 119935	8 m	good	White flash: good Infrared: inadequate	Yes - motive centered	2	2	unreliable	Black images, overexposure material for mounting	3
Cuddeback® Capture™	7 m	good	excellent	Yes - motive centered	1	1	reliable	Overexposure	1
Cuddeback® Capture™ IR	8 m	good	inadequate	Yes - motive centered	1	1	unreliable	Poor IR cover-age+ image quality	3
Cuddeback® Expert™ C3300	7 m	good	good	No - motive not centered	2	3	unreliable	Slow triggering, battery case unhandy	2
Reconyx® RC 45	8 m	good	sufficient	Yes - motive centered	1	2	reliable	Poor IR image quality	3
Reconyx® RC 60	8 m	sufficient	inadequate	Yes - motive centered	1	2	reliable	Poor IR Image quality	3

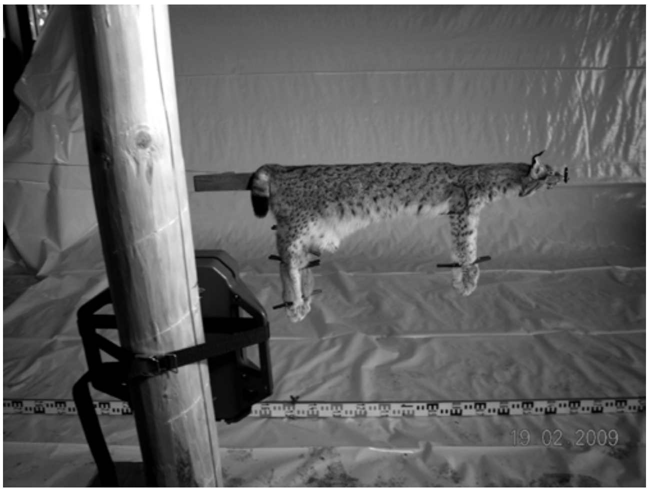

Fig. 1: Installations of the laboratory controlled camera test.

Abb. 1: *Testaufbau des Fotofallentests unter Laborbedingungen.*

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