Parallel Lasers for Remote Measurements of Morphological Traits

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ABSTRACT Animal ecology research could benefit from the measurement of individual morphological traits. In bovids, male horn size often correlates with annual reproductive success, is sensitive to resource abundance, and could be a predictor of survival. However, live captures are costly, involve some risk of injury or substantial disturbance to the animals, and are impossible in many situations. To remotely measure horn growth of free-ranging Alpine ibex (*Capra ibex*), I designed an aluminum frame that holds parallel laser pointers and a digital camera. I took digital pictures of ibex horns and calculated horn growth based on the fixed distance between the 2 laser points. This simple and accurate technique could benefit many ecological studies that require linear measurements, such as shoulder height, body length, leg length, or fin length. It could also help measure body features (e.g., fur or skin patterns, scars), increasing the reliability of individual photographic identification. (JOURNAL OF WILDLIFE MANAGEMENT 71(1):289–292; 2007)

DOI: 10.2193.2006-290

KEY WORDS annulus, *Capra ibex*, horn size, laser, photography, remote measurement.

Biologists frequently use measurements of individual morphological traits in ecological research to guide conservation and management efforts. A well-known example is the variation in beak length of *Geospiza* finches that was instrumental in shaping Darwin's thoughts about natural selection (Darwin 1859). Ecologists and evolutionary biologists measure animal morphological traits because there are correlations between size and fitness. In lizards and snakes, there is a correlation between body shape and relative clutch mass (Shine 1992, Du et al. 2005). In males of polygynous ungulates, heavier individuals with larger horns or antlers are dominant and sire more offspring (McElligott et al. 2001, Coltman et al. 2002, Preston et al. 2003). The size of secondary sexual traits could also signal individual quality (Malo et al. 2005, Weladji et al. 2005). Finally, morphological measurements are also important to evaluate the consequences of different conservation strategies (Coltman et al. 2003).

Biologists can easily measure morphological traits on dead or live-captured animals (Jorgenson et al. 1998, Malo et al. 2005). However, live captures are typically costly, often involve some risk of injury or substantial disturbance to the animals, and are impossible in many situations (Côté et al. 1998, Pelletier et al. 2004). Consequently, biologists often capture animals only once to mark individuals and take body measurements at that time only. Very few studies have collected repeated morphological measurements on marked individuals. A method of measuring free-ranging animals would avoid the risks associated with captures and provide longitudinal data that could be useful for many fundamental and applied research objectives.

In bovids, male horn size often correlates with annual reproductive success, is sensitive to resource abundance (Jorgenson et al. 1998, Coltman et al. 2002), and is a predictor of survival in ibex (*Capra ibex*; von Hardenberg et al. 2004). Therefore, horn measurements are useful to understand population and behavioral ecology of ibex. However, as in most ungulate studies, biologists only catch and individually mark ibex in the Gran Paradiso National Park (GPNP) once. Bassano et al. (2003) developed a method to weigh individuals without handling for this population. Here I present a technique to measure annual horn growth of free-ranging ibex. My method involves use of commercially available laser pointers and a digital camera.

STUDY AREA

The GPNP is located in the Italian Alps (45°26′N, 7°08′E). Ibex males wintered at elevations of 1,500–2,300 m and migrated in mid-June to their summer range (2,300–3,500 m) dominated by alpine meadows, rocks, and cliffs. During fall 2005, park wardens counted 95 males and 112 females in the Levionaz study area, including 55 males marked with ear tags or radiocollars.

METHODS

I based my technique on the principle that parallel lasers are equidistant regardless of the distance from the origin. I designed an L-shaped frame, cut from a single block of aluminum, to hold 2 lasers and a camera (Fig. 1). The vertical section has 2 parallel holes in which I inserted and immobilized lasers with screws. Preliminary field trials suggested that a distance of 4.0 cm was adequate for annulus measurements, thus I drilled the holes 4.0 cm apart. Green laser is much more visible than standard red laser in daylight; therefore, I used green laser pointers (Module GLP-COII-05a; Apinex, Montreal, PQ, Canada). I cut the laser pointers to connect both to the same on–off switch and to reduce their length by removing the battery casing (Fig. 1b). A modified flashlight holds the 2 AA (1.5 V) batteries. I used a digital Fuji Finepix S5100 camera (Fuji Photo Film U.S.A., Inc., Valhalla, NY) with 4 megapixels and an optical zoom of 10×. The entire apparatus including the camera cost about US$600. The lasers are classified IIIA; therefore, users should avoid contact with eyes, but there are no risks of injury associated with a short accidental

