How many brown bear fecal samples are enough?

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**Abstract**

Understanding how large a sample size is needed for reliable dietary analysis, based on fecal samples, is an important step in studying a species’ ecology. Research projects spend a lot of time and money searching for and collecting fecal samples, when perhaps only a fraction of that time and money is needed to obtain necessary sample size for a reliable dietary analysis. I analyzed the diet of brown bears based on 498 fecal samples collected in the study area of the Scandinavian Brown Bear Research project from 2015-2016, to test how many fecal samples would be needed to obtain a reliable estimate of the dietary content in a given year. Using the Chi-squared goodness of fit test I show that only a fraction of the fecal samples collected are needed for dietary analysis. For population fecal sample analysis, without dividing the data into too many subcategories, found that 10% of the fecal samples would provide reliable dietary analysis results. However, when dividing the data into categories based on sex and season I found that a larger percent of the data was needed. I found that females accompanied by cubs-of-the-year show results representative of the population sample, and would require a sample size of 72 fecal samples. My suggested sampling size depends on the depth of the question being asked. For more basic, rudimentary understanding of brown bear dietary analysis, I recommend n=49, but for a question that needs a further sub-division into categories, I recommend n=99 with ~25% of the samples falling in each of the following categories: male & mating, male & berry, female & mating, and female & berry.

Key words: brown bears, fecal samples, dietary analysis

**Introduction**

This article reviews the various ways in which animal faeces may be exploited by the ecolo-

gist. While we tend to think of animal excrement purely as a waste product, the amount

of information which can be gleaned from it is amazing. Indeed it proves to be one of the

mammal-ecologist’s, or wildlife manager’s, most invaluable tools.

Even to the animals themselves, the faeces are not purely a waste product. They may

be used as ownership markers: badgers delineate the boundaries of their territories with

latrine pits (e.g. Neal,

1948, 1977,

Kruuk,

1978);

free-ranging stallions cover the

dung-piles

of

the mares

of

their harems with their own dung (Klingel,

1974,

Feist

&

McCullough,

1976)

etc.

In

addition the dung may act as a vector for olfactory secretions

from the

anal

glands, acting as a substrate for chemical communication between individuals

(e.g. review by Stoddart

1980).

To the student of wildlife, faeces provide potential for ‘ecological detection’

on

a

tremendous variety

of

fronts. From studies of faecal distribution and accumulation, one

can derive very accurate estimates of population size of the defaecator in a given area.

Since

it

is often possible to distinguish sex, as well as species

of

dunger, you not only

have population size but

also

sex-structure. Further, recent work suggests that, within any

Dietary analysis is a vital aspect of ecology. Knowledge of feeding habits are key in understanding the biology and ecology of organisms (López-Wilchis & Torres-Flores 2007) Data on feeding habits and rates of consumption are needed for several aspects: (1) to determine the relationship of food availability to population dynamics, (2) to examine mechanisms of competitive interactions, and (3) to assess the role of consumers in ecosystems (Batzli & Cole, 1979). Animals can have strong impacts on the environment around them based on their feeding habits. Herbivores, for example, regulate plant standing crops and the structure of plant communities via selective foraging (Huntly 1991). Dietary analysis also has a role in animal husbandry and care (Norris 1943).

The study of brown bear (*Ursus arctos)* diet and feeding ecology is essential on several fronts. On one front, the brown bear is a predator of the free-ranging domestic sheep in Norway which is considered the preeminent threat to brown bear reestablishment and conservation (Sagør et al. 1997). Sheep farmers were compensated for 1,821 sheep killed by bears in 1995, which represented 0.13% of the total number of sheep at the time (Aanes et al. 1996). In addition, during a 10-year study, Mabille et al. (2015) found the number of carcasses confirmed to have been killed by bears represented 8.1% of the number of claims made. To further complicate the image, the population of brown bears is increasing in Scandinavia (Sæther et al. 1998). This implies a future increase in bears numbers, distribution, and density across Norway and Sweden (Persson et al. 2001). Ultimately, understanding the feeding ecology is vital to understanding not only the ecology of an animal, but also for successful management and conservation of said animal (Putman 1984). To study their diet, brown bear fecal samples must be collected. This is normally done by walking along transects (Dahle et al. 1998, Persson et al. 2001, Hamer & Herrero 1987). Fecal sample collection takes a long time and depending on the terrain can be an arduous task. Hamer & Herrero dedicated 945 man-days over a five-year period in the field and collected 405 fecal samples (Hamer & Herrero 1987). This is a very time and energy consuming project to undertake.

