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Comparing radio-tracking and visual detection methods to quantify group size measures

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ABSTRACT

1. Average values of animal group sizes are prone to be overestimated in traditional field studies because small groups and singletons are easier to overlook than large ones. This kind of bias also applies for the method of locating groups by tracking previously radio-collared individuals in the wild. If the researcher randomly chooses a collared animal to locate a group to visit, a large group has higher probability to be selected than a small one, simply because it has more members.
2. The question arises whether location of groups by means of finding collared animals has smaller or greater bias than searching for groups by visual observation. If the bias is smaller or same, this method can be recommended for finding groups. However, such a comparison cannot be made by speculation, only by empirical investigation.
3. The present study compares the two methods empirically, by statistically comparing group size measures (mean, median, quantiles, frequency distribution, and 'typical group size') between two data sets. These data sets comprise of Rocky Mountain mule deer group size values collected in the same area during the same period of time, referring either to groups located by the traditional 'search and observe method' or located by tracking formerly collared individuals.
4. All group size measures are statistically similar in the two samples, thus we conclude that the two methods yielded similar biases. Although the true group size measures are not known, we presume that both methods have overestimated them. We propose that these results do not necessary apply to other species, thus cannot be generalized. The reason for this is that bias may depend on factors specific to the species: bias of visual observation may depend on how well the species conceals itself in the existing habitat, and the bias associated with finding groups using collared animals is likely dependent on group size distribution and also on the proportion of collared animals in the population.

KEYWORDS

Mule deer (*Odocoileus hemiounus*) – group size measures – crowding – typical group size – radio-tracking

INTRODUCTION

Several animal species normally live in groups, and their social environment is greatly influenced by group size. Therefore, assessing group size characteristics is a major task of descriptive and comparative studies in behavioural ecology (Krause & Ruxton 2002). When analysing mammal or bird group sizes quantitatively, one has to consider the right-skewed nature of group size distributions characteristic to most species (Reiczigel et al. 2008): most groups are small (including singletons), large groups are rare and very large groups are exceedingly rare. A general approach to dealing with outliers in statistical analysis is to exclude them from the analysis. This is not appropriate in studies of group size distribution because that would mean excluding a large proportion (often the majority) of observed individuals, thus greatly falsifying the results. Similar right-skewed frequency distributions characterise herds of many ungulate species (Sinclair 1977; Clutton-Brock 1982; Gueron 1995; Wronski et al. 2009; Ramesh et al. 2011; Dar et al. 2012; Buuveibaatar 2013; Brennan et al. 2015; Djaković et al. 2015; Semeñiuk 2015), including the subject of our present paper, the Rocky Mountain mule deer (*Odocoileus hemiounus hemionus*) (Bowyer 2001; Lingle 2003; Mejía Salazar et al. 2016).

Independent of the problems caused by right-skewed distributions, another problem arises when calculating an average value for group size data. Mean group size (data averaged over the groups) is the most common measure in the literature. However, average individuals necessarily live in groups larger than the mean group size, thus this measure underestimates the group size characteristics of average individuals. Therefore, Jarman (1974) proposed a measure called 'typical group size' (TGS), also called 'mean crowding', that is, group size data averaged over individuals. Briefly, for a sample of three groups containing 1, 2 and 3 individuals, mean group size equals (1+2+3)/3=2, while mean crowding equals (1+2+2+3+3+3)/6=2.33. A statistical comparison of mean crowding across samples is difficult because individual data points are not independent; whenever an individual joins or leaves a group, individual crowding values of all the other group members change in a coordinated manner. Flocker 1.1 (Reiczigel & Rózsa 2008) and QPweb (Reiczigel et al. 2013) are free statistical tools to handle these problems.

Biased sampling, however, still remains a major technical problem. Under field circumstances, the average group size tends to be overestimated because smaller groups and singletons are easier to overlook than large groups. This can possibly also apply to studies that use radio-collared individuals to locate groups that the formerly marked individuals happen to join.

