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The need for standardization in wildlife science: home range estimators as an example

Roman Gula · Jörn Theuerkauf

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Abstract Individual studies in wildlife science are indicative rather than conclusive. Although multiple studies can be meta-analyzed in such a way that scientific hypotheses can be tested, robust meta-analyses are often difficult or impossible if variables of interest are not measured in a uniform manner. We hypothesized that measurements, even of basic and unequivocal variables, are rarely standardized in wildlife sciences. We tested this assumption by reviewing randomly selected papers that describe the home range of mammals (n=25) and birds (n=25). In these papers, home ranges were calculated using 11 methods and 8 computer programs. The number of radiolocations used to calculate home ranges varied from 9 to >2,000. By estimating home ranges for two radiotelemetry data sets, we demonstrate that home ranges are not comparable if different methods are used and that estimates of home range are not standardized. We assume that measurements of other biological variables are even less consistent across studies. In order to advance wildlife sciences, we believe that standardization initiatives are required at an international level.

Keywords Methods · Home range · Meta-analysis · Scientific hypothesis testing · Standardization · Measurements

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R. Gula (✉) · J. Theuerkauf
Museum and Institute of Zoology,
Polish Academy of Sciences, Wilcza 64,
00679 Warsaw, Poland
e-mail: rgula@miiz.waw.pl

Introduction

The limited applicability, misuse, and overuse of statistical hypothesis testing in wildlife sciences have been discussed for more than a decade (Cherry 1998; Johnson 1999; Anderson et al. 2000; Guthery et al. 2001). As pointed out by Johnson (1999), products of statistical hypothesis testing are not very informative, and the procedure is often mistakenly believed to provide strong inference on the basis of a single study or sample. Several alternative methods have been proposed, yet none of them allow researchers to make conclusive statements without replication of the study (Anderson et al. 2000, 2001; Johnson 2002a, b). The only way to test scientific hypotheses is by replicating entire studies, possibly with different methods (Johnson 2002a). However, such opportunities are rare in wildlife sciences. Usually, knowledge is accumulated through the publication of single sets of results, which rarely contain sufficient information to allow global conclusions. Hypotheses are tested by meta-analyzing the results from individual studies carried out in different locations by different researchers. Meta-analyses can suffer from bias if results were not published that were either not statistically significant or inconsistent with current scientific beliefs (Johnson 1999). In many cases, robust meta-analyses may not be possible because suitable studies were not carried out using standardized methods, or because the results were not published in a standardized way. Recommendations for standardizing statistical data analyses have been offered in the past (Anderson et al. 2001). However, we believe that the problem is not limited to appropriate statistical procedures but stems from a lack of standardization with respect to the quantification of ecological variables. The lack of standardized measurements in wildlife sciences not only prevents robust meta-analyses but also restricts the potential for simple comparisons of basic biological variables across multiple studies. In 1929, Graham published a paper calling for standardization in forest biology. In our opinion, the issue of standardization still exists. With the emergence of new research tools and methods and the number of wildlife studies being carried out today, there is now even more confusion among the accumulated literature. In this paper, we tested the assumption that the level of standardization in wildlife sciences is insufficient for objective comparisons of variables across studies. We chose a widely used variable, the home range of an animal, and we reviewed two sets of publications (one on birds and one on mammals) presenting results on home ranges. Additionally, to demonstrate that standardization is necessary, we compared several home range estimators for radiotelemetry data sets of a mammal and a bird species—the wolf *Canis lupus* and the kagu *Rhynochetos jubatus*. Although we use home range as an example to illustrate the lack of standardization in wildlife research, the aim of this paper is not to discuss the best method for analyzing home ranges but to demonstrate the need for standardization in wildlife research in general.

Methods

We searched the ISI Web of Knowledge database for articles that included the term "home range size" in the title. Of the 136 results returned, we selected 88 publications presenting study on larger mammals (excluding bats and rodents) or birds in which radiotelemetry was used to locate the animals. From each of the categories, we selected the first 25 articles that were available online for further analyses. Ornithological papers were published in 15 journals and covered 23 species: *Accipiter cooperii*, *Accipiter gentilis*, *Aimophila aestivalis*, *Alectoris rufa*, *Anas platyrhynchos*, *Ammodramus henslowii*, *Bonasa umbellus* (three), *Botaurus stellaris*, *Chlamydotis undulate*, *Colaptes auratus*, *Dendrocopos medius*, *Dendrocopos minor*, *Francolinus gularis*, *Hylocichla mustelina*, *Lagonosticta sanguinodorsalis*, *Laterallus jamaicensis*, *Meleagris gallopavo*, *Neomorphus radiolosus*, *Numida meleagris* (two), *Passerculus sandwichensis*, *Picoides borealis*, and *Xiphorhynchus flavigaster*.