With that in mind, I wondered whether there is a more efficient way go about the process of collecting bear fecal samples. The overall goal of my study was to determine how many fecal samples are needed to obtain a reliable estimate of dietary content on the population level. I asked the questions: at what point does the sample size grow too small, where the results are no longer representative of the total sample population? And, is a dietary estimate biased if sample collection is not random, but based on a certain sex and age class? To answer these questions, I hypothesized that the accuracy of population diet analysis based on fecal samples would decrease with a decreasing number of fecal samples a diet analysis is based upon. I further hypothesized that the accuracy of population diet analysis decreased when dietary analysis was based on a specific sex or age class, or only a few individuals.

**Study area**

The study area was the main study area of the Scandinavian Brown Bear Research project in Dalarna and Gävleborg counties in southcentral Sweden (61°N, 15°E). This area is located in the boreal zone and is comprised of approximately 12,000 km² of intensively managed forest (Zedrosser et al. 2006). The mean daily temperatures are -7°C in January and 15°C in June and the precipitation is 350-450 mm of during the growing season (Elfström et al. 2008). The region is mostly hilly and undulating, with elevations ranging from 175 to 725 m above sea level and thus below the timberline (Dahle & Swenson 2003, Martin et al. 2010). The area is dominated by Scots pine (*Pinus* sylvestris), Norwegian spruce (*Picea* abies) (Zedrosser et al. 2006). Bear density is estimated at 30 bears/1000 km² (Bellemain et al. 2005).

**Methods**

*Sample collection, preparation, and analysis*

Fecal samples were collected from free-ranging brown bears equipped with GPS-GSM (Global System for Mobile Communications, Vectronic Aerospace GmbH; Berlin, Germany) collars (Steyaert et al. 2012). Refer to Arnemo et al. (2006) for bear capture and handling details. The collars were scheduled to provide one location every 30 minutes. Sites were visited where an individual bear had stayed for ≥1.5 hours at a cluster site, defined as an area with at least three consecutive GPS locations within a 30 m radius. Fecal samples were only collected when there were no observable signs, such as different sized tracks or multiple day beds, indicating that another bear might have been present at the cluster site. Each sample was collected in a plastic bag, avoiding soil and debris, and stored at -20°C in a freezer until later analysis.

The fecal samples were analyzed following the methods described by Hamer & Herrero (1987), Dahle et al. (1998), and Persson et al. (2001). Each fecal sample was defrosted and homogenized, then five random 6ml subsamples were collected. Each subsample was individually washed through a 0.8 mm wire mesh and then analyzed with a 6.3-30 stereoscope and a 40-630 microscope. All food items were visually identified to the lowest taxonomic level possible and sorted into five categories: berries, insects, vertebrates, vegetation, and other. The percent volume of each food item was visually estimated, as visual estimations of percent volume corresponds well with percent based on exact volume (Mattson et al. 1991). The mean of the five subsamples was used as representative of the dietary content of the one fecal sample.

*Statistical analysis*

For each fecal sample, the proportional volume of the 5 fecal subsamples were averaged; this was the overall population sample. I separated the average dietary proportions of the fecal samples into different categories to be analyzed. The categories were as follows: Population, Mating, Berry, Male, Male & Mating, Male & Berry, Female, Female & Mating, and Female & Berry (Table 1). Mating (May-July 15th) and Berry (July 15th-September) based on Steyaert (2012).

Table 1. Categories based on season and sex used to analyze the dietary content of brown bears in Scandinavia 2015-2016.

|  |  |  |
| --- | --- | --- |
| Category | N | Description |
| Population | 498 | Mean of all fecal samples |
| Mating | 152 | Mean of fecal samples from the Mating season |
| Berry | 346 | Mean of fecal samples from the Berry season |
| Male | 111 | Mean of fecal samples from male bears |
| Male & Mating | 43 | Mean of fecal samples from male bears during the Mating season |
| Male & Berry | 68 | Mean of fecal samples from male bears during the Berry season |
| Female | 387 | Mean of fecal samples from female bears |
| Female & Mating | 109 | Mean of fecal samples from female bears during the Mating season |
| Female & Berry | 278 | Mean of fecal samples from female bears during the Berry season |

Using a random number generator, fecal samples from each category were removed by 10% increments. At each increment, the remaining average proportional distribution of dietary items were statistically compared to the original sample size in the category with a Chi-squared goodness of fit test, to see if the dietary proportions were significantly different. This process was repeated until either there was only 10% of the original data remaining, or the p-value of the Chi-squared test was ≤0.05.