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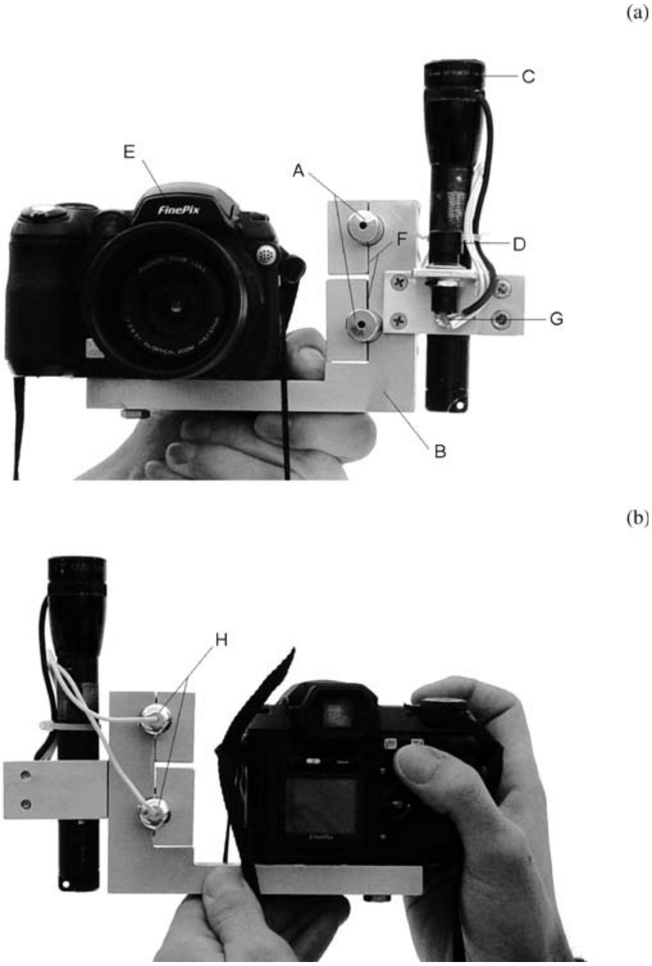

Figure 1. The aluminum frame holding 2 parallel lasers and a camera used to photograph ibex in the Gran Paradiso National Park, Italy, summer 2005. (a) A: lasers, B: "L" frame, C: battery casing, D: on-off switch, E: camera, F: vertical section of the "L" frame cut vertically and holding each laser with two screws, G: connection to the on–off switch, (b) H: Back of the lasers cut and connected together to the switch. Photo by P. Bergeron.

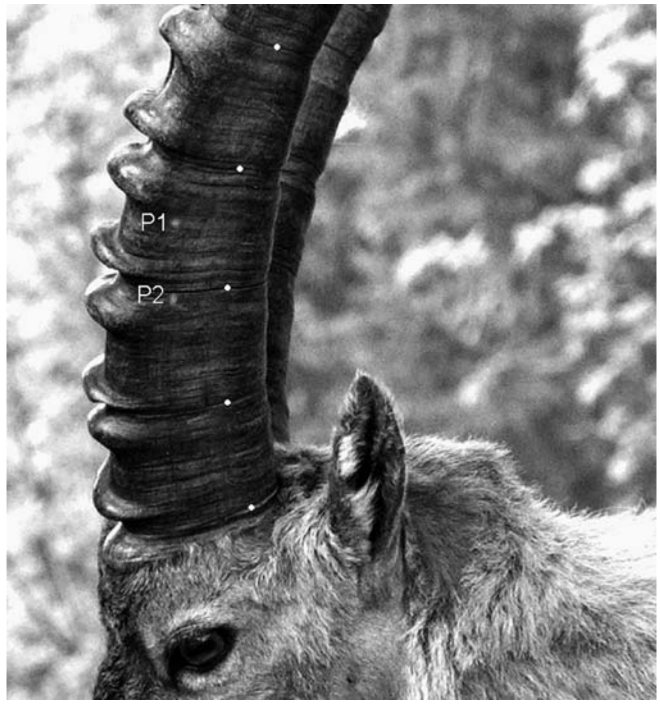

Figure 2. Lasers (P1 and P2) aimed at the left horn of an ibex in the Gran Paradiso National Park, Italy, summer 2005. From this picture, I measured 4 visible annuli (white dots). Photo by P. Bergeron.

exposure. The single switch turned both lasers off simultaneously to avoid projecting them on the eye of the animal.