The papers on mammals were published in 17 journals and covered 21 species: *Bison bonasus*, *Callithrix argentata*, *Capreolus capreolus* (three), *Dama dama*, *Dasyprocta leporine*, *Felis nigripes*, *Lynx lynx*, *Martes americana*, *Mellivora capensis*, *Odocoileus virginianus*, *Panthera pardus*, *Pongo pygmaeus*, *Puma concolor* (two), *Rangifer tarandus*, *Rupicapra rupicapra*, *Sus scrofa* (two), *Urocyon cinereoargenteus*, *Ursus americanus*, *Ursus arctos*, *Ursus maritimus*, and *Vulpes vulpes*. We scanned the papers for (1) the method used to estimate the size of home range, (2) the software used, (3) the sample size, and (4) the period over which the home range was calculated.

We used various methods to estimate the home range of one wolf and one kagu. The radiotelemetry fixes of the wolf were collected from 2003 to 2005 in the Bieszczady Mountains, Poland (Gula 2008; Theuerkauf et al. 2007). The wolf was a breeding female from a pack that consisted of five to seven individuals (Tsunoda et al. 2009). We used only the fixes that were collected during 24-h continuous radiotelemetry of the female (see details in Eggermann et al. 2009). Our data set consisted of 4,032 locations collected over the course of 42 continuous 24-h radio-tracking sessions. We collected one fix every 15 min, for a total of 96 fixes per session. We used all of the fixes to calculate minimum convex polygons (MCPs); then, we randomly selected two fixes from each 24-h session to obtain a set of 84 independent fixes. In doing so, we assumed that a 12-h interval was sufficient to obtain independent locations.

From 2007 to 2009, we collected location data on a male kagu in Parc Provincial de la Rivière Bleue, New Caledonia (Theuerkauf et al. 2009; Gula et al. 2010). We located the kagu approximately three times per month, either during the day by triangulation or during the night by homing in. The data set consisted of 93 independent locations.

For each data set, we estimated 100 and 95 % MCP and 95 and 50 % kernel home ranges. We produced separate estimates for (1) all locations, (2) daylight locations, and (3) night locations. We estimated home ranges using the Animal Movement Program (version 2.0 Beta 12/9/98), an extension for ArcView (Hooge et al. 1999) with default settings (least square cross-validation). We used the outlier removal function of the Animal Movement Program to exclude 5 % of fixes during the estimation of 95 % MCPs.

Results

The authors of the scanned papers used 11 methods to estimate home ranges in 25 studies involving birds and 8 methods to estimate home ranges in 25 studies involving mammals (Table 1). In 13 of the bird studies and 9 of the mammal studies, home range was estimated by more than one method. Only two studies on mammals and six studies on birds did not report home ranges estimated by MCP. However, only 12 studies on mammals and 9 studies on birds provided 100 % MCPs. Home range estimates based on 95 % MCPs were just as common (12 studies on mammals and 10 studies on birds). Kernel estimates were used more frequently for birds (19) than mammals (8), and 95 % kernels were employed in most of these cases. Home range estimates were calculated using eight types of software. The most frequently used software was Animal Movement, followed by various versions of Ranges (Anatrack Ltd., UK). In eight of the publications, authors did not specify which type of software was used.

Table 1 Number (%) of studies which used various methods, software, sample size, and periods used to estimate home ranges in 50 studies of mammals and birds

	Birds (n=25)	Mammals (n=25)
Method		
MCP 100 %	9 (36)	12 (48)
MCP 95 %	10 (40)	12 (48)
Other MCP	2 (8)	4 (16)
Kernel 95 %	11 (44)	6 (24)
Other kernel	8 (32)	2 (8)
Other method (core area; partial area; harmonic mean 75 and 95 %; 95 ellipse; grids and circles)	5 (20)	2 (8)
Software		
AM ArcView	10 (40)	6 (24)
Ranges (v. 4–6)	7 (28)	6 (24)
Other software (Calhome, Home Ranger, Kernelhr 3.07, Biotas 1.03, Tracker, Telem-88)	6 (24)	7 (28)
Not specified	7 (28)	6 (24)
Number of locations		
Provided	20 (80) ranging from 9 to 2,313	17 (68) ranging from 16 to 848
Not specified	5 (20)	8 (32)
Period		
Annual	3 (12)	8 (32)
Seasonal (4 seasons, breeding, nesting, brood rearing, natal, post-dispersal)	17 (68)	11 (44)
Other (monthly, daily, multiannual)	8 (32)	7 (28)
Not specified	2 (8)	2 (8)