For the second hypothesis, the fecal samples were categorized into different categories based on the bear’s sex and age class and whether they had dependent offspring or not. The categories were: adult male (> 4 years of age; AM), sub-adult male (1-3 years, SM), lone female (> 4 years, LF), sub-adult female (1-3 years, SF), female with cubs-of-the-year (COY), and females accompanied by yearling offspring (YF) (Steyaert 2012) (Table 2). At each 10% increment, the remaining proportional distribution of dietary items were statistically compared with the population base line with a Chi-squared goodness of fit test, to see if the dietary proportions were significantly different. In addition, I randomly selected from each of these categories the fecal samples of two individual bears. The fecal samples from the two individuals represent following individual bears, while the above categories represent the random assortment of fecal samples available in the woods. The average dietary proportion of the fecal samples calculated from the two individuals were compared to both the population category and the categories from which they had been selected from.

All analyses were carried out in the statistical software R 3.4.0 (R Core Team 2017). Although I carried out sequential testing, I did not use a Bonferroni correction of the p-values, because this procedure is assumed as too conservative (Moran 2003, Garamszegi 2006).

Table 2. Categories based on age, sex, and whether they had dependent offspring or not, used to analyze the dietary content of brown bears in Scandinavia 2015-2016.

|  |  |  |
| --- | --- | --- |
| Category | N | Description |
| Population | 498 | Mean of fecal samples of all bears |
| Adult male | 64 | Mean of fecal samples of fully mature males living alone |
| Sub-adult male | 47 | Mean of fecal samples of males 1-3 years old living alone |
| Lone females | 218 | Mean of fecal samples of fully mature females living alone |
| Sub-adult females | 84 | Mean of fecal samples of females 1-3 years old living alone |
| Females with cub-of-the-year | 72 | Mean of fecal samples of fully mature females living with cubs under a year old |
| Females with yearlings | 13 | Mean of fecal samples of fully mature females living with a cub 1-2 years old |

**Results**

An overall sample population of 498 fecal samples was collected in 2015-2016(Table 3). I found no significant differences between the average dietary content proportions when comparing the overall population sample with sample sizes decreasing 90%-10% from the overall sample size (Table 4). Even with only 10% of the original sample size (49/498) the results showed no significant differences between the average dietary proportions of food items (p=0.964).

Table 3. Average dietary content proportions of brown bears in Scandinavia 2015-2016.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Category | Berries | Insects | Vertebrates | Vegetation | Other | N |
| Population | 40 | 19 | 9 | 27 | 1 | 498 |
| Mating | 2 | 28 | 16 | 48 | 0 | 154 |
| Berry | 57 | 15 | 6 | 18 | 2 | 346 |
| Male | 29 | 17 | 9 | 42 | 1 | 111 |
| Male & Mating | 3 | 20 | 16 | 55 | 1 | 43 |
| Male & Berry | 45 | 15 | 4 | 35 | 0 | 68 |
| Female | 43 | 19 | 9 | 23 | 1 | 387 |
| Female & Mating | 1 | 31 | 17 | 46 | 0 | 109 |
| Female & Berry | 60 | 15 | 6 | 14 | 2 | 278 |
| Adult male | 30 | 11 | 13 | 42 | 1 | 64 |
| Sub-adult male | 28 | 24 | 2 | 43 | 0 | 47 |
| Lone females | 47 | 17 | 10 | 20 | 2 | 218 |
| Sub-adult females | 37 | 22 | 5 | 27 | 1 | 84 |
| Females with cub-of-the-year | 45 | 19 | 8 | 24 | 1 | 72 |
| Females with yearlings | 17 | 30 | 18 | 33 | 0 | 13 |

Table 4. The results of a Chi-squared test comparing the reduced sample sizes of brown bear average dietary content proportions collected in Sweden in 2015-2016, to the average dietary proportions of the total sample population.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| N | Percent | χ² | DF | p-value |
| 448 | 90 | 0.10 | 4 | 0.999 |
| 398 | 80 | 0.08 | 4 | 0.999 |
| 348 | 70 | 0.04 | 4 | 1 |
| 299 | 60 | 0.10 | 4 | 0.999 |
| 249 | 50 | 0.10 | 4 | 0.999 |
| 198 | 40 | 0.24 | 4 | 0.994 |
| 148 | 30 | 0.18 | 4 | 0.996 |
| 99 | 20 | 1.18 | 4 | 0.881 |
| 49 | 10 | 0.59 | 4 | 0.964 |

