Commentary

A Note on Opportunism and Parsimony in Data Collection

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ABSTRACT Out of precaution, opportunism, and a general tendency towards thoroughness, researchers studying wildlife often collect multiple, sometimes highly correlated measurements or samples. Although such redundancy has its benefits in terms of quality control, increased resolution, and unforeseen future utility, it also comes at a cost if animal welfare (e.g., duration of handling) or time and resource limitation are a concern. Using principle components analysis and bootstrapping, we analyzed sets of morphometric measurements collected on 171 brown bears in Sweden during a long-term monitoring study (1984–2006). We show that of 11 measurements, 7 were so similar in terms of their predictive power for an overall size index that each individual measurement provided little additional information. We argue that when multiple research objectives or data collection goals compete for a limited amount of time or resources, it is advisable to critically evaluate the amount of additional information contributed by extra measurements. We recommend that wildlife researchers look critically at the data they collect not just in terms of quality but also in terms of need. (JOURNAL OF WILDLIFE MANAGEMENT 73(6):1021–1024; 2009)

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When capturing wildlife during monitoring or other studies, we are often inclined to collect as many types of data (e.g., measurements, samples, observations) on each individual as possible, particularly when collection of these data is relatively noninvasive and capture itself is effort and cost-intensive. We may be motivated by a need for redundancy, quality control, uncertainty about which of a set of measurements or samples will be the most appropriate in subsequent analyses, or a more or less vague hunch that it may be useful in a future study. Occasionally, the motivation for collecting a certain type of data is simply "Why not?" Although the question's intention is rhetorical, there are answers, including 1) animal welfare concerns (Arnemo et al. 2006, Cattet et al. 2008); even nonintrusive data collection methods prolong handling time, and cumulative fitness effects of manipulation may not be discountable, 2) time constraints; one measurement is often collected at the expense of other measurements, because in most situations handling time (e.g., anesthesia duration) is limited, and 3) a general effort to work efficiently.

Fluctuations in financial support, shifts in priorities, changes in personnel, and technological advancement can make longitudinal studies dynamic affairs. Often the number of different types of data collected increases over time, as new procedures are added with ease. On the other hand, most researchers are reluctant to omit a data type that has been collected for a long time, even if its current or future utility is not apparent. When it becomes clear that some reduction or change in processes is in order, how should one decide which types of data to keep and which to drop?

The Scandinavian Brown Bear Research Project's (SBBRP) long-term monitoring program on brown bears (*Ursus arctos*) in Sweden (e.g., Swenson et al. 1994, Zedrosser et al. 2007*a*) is no exception from the aforementioned patterns of procedural congestion. During the 24 years of its existence, the capture–mark–recapture study has seen its share of protocol modifications and a proliferation of measurements taken and samples collected. At the time of writing, processing (e.g., marking, data, and sample collection) takes up a substantial portion (30–45 min, depending on surgical procedures for transmitter implantation) of the period during which an anesthetized bear can safely be manipulated (60 min) given the current anesthesia regime. Meanwhile, various new research questions and pilot studies compete for timeslots and manpower allocated for processing anaesthetized bears. Furthermore, an ever-growing list of protocol items and manipulations increases the risk of distraction and errors or omissions. Using data from the SBBRP as an example, specifically the collection of morphometric data intended for size and growth estimation, we illustrate how one may identify measurements that add little additional information and, thus, are potential candidates for elimination or replacement. We hope that this example will motivate others working with wildlife to critically evaluate the level of redundancy in their data collection protocols.

STUDY AREA

Monitoring occurred in 2 study areas located in northern and south-central Sweden. The northern study area (North, 67°N, 18°E) encompassed 12,000 km^2; the other site (South, 61°N, 18°E) was 11,500 km^2. These areas were based on genetically distinct subpopulations that correspond with geographical clusters of bears with no or very little interchange of females (Manel et al. 2004). Both study areas were within the southern, intermediate, and northern boreal vegetation zones (Nordiska ministerrådet 1984, Bernes

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Table 1. Description of the 11 morphometric measurements collected from brown bears captured during 1984–2006 in Sweden.