The number of locations varied from 9 to 2,313, depending on the study. Twelve publications did not report the number of fixes. Authors performed an asymptotic test in only six studies on mammals and nine studies on birds. Most of the time, seasonal estimates of home range were provided. Seasons were defined either by the climate (e.g., four seasons, dry/wet) or based on the biology of the studied species (e.g., breeding, nesting, brood rearing, natal, post dispersal), but usually precise dates were not provided. Four studies did not give any information about the period for which the home range was estimated.

In our study, using different methods to estimate the home ranges of a wolf and a kagu led to inconsistent results (Table 2). The MCP calculated using all locations (n=4,032) was 37 % larger than the MCP calculated using only 84 independent locations. For the wolf, estimates derived from 100 % MCPs were larger than those from 95 % kernels, whereas the opposite was true for the kagu.

Discussion

As shown in this review, even the assessment of an animal's home range, a presumably unequivocal and straightforward measure, is far from being standardized in the wildlife literature. The lack of standardization comprises radiotelemetry procedures, calculation methods, and data presentation. All estimates of the home range size of an animal depend on the sampling method, sampling scheme, and sample size. For example, estimation of home range based on fixes collected in daylight compared to the entire day differs because of different day and night activity patterns of animals. The accuracy of fixes collected by ground triangulation is limited by the accuracy of the determination of VHF signal direction, while locations obtained by homing are as precise as GPS receiver's error. Triangulation errors might be as large as several hundred meters, while GPS errors usually do not exceed a few meters. Also, the number of locations influences home range estimators. In this review, the number of locations varied from 9 to 2,313 (see Table 1) which exclude the potential for unbiased comparisons. The lack of standardization is also caused by the use of various estimators that produce substantially different results, despite being based on the same data sets (see Tables 1 and 2). Some of the methods used to estimate home ranges depend on parameters that can be arbitrarily chosen (e.g., <100 % MCPs, kernels, harmonic means, core areas, and ellipse methods). As a result, these estimators are not comparable

Table 2 Home ranges of one wolf and one kagu, estimated from radiotelemetry locations, using a variety of methods

Estimator	Wolf			Kagu		
	Mean (km^2)	SD	Number of fixes	Mean (km^2)	SD	Number of fixes
Multiannual						
MCP 100 % C	118.0		4,032			
MCP 100 %	74.8		84	0.182		93
MCP 100 % D	70.2		40	0.102		58
MCP 100 % N	66.8		44	0.170		35
MCP 95 %	71.5		84	0.129		93
MCP 95 % D	64.7		40	0.093		58
MCP 95 % N	60.1		44	0.127		35
Kernel 95 %	106.6		84	0.212		93
Kernel 50 %	13.7		84	0.038		93
Kernel 95 % N	113.4		40	0.293		35
Kernel 50 % N	9.3		40	0.033		35
Kernel 95 % D	96.3		44	0.165		58
Kernel 50 % D	9.8		44	0.031		58
Annual						
MCP 100 %	97.0	19.2	538–1,821	0.117	0.014	22–38
MCP 95 %	82.8	13.8	538–1,821	0.095	0.005	22–38
Kernel 95 %	90.8	31.9	10–37	0.211	0.018	22–38
Kernel 50 %	15.6	8.1	10–37	0.040	0.005	22–38

C continuous radio-tracking, *D* daylight locations, *N* night locations

among studies, particularly if different softwares are used to generate them. Additionally, many authors chose estimators which they considered as "realistic" or "the most accurate." We believe that one of the reasons for this is that there is a tendency to select estimators that appear to only include the space used by an animal. For instance, kernel estimates of home range are usually considered to be representative of the space actually used by an animal. On the other hand, MCP estimates are often considered to include a lot of space that is never visited by an animal. In reality, all estimates of home range include space that is not used. Secondly, there is a tendency to select estimators that attempt to distinguish between areas regularly used by the animal from those that are only visited sporadically. This stems from the definition of home range given by Burt (1943, p. 351): "… I would restrict the home range to that area traversed by the individual in its normal activities of food gathering, mating, and caring for young. Occasional sallies outside the area, perhaps exploratory in nature, should not be considered as part of the home range." Although this definition has an obvious biological meaning, it seems impractical and causes confusion when researchers need to interpret their data, especially considering that home ranges are usually dynamic in space and time. How can one distinguish which locations are related to "normal activities" from "exploratory" ones? In practice, this is done by excluding fixes based on their relative density (kernel) or distance from the core (harmonic mean). However, it is difficult to verify if home ranges estimated with such exclusions are truly representative. It would be a challenge to standardize the methods used for excluding fixes, and we consider this to be unnecessary.