In principle, radio-collared animals can be used for sampling groups in two ways. One possible way, though probably rarely applied in practice, is using it in the same way as sampling individuals. This implies that if three collared animals happen to be found in the same group, the group size is recorded three times. In this way, the average of group sizes recorded results directly in TGS. The other – perhaps more intuitive, and more often used – way is when collared animals are used just to locate a group, and each group found is counted just once, independently of the number of collared animals in it. In this case, the average of group sizes results in the mean group size and TGS should be calculated by the formula:

$$\sum_{i=1}^{G} n_i^2 \;/\; \sum_{i=1}^{G} n_i$$

where G is the number of groups, and $n_1, n_2, \ldots, n_G$ are the group size values.

It is clear, however, that this method overestimates the true mean group size, as small groups are less likely to be detected, simply because they have fewer members. Therefore mean group size, either based on visual observation or by tracking radio-marked individuals, overestimates the true value. We faced this problem during field works focused on mule deer and realised that true measures remain unknown, as the selection bias cannot be quantified.

Nevertheless, this is not necessarily the most important question from a practical point of view. The practical question is whether or not we may compare group size data obtained in a traditional way (field observations of groups) with data obtained through radio tracking marked individuals to locate the groups. Supposedly, both methods tend to overestimate average group sizes, but how much do these biases differ? Below we attempt to answer this question by statistically comparing the mule deer group size data collected in the same area and during the same period either by traditional observations or by tracking radio-collared individuals.

1. METHODS AND MATERIALS

1.1. Data source

A study on chronic wasting disease (CWD) transmission dynamics was conducted at Antelope Creek (50.66°N, 108.27°W), a 248 km^2 CWD endemic area in south Saskatchewan, Canada (Silbernagel 2011; Mejía Salazar et al. 2016). This study site is within the mixed grassland ecoregion and consists of crop (46.6%), grassland (35.6%), shrub (7.6%), woodland (2%) and open water (0.3%). A total of 365 Rocky Mountain mule deer (*Odocoileus hemionus hemionus*) were captured during two time periods each year between 2007 and 2012. In March, juvenile (8-month-old) and adult deer were captured using a helicopter and a net-gun. In June and July, fawns from collared adult females were captured by hand. Juveniles and adults were tagged with either a very-high-frequency (VHF) or a global positioning system (GPS) radio-collar (Lotek Wireless, Ontario, Canada; Advanced Telemetry Systems, Minnesota, USA), and fawns with an expandable VHF. Deer were helicopter-captured to obtain a balanced sample of adult males and females, and juvenile males and females in each year. Deer were captured whether or not they were found in groups.

From 2008 to 2013, all year round, select individuals (n = 197 collared deer) were tracked at least twice a month and their group characteristics were recorded (date, time, habitat, number of individuals in the group, sex and age class of every individual in the group, location using a hand-held GPS, and the distance from observer). To avoid double tracking of the same focal deer, observers were assigned different deer within a day. A group was defined as a behaviourally coordinated and spatially cohesive aggregation of deer, in which every deer was within 10 body lengths of at least another one (Bowyer 2001). Solitary deer were defined as a group of 1 to consider all social units relevant to the study of social organisation (Hirth 1977; Bowyer 2001; Monteith 2007). Groups with no collared deer were also spotted while following specific trails and their group characteristics recorded. This study was approved by the University of Saskatchewan's Animal Research Ethics Board (Permit number 20050135), and adhered to the Canadian Council on Animal Care guidelines for humane animal use.

1.2. Analysis

We removed records with deer in tall shrub or those fleeing from a location of cover as it is difficult to accurately count and classify deer in a group under such circumstances. We also removed time periods in which the sample size was small. A final dataset with 2656 records from 16 December 2008 to 15 December 2012 was obtained. We divided this data set into two parts, one considering groups with at least one collared deer ('radio-collared', n = 2195 groups), and the other with groups in which none of the members were collared ('conventional',

n = 461 groups). Groups with several collared deer were entered in the data set just once, independently of the number of collared deer in them.