The sample size was divided into seasons, mating and berry, and the process repeated. I found no significant difference between the average dietary content proportions when comparing the overall mating population sample with sample sizes decreasing 90%-10% from the overall mating sample size, this proved true with the berry season as well (Table 5). In both cases, 10% of each total seasonal population was not significantly different from the entire seasonal populations.

Table 5. The results of 2 Chi-squared tests comparing the reduced sample sizes of brown bear average dietary content proportion, in mating and berry seasons, to the average dietary content proportions of each total season population sample size. DF was decreased here and in further tables due to the samples lacking one, or more, of the 5 food categories: berries, insects, vertebrates, vegetation, other. \* The average dietary proportion had no food category: other.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Season | N | Percent | χ² | DF | p-value |
| Mating | 137 | 90 | 0.01 | 3\* | 1 |
| 122 | 80 | 0.08 | 3\* | 0.994 |
| 107 | 70 | 0.73 | 3\* | 0.866 |
| 92 | 60 | 0.11 | 3\* | 0.991 |
| 75 | 50 | 0.57 | 3\* | 0.904 |
| 60 | 40 | 0.66 | 3\* | 0.882 |
| 45 | 30 | 1.69 | 3\* | 0.638 |
| 29 | 20 | 0.96 | 3\* | 0.812 |
| 14 | 10 | 4.04 | 3\* | 0.257 |
| Berry | 312 | 90 | 0.00 | 4 | 1 |
| 277 | 80 | 0.00 | 4 | 1 |
| 242 | 70 | 0.00 | 4 | 1 |
| 208 | 60 | 0.18 | 4 | 0.996 |
| 173 | 50 | 0.23 | 4 | 0.994 |
| 138 | 40 | 0.46 | 4 | 0.978 |
| 104 | 30 | 1.33 | 4 | 0.857 |
| 71 | 20 | 1.29 | 4 | 0.863 |
| 35 | 10 | 1.66 | 4 | 0.799 |

The sample size was divided by sex, and the process repeated. I found no significant difference between the average dietary content proportions when comparing the overall male/female population sample with sample sizes decreasing 90%-10% from the overall male/female sample sizes (Table 6).

Table 6. The results of 2 Chi-squared tests comparing the reduced sample sizes of male and female brown bear average dietary content proportion to the average dietary content proportions of each total sex sub-population sample size. \* The average dietary proportion had no food category: other.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Sex | N | Percent | χ² | DF | p-value |
| Male | 100 | 90 | 0.26 | 4 | 0.992 |
| 89 | 80 | 0.51 | 3\* | 0.917 |
| 78 | 70 | 1.10 | 3\* | 0.776 |
| 67 | 60 | 0.58 | 3\* | 0.902 |
| 56 | 50 | 2.30 | 3\* | 0.513 |
| 45 | 40 | 1.64 | 4 | 0.801 |
| 34 | 30 | 1.35 | 4 | 0.853 |
| 22 | 20 | 5.92 | 3\* | 0.115 |
| 11 | 10 | 3.74 | 3\* | 0.291 |
| Female | 349 | 90 | 0.07 | 4 | 1 |
| 309 | 80 | 0.10 | 4 | 0.999 |
| 270 | 70 | 1.12 | 4 | 0.891 |
| 231 | 60 | 1.20 | 4 | 0.877 |
| 192 | 50 | 1.20 | 4 | 0.877 |
| 153 | 40 | 1.21 | 4 | 0.877 |
| 115 | 30 | 1.36 | 4 | 0.850 |
| 77 | 20 | 1.57 | 4 | 0.814 |
| 39 | 10 | 4.33 | 4 | 0.363 |

Male sub-population was further divided into by the mating and berry seasons. Here I found significant difference between the average dietary content proportions when comparing the overall male & mating/male & berry population sample with sample sizes decreasing 90%-40/30% from the overall male & mating/male & berry sample sizes (Table 7). The male & mating sub-population becomes significantly different (p=0.009) at 40% of the overall male & mating sub-population sample size (Figure 1). The male & berry sub-population becomes significantly different (p=0.011) at 30% of the overall male & berry sub-population sample size (Figure 2).