All estimates of the home range of an animal depend on the sampling scheme and sample size. For example, the MCP of the wolf in this study was 37 % larger when it was based on all available dependent locations than when it was based on only independent fixes. The procedure of reducing fixes causes additional variation as it is based on a time interval that is presumed to be necessary to obtain independent locations. It has been shown that this commonly used method of reducing data also decreases the accuracy and relevance of estimates (Rooney et al. 1998; de Solla et al. 1999). Most wildlife studies are long-term, and sampling frequency is often influenced by intermittent funding, logistic limitations, inclement weather, and difficult field conditions. Unfortunately, this is the reality of most wildlife studies, especially those targeting larger species or those occurring in low densities. Thus, instead of standardizing sample sizes or sampling intervals, a better option may be to determine when the sample size is saturated (i.e., when its increase no longer causes a substantial change in the measured parameter).

Standardized methods for the calculation of biological variables can be relatively easy worked out if there is an agreement for the necessity of their calculation and presentation. The use of standardized metrics would not exclude the use of other not standardized ones. Methods of personal choice desired by the author and adjusted to particular type of inference might be presented additionally to standardized results.

One may argue that details in data collection are frequently described in the publications; therefore, they might theoretically be taken into account when estimators are compared. Our review, however, showed that such a posteriori standardization is difficult or often impossible if no raw data are presented. Presentation of raw data is not a common practice but might not always be possible if large data sets are involved. There is a potential for access to the original data by directly contacting the author. However, in our opinion, this can be difficult and certainly less convenient than standardization of data collection and presentation. Standardized information on data contents (metadata) integrated into publications would support access and exchange of standardized data. Moreover, as shown in this review, in many cases, the potential for unbiased comparison is often lost from the beginning because of the not standardized design of studies.

Standardization of measurements is crucial in physical sciences and technology. In chemistry, most lab procedures are normalized according to either national or international standards (e.g., ASA, DIN). Biological systems are usually more complicated, but at least measurements of basic biological variables should be standardized. The clinical research is already standardized (European Commission Directive 2001/20), and various attempts at standardization have taken place in biochemistry, genetics, systems biology, and bioinformatics (Brazma et al. 2006; Klipp et al. 2007). To a certain degree, proposals of science-based wildlife management decisions by Huettmann (2005) and standardized terminology in habitat evaluation by Hall et al. (1997) and Morrison (2001) are related to standardization. Wildlife techniques textbooks such as of Braun (2005), Sutherland (2006) or Sinclair et al. (2006) are attempts of standardizations at the level of undergraduate education. We are, however, not aware of broader standardization initiatives in wildlife sciences at an international scale.

In our opinion, measurement protocols in wildlife research are so diverse for basically two reasons. The first is that there are no standards to follow. The lack of standardization is partially related to the diverse nature of ecological systems and organisms but is a problem per se. The second reason is that scientists prefer to use methods which, in their opinions, best fit to their research objectives. We basically agree that there is no way to set standards of measurements that would fit all research needs, and this is also not our intention. We believe, however, that it is possible to set basic standards that allow further comparison and meta-analysis. In our opinion, standardization of procedures should be attempted first on a lower taxonomic level (family, genus, or species). There are two basic reasons for this. First, biologists at an international level are frequently organized according to taxa. Thus, groups of species experts working under the IUCN or organizations such as the International Bear Association can serve as platforms for standardization. Secondly, standardization is most likely to occur across studies that are performed on similar organisms because they share certain biological features. Moreover, an initial attempt at standardization on a lower taxonomic level might provide a useful model for other taxonomic groups to follow.

We conclude with a quote by Graham (1929, p. 245): “Biologists in every field are today finding themselves continually hampered by the incompleteness of their information concerning the biotic factors of environment. Furthermore, much of the information now available is not of the maximum possible value because the basic data are often not comparable. In order that biotic information may be of maximum value, it must be expressed in accurate comparable terms. This necessitates a standardization of methods used in collecting and recording information.” We think that, after over 80 years, Graham's statements are still valid, and standardization in wildlife sciences has yet to be achieved.

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