Measurement	Acronym	Description
Neck circumference	NC	Circumference of the neck in the middle between head and shoulders; recorded to the closest 0.5 cm.
Head circumference	HC	Circumference of the head at the widest part of the zygomatic arch between eyes and ears; recorded to the closest 0.5 cm.
Distance between ears	ED	Straight-line distance between the medial bases of the ears; recorded to the closest 0.5 cm.
Ear ht	EH	Straight-line distance from the center of the superior base of the ear to the tip of the ear; recorded to the closest 0.5 cm.
Chest girth	G	Circumference of the thorax at the level of the axilla. The bear was positioned in sternal recumbency with head and vertebral column linearly aligned; recorded to the closest cm.
Body ht	H	Straight-line distance from the caudal pad at the level of the *calcaneus* of the superior extremity to the highest point of the body at the superior tip of the *scapula* (i.e., the hump). The bear was positioned in ventral recumbency with head and vertebral column linearly aligned; recorded to the closest cm.
Body length	BL	Distance from tip of the nose to the base of the tail following the contour lines. The bear was positioned in sternal recumbency with head and vertebral column linearly aligned; recorded to the closest cm.
Tail length	TL	Distance from the base to the tip of the tail. The bear was positioned in sternal recumbency with head and vertebral column linearly aligned; recorded to the closest cm.
Front foot width	FFW	Width of the caudal pad of the front foot at its widest part; recorded to the closest 0.5 cm.
Back foot width	BFW	Width of the caudal pad of the back foot at its widest part; recorded to the closest 0.5 cm.
Back foot length	BFL	Max. distance from the proximal end of the caudal pad of the back foot to the superior end of the caudal pad of the toe; recorded to the closest 0.5 cm.

1994). Detailed descriptions of the study areas are provided in Zedrosser et al. (2006).

METHODS

As part of a larger study, brown bears were darted from a helicopter using a remote drug-delivery system during 1984–2006. Most captures occurred in mid-April in the south and in early May in the north, shortly after den emergence, to avoid danger of drowning (open water) and high ambient temperatures. Anesthetized bears were subjected to a data collection protocol aimed at obtaining various vital rates, biological samples, physiological data, and the morphometric measurements that are the focus of this investigation. All measurements we used in this study (Table 1) were taken with a tape measure. Because most bears were captured within a 2-week period in each study area, we did not adjust body size for capture date. All capture and handling conformed to current laws regulating treatment of animals in Sweden and were approved by the appropriate Swedish ethical committee (Djuretiska nämden i Uppsala). For further details regarding capture and handling of bears in this study, refer to Arnemo et al. (2006) and Zedrosser et al. (2007*b*).

We included only the 11 morphometric measurements (Table 1) taken consistently for a period exceeding 10 years, and only from those captures for which all 11 measurements were available. We performed principal components analysis on the scaled measurements (Everitt and Hothorn 2006) to visually inspect them for similarity and to identify the principal component that accounted for the most variation. We then predicted values for each individual bear along the first principal component (PC1), which we interpreted as an overall size index (Green 2001). Although factor loadings relate the original variables to the ordination axes, we calculated the correlation between each measurement and the predicted PC1 values, because we found this statistic (and associated estimates of uncertainty) easier to interpret. We constructed 95% confidence interval limits around the correlation between each measurement type and PC1 using 1,000 bootstrap replicas to facilitate comparison among measurements in terms of their reliability to predict the overall size index. We chose multivariate statistics over pair-wise correlations (correlation matrix) because we wanted to evaluate and compare the degree of correspondence of individual measurements with an overall size index based on the entire set of measurements. Because repeated measurements (i.e., at multiple capture occasions) from the same bear were not independent, we randomly selected one set of measurements from each bear in each available age category (yearlings, 2- to 3-yr-olds, and ad). This approach assumed that, due to their temporal spread, the remaining dependencies contributed little to the overall pattern of variation.

We conducted analyses both on pooled and separate data from each demographic group (sex × age category × subpopulation). We used R 2.8.0 (R Development Core Team 2008) for statistical analysis.