We compared the frequency distribution, mean, standard deviation, median, quartiles and quantiles of the group size, and TGS in the two parts of the data set. Means were compared by bootstrap *t*-test, variances by Levene's test, medians and quartiles by Mood's median test, distributions by bootstrap Wilcoxon-Mann-Whitney-test, chi-square test, and Fisher's exact test. Bootstrap tests and confidence intervals were computed using 5000 bootstrap replications. Analyses were made by R and QPweb. All reported *p*-values are two-sided.

2. RESULTS

Group size distributions are presented in Figure 1, and statistical measures characterising them are shown in Table 1.

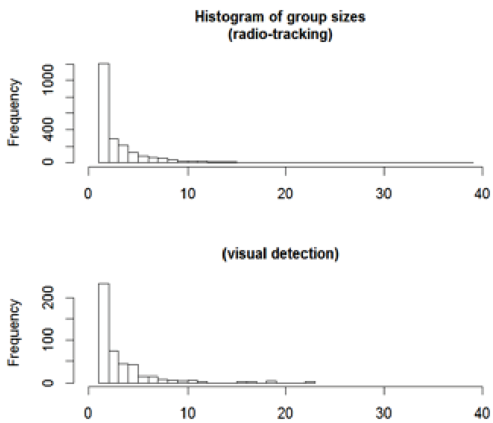

Figure 1. Distribution of group size by detection methods.

Medians as well as quartiles and deciles are equal in the two parts of the data set. The only significant difference is that singletons have higher frequency in the radio group (36% vs 30%, p=0.0357). Other parameters do not differ significantly (means: p=0.7280, variances: p=0.8095, TGS: p>0.4). The same is true for the comparison of distributions (bootstrap Wilcoxon-Mann-Whitney test: p=0.9640, chi-squared test: p=0.1495).

3. DISCUSSION

To the best of our knowledge, this is the first study in the literature to compare group size measures between field data obtained through the conventional 'search and observe groups' method versus the 'locate groups by radio-tracked individuals' method. None of the analysed measures differed significantly between the two data sets even though we have applied rather large sample sizes.

Slightly better detection of singletons may be regarded as an advantage of the radio method.

We cannot know the true (unbiased) measures of mule deer group sizes, although it is very likely that our measures overestimated these values due to the reduced observability of small groups, and singletons in particular. We conclude that the bias caused by the conventional 'search and observe groups' method was similar to the bias caused by the 'locate groups by radio-tracked individuals' method, thus the two methods yielded statistically comparable results.

It seems likely that animals' perception of conspecific groups and their motivation to join groups of different sizes may differ among species, just like the human observational bias is likely to vary across different species observed. Therefore, we believe that our above results do not necessarily apply for other species and thus should not be generalised.

Table 1. Various statistics of group size distributions. The only feature in which the two groups differ significantly is the frequency of singletons.

Measure	Radio (n=2195)	Conventional (n=461)
Mean group size	3.44 (95% CI: 3.30 to 3.61)	3.51 (95% CI: 3.22 to 3.84)
Typical group size	7.45 (95% CI: 6.82 to 8.36)	6.86 (95% CI: 5.95 to 8.01)
Median group size	2 (95% CI: 2 to 2)	2 (95% CI: 2 to 3)
Lower and upper quartile	1 and 4	1 and 4
Deciles (10%, 20%, … 90% percentiles)	1, 1, 1, 2, 2, 3, 4, 5, 7	1, 1, 1, 2, 2, 3, 4, 5, 7
Range	1 to 39	1 to 23
Relative frequency of the smallest groups (groups of 1, 2, and 3 deer)	36%, 19%, 13%	30%, 20%, 16%
Relative frequency of the largest groups (7-10 and >10 deer)	7.7% and 5.1%	7.2% and 4.8%

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