I took digital pictures of ibex horns showing the 2 parallel laser points separated by a known width (Fig. 2). From these pictures, I calculated annulus length as $A_r = (A_p/L_p) \times L_r$, where A and L refer to the annulus length and the distance between laser points, while the subscripts r and p refer to real measurements and picture measurements, respectively. L_r is the fixed distance between the parallel lasers at the source. Annuli are obvious because of a sharp demarcation left by the cessation of horn growth in winter (Fig. 2).

Annulus length measured from a picture can only decrease as the horn tilts from a perfect vertical. The measure A_p decreases according to the relation $A_p' = A_p\sin(\theta)$, where θ is the tilt angle and A_p' is the observed measure on the picture. Since $\sin(\theta)$ can vary between zero and one, $A_p' \leq A_p$. The distance between the laser points will increase as the horn surface tilts, but its projection on the picture will remain constant. Accordingly, the ratio of the annulus length over the distance between laser points in the photo can only underestimate the annulus length as the horn tilts. Therefore, when researchers take repeated pictures of the same annulus, the longest (or asymptotic) calculated annulus length will provide the most accurate estimate.

To test their parallelism, I shot the lasers on graph paper held perpendicular at a distance of approximately 15 m. I adjusted the lasers before each series of pictures of one individual ibex, and I checked their parallelism on graph paper after each photo session. The digital camera allowed multiple pictures of the same individuals, and I discarded pictures where the target annulus was obviously not perpendicular to the laser beams.

I downloaded the pictures in Paintbrush (Microsoft® Paint 5.1, Redmond, WA) and measured the distances A_p and L_p in pixels. To test the precision of the system, I measured 76 annuli from both horns of 7 ibex skulls 10 m away with the system fixed on a tripod. Then I used linear regression forced through the origin to compare these measurements with the annulus length measured with a ruler to the nearest millimeter. A slope of one indicates that lengths estimated with the lasers are unbiased. I also manually measured 2 live ibex captured for ear tagging, repeatedly photographed them while free ranging later in the summer, and compared the annuli measurements taken at capture with those estimated from photographs. Finally, I took a series of photographs of 75 annuli from 16 free-ranging ibex (Fig. 3) from June to August 2005 ($\geq$1 d apart) to calculate the repeatability (r) of multiple measurements of the same annulus. This method uses a one-way analysis of variance to compare the mean square (MS) of multiple measurements of a given annulus (within, w), and among (a)

Figure 3. The lasers and camera handheld to photograph ibex males in the Gran Paradiso National Park, Italy, to measure their horns, summer 2005. Photo by J.-S. Babin.

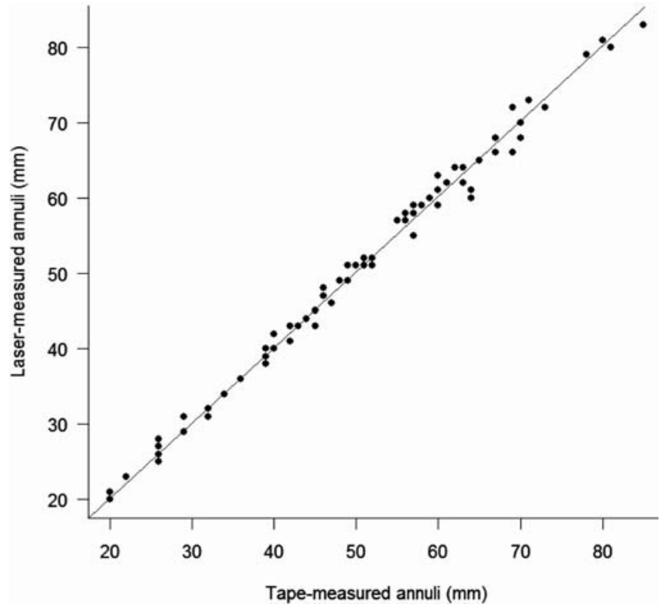

Figure 4. Regression (forced through the origin) of the measurement of 76 annuli from 7 ibex skulls measured with a tape and with lasers. Skulls came from animals found dead in the Gran Paradiso National Park, Italy, and we measured them during summer 2005.

all measured annuli. I calculated repeatability using MS_w, MS_a, and a coefficient accounting for the unbalanced distribution of multiple measurements and sample size (see results). Value of *r* ranged from zero to one, zero being no repeatability and one indicating perfect repeatability of all measurements of a given annulus. Repeatability will approach one if MS_w is significantly smaller than MS_a (see Lessells and Boag 1987 for a detailed description of the calculation of *r*). I took every measurement as a straight line along the center of the external side of the horns, which is the flattest section of the horns.