RESULTS

We included 424 size measurements (for each of 11 measurement types; Table 1) from 171 bears in the analysis. The PC1 explained 80% of the total variation (Fig. 1), justifying its use as an overall index of size. Of all size measurements, head circumference showed the greatest correlation with PC1 (the size index) and had a narrow 95% confidence band around the correlation (even after logit transformation; Fig. 2). Tail length was the least correlated with PC1 (Fig. 2), which also showed clearly in the bi-plot (Fig. 1). A tight clustering and similar length of vectors associated with 7 of the 11 measurements along PC1 (i.e., their loading in PC1) in the bi-plot (Fig. 1) indicated a high degree of similarity between these measurements in terms of their predictive power for an overall size index. We initially performed separate analyses for each combination of subpopulation, sex, and age class, but consistency in the outcome ultimately allowed us to interpret results from a joint analysis.

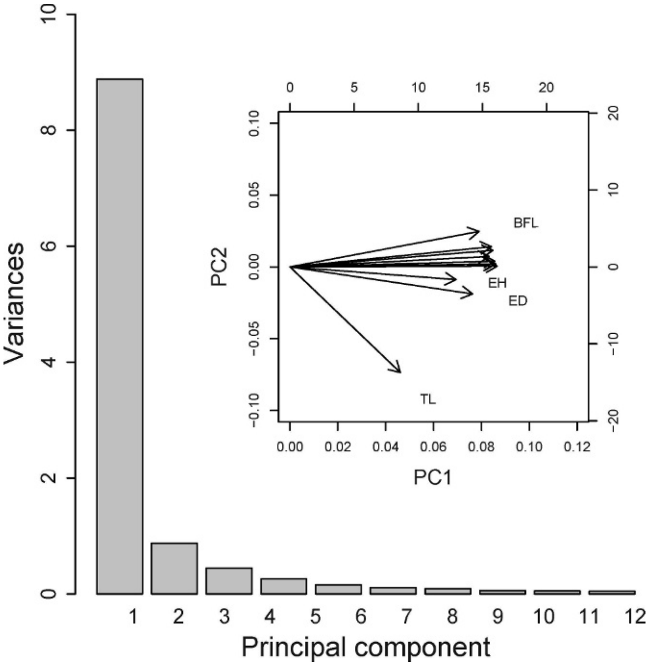

Figure 1. Scree plot (main frame) and bi-plot (sub-frame) showing results of the principal components analysis performed on 11 morphometric measurements collected on brown bears captured in Sweden during 1984–2006. The scree plot shows the variation explained by each principle component (PC). Arrows in the bi-plot indicate relative loadings for each measurement in the first and second PC. Loading vectors for the following 7 measurements are tightly clustered (labels not shown in bi-plot to avoid clutter): NC, HC, G, H, BL, FFW, and BFW. Measurements are defined in Table 1.

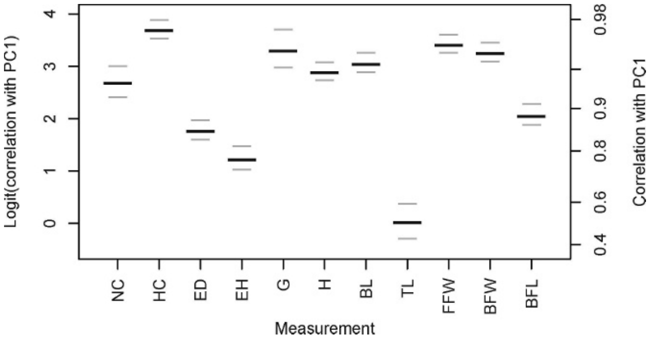

Figure 2. Estimated correlation (horizontal black bars) between each of 11 morphological measurements collected on brown bears captured in Sweden during 1984–2006 and the first principal component (PC1) based on a principal components analysis performed on the same 11 measurements. Bootstrap-derived 95% confidence limits are marked with horizontal gray bars. We used absolute values of PC1 in calculation of correlations to avoid problems (bimodality) during confidence interval estimation via bootstrapping. We logit-transformed correlations to facilitate visual separation of values close to one and for comparison of confidence interval bands; we provide tick marks indicating location of untransformed correlations for reference (right side). Measurements are defined in Table 1.

DISCUSSION

Evaluating long-term monitoring data from a population of brown bears in Scandinavia, we found that 7 of 11 morphometric measurements were so highly correlated with the overall size index that one measurement would suffice to reliably describe overall size. Of all measurements head circumference was the most predictive in terms of overall size index. Brown bear head circumference has been used in all peer-reviewed publications by the SBBRP to date that used size data (7 publications out of 92 total), due to comparability with the literature (Zedrosser et al. 2006). Coincidentally, the measurement of head circumference is required for all bears equipped with radio or Global Positioning System collars to properly adjust collars and thereby minimize risk of subsequent collar loss. Only one other measurement (i.e., total length) was used in one of these publications (Zedrosser et al. 2006), and it was used solely to highlight the preference for head circumference. Naturally one cannot rule out possible future needs for a hitherto unused measurement or sample. Nonetheless, a couple of decades' worth of data without obvious utility can be indicative of its low priority.

The collection of data because an opportunity arises rather than a concrete need could also lead to the pitfalls of convenience sampling. The latter term refers to potentially biased sampling based on ease or convenience of data collection rather than randomization (e.g., Anderson 2001). An example would be the collection of certain measurements only on individuals that are not subjected to transmitter implantation because it leaves more time for additional procedures.

It would be foolish to advocate the elimination of all but one (or a few) measurements just because they are highly correlated. Data have to have been collected with the intention to measure something similar (e.g., structural size) and they have to be of similar type or source (e.g., morphometric measurements) to consider a set of measurements or samples reducible. For example, body mass and body length are highly correlated in most species, yet both values are used in combination to calculate an index of individual body condition (Torbit et al. 1985, Cattet et al. 2002), arguably an important metric. In some situations assessing the degree of correlation between ≥2 measurements is precisely the goal of the investigation. Additionally, although some types of data are highly correlated when looking at the population as a whole, they may be less so for certain age classes (e.g., senescent stage) or other demographic categories.

There are merits in making data collection more parsimonious or at least being aware of priorities among measurements collected. The collection of size measurements we used in our analysis took 5–10 minutes, depending on proficiency of the collector and size of the bear. Whereas in some situations the effort and time required to collect each type of measurement or sample may seem negligible if looked at in isolation, combining them and multiplying with the total number of captures during a project's life can quickly add up to a more substantial investment. Although most of us are reluctant to be responsible for the cessation of the collection of a particular measurement, especially if it has been collected for many years, reductions or replacements of procedures performed on captured animals may eventually be required in most long-term projects. The need for parsimony also arises outside of wildlife capture and release studies. For example, harvested animals provide useful information about the harvest and the underlying population; hence, management agencies often require collection of data and samples on bagged animals (Mysterud et al. 2006, Bischof et al. 2008). Although animal welfare concerns are typically not an issue when dealing with harvested animals, the patience of harvesters and competition for financial and personnel resources need to be considered when planning or reviewing data collection procedures.

We recommend that researchers take a close look at the data collected and evaluate them critically with respect to current need and future potential, especially when designing or adjusting longitudinal studies. We note that although we used morphometric measurements as an example, the same considerations apply to all kinds of data collected, including samples and behavioral observations. Selecting the appropriate measurement(s) to retain out of a set of highly correlated similar measurements will be dependent on the given study system, research questions, and practical considerations. Nonetheless, the following considerations can be used to prioritize measurements that are similar. The list is by no means complete. 1) loss of information if the measurement or sample collection were to be dropped, 2) cost of collection (e.g., in terms of time, effort), 3) achievable measurement accuracy (e.g., observer and measurement error), 4) attainability (i.e., some measurements or samples are not always attainable for every individual or during each capture), 5) prevalence (frequency, duration) in the dataset to date, 6) history of use (e.g., publications, reports, contribution to adaptation or development of field procedures), 7) potential for future use, 8) comparability of desired analyses with similar studies performed elsewhere (i.e., conventional measurements), 9) other, unrelated uses (e.g., neck circumference for radiocollar application).

MANAGEMENT IMPLICATIONS

When multiple measurements are highly correlated and essentially document the same metric (in our example body size), eliminating some measurements in the field may be appropriate. Statistical tools such as principal components analysis may help decide which measurements provide similar information, and other criteria can be used to determine how to prioritize a set of closely related measurements. Although these recommendations apply to most field research, they are particularly relevant for long-term studies, where years of protocol refinements and extensions can lead to a congestion of measurements taken if procedures performed on individual animals are added at a greater rate than they are removed.

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