RESULTS

Comparison of Photographic Estimates with Annuli Measured by Hand

The slope of the regression line of the lengths of 76 annuli measured on ibex skulls using the photographic technique with those hand-measured approaches one, indicating that the measurements using the lasers are unbiased compared to the manual measurements ($b = 1.003$, SE = 0.003, $r^2 = 0.999$; Fig. 4). For 93.4% of the annuli (71/76), the estimated lengths from photographs were within 2 mm of the measured lengths, or 3.9% of the mean length ($\bar{x} = 51$ mm, SE = 1.8 mm, $n = 76$) of the measured annuli. Only one remote measurement differed by 4 mm from the manual measurement.

For the 2 ibex captured in 2005, all annuli lengths estimated from pictures after their release were within 3 mm of the manual measurements, or 5.2% of their mean length ($\bar{x} = 58$ mm, SE = 1.7 mm, $n = 27$).

Calculation of Repeatability with Free-Ranging Individuals

To estimate the repeatability of laser measurements, I repeatedly photographed 75 annuli from 16 free-ranging individuals (43 twice, 18 3 times, 12 4 times, and 2 5 times) during summer 2005, representing 29% of the marked population (16/55). Repeatability (*r*) of these measurements was very high ($F_{74,123} = 315.08$, $r = 0.992$, $P \leq 0.001$) and only 3.14% of the within-annulus variance was due to measurement error ($MS_w/MS_a \times 100$).

DISCUSSION

Using this simple technique, I obtained accurate and highly repeatable horn measurements of free-ranging animals. Measurement precision was comparable to that of studies on horn length based on measurements of anesthetized individuals or dead specimens (Fandos 1995 [3 mm], Toïgo et al. 1999 [5 mm]). This system is also relatively inexpensive and one person can measure animals repeatedly. Given the importance of horn length for individual fitness, this method will help understand the life-history strategies of ibex and the correlation of horn growth with environmental variables (Giacometti et al. 2002, von Hardenberg et al. 2004).

Limitations of this method include the short range at which it is efficient and the surface it can measure. With a similar technique, Durban and Parsons (2006) used a lens to concentrate the laser beams, increasing the distance at which they were able to measure the fins of killer whales (*Orcinus orca*). To have a precise measurement, parallelism of the laser must be accurate and the measured structure must be perpendicular to the beams so that the laser projections on the image are at the same distance apart as the laser pointers. To reduce the risk of edge distortion, researchers should use only pictures in which the laser points and the measured object are in the center of the frame. The method is most appropriate on a fixed camera setup because the lasers do not move, substantially reducing the need to frequently check laser width. Researchers can underestimate measurements on photographs when the measured surface tilts. However, with a digital camera, one can take many pictures at low cost and then measure those that appear most perpendicular. Some structures, however, may be more challenging to measure using this system, such as the horns of bighorn sheep (*Ovis canadensis*) that have a complex three-dimensional shape. Addition of a third laser on the setup may create a triangle with known angles (e.g. equilateral triangle) that could allow estimation of (and correction for) the tilt of the measured structure.

MANAGEMENT IMPLICATIONS

The projection of parallel lasers provided precise measurements of annuli length without the need to handle the animal. Other potential applications of this technique include total horn or antler length of species with relatively straight ornaments, scrotum diameter, body length, leg length, and any linear body measurement. Also, by providing a reference point of known dimensions, my method could help measure body features (e.g., fur or skin patterns, scars), and increase the reliability of individual photographic identification. I recommend the use of a blind at a bait site or modifications fitting parallel laser beams on cameras triggered by movement for studies that involve species that are difficult to approach.

ACKNOWLEDGMENTS

I am grateful to M. Festa-Bianchet, G. C. White, and 2 anonymous referees for useful comments on the manuscript. I thank B. Bassano, L. Jocollé, and A. von Hardenberg for capturing ibex; the GPNP wardens and J.-S. Babin for help in the field; and J.-L. Bédard, D. Poulin, and S. Fauchon for technical support. The Natural Sciences and Engineering Research Council of Canada (scholarship to P. B. and research grant to M. F.-B.) provided financial support and GPNP provided logistical support.

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Associate Editor: White.