Table 7. The results of 2 Chi-squared tests comparing the reduced sample sizes of male brown bears in mating and berry seasons’ average dietary content proportions, to the average dietary content proportions of each total sex & season sub-population sample size. \* The average dietary proportion had no food category: other.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Sex & Season | N | Percent | χ² | DF | p-value |
| Male & Mating | 39 | 90 | 0.47 | 4 | 0.976 |
| 35 | 80 | 1.05 | 4 | 0.903 |
| 31 | 70 | 1.92 | 4 | 0.751 |
| 27 | 60 | 2.88 | 4 | 0.579 |
| 21 | 50 | 6.59 | 4 | 0.160 |
| 17 | 40 | 13.74 | 4 | 0.009 |
| Male & Berry | 61 | 90 | 0.18 | 3\* | 0.980 |
| 54 | 80 | 0.01 | 3\* | 1 |
| 48 | 70 | 0.79 | 3\* | 0.853 |
| 41 | 60 | 0.87 | 3\* | 0.832 |
| 34 | 50 | 1.69 | 3\* | 0.640 |
| 28 | 40 | 2.06 | 3\* | 0.559 |
| 21 | 30 | 11.10 | 3\* | 0.011 |

Figure 1. The p-values of a Chi-squared test comparing the reduced sample size of male brown bears in the mating season’s average dietary content proportions, to the average dietary content proportions of the total male & mating sub-population sample size.

Figure 2. The p-values of a Chi-squared test comparing the reduced sample size of male brown bears in the berry season’s average dietary content proportions, to the average dietary content proportions of the total male & berry population sample size.

Dividing the female sub-population into mating and berry seasons also has an effect at a low sample size (Table 8). At 10% of the total female & mating sample size, the female & mating sub-population’s average dietary content proportions becomes significantly different (Figure 3). However, the female & berry sub-population does not significantly differ at 10% (0.702).

Table 8. The results of 2 Chi-squared tests comparing the reduced sample size of female brown bears in the mating and berry season’s dietary content proportions, to the average dietary content proportions of each total sex & season population sample size. \* The average dietary proportion had no food category: other. \*\* The average dietary proportion had no food categories: berry, other.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Sex & Season | N | Percent | χ² | DF | P-value |
| Female & Mating | 98 | 90 | 0.01 | 3\* | 1 |
| 87 | 80 | 0.01 | 3\* | 1 |
| 76 | 70 | 1.03 | 3\* | 0.793 |
| 66 | 60 | 0.26 | 2\*\* | 0.876 |
| 55 | 50 | 0.16 | 2\*\* | 0.922 |
| 44 | 40 | 1.35 | 3\* | 0.728 |
| 33 | 30 | 0.10 | 3\* | 0.992 |
| 22 | 20 | 0.97 | 2\*\* | 0.617 |
| 11 | 10 | 27.50 | 2\*\* | 0.000 |
| Female & Berry | 250 | 90 | 0.15 | 4 | 0.998 |
| 222 | 80 | 0.67 | 4 | 0.956 |
| 195 | 70 | 0.60 | 4 | 0.963 |
| 168 | 60 | 0.60 | 4 | 0.963 |
| 140 | 50 | 1.64 | 4 | 0.801 |
| 112 | 40 | 1.34 | 4 | 0.854 |
| 84 | 30 | 2.19 | 4 | 0.701 |
| 56 | 20 | 1.78 | 4 | 0.777 |
| 28 | 10 | 2.19 | 4 | 0.702 |

Figure 3. The results of a Chi-squared test comparing the reduced sample size of female brown bears in the mating season’s average dietary content proportions, to the average dietary content proportions of the total female & mating population sample size.

I found that the average dietary content proportions of AM, SM, and YF were significantly different compared to the overall sample population (Table 9). In addition, Table 9 shows that the fecal samples from the 2 individuals were significantly different from the categories that the individuals were selected from; this is true of all but the SM. I found no significant differences between the average dietary content proportions when comparing the LF, SF, and COY with the overall population sample or between the average dietary content proportions when comparing the SM with the fecal samples collected from the 2 individual SM (Figure 4).

Table 9. The results of Chi-squared tests comparing the difference between the average dietary content proportions in different categories of brown bear fecal samples. Adult male (AM), Sub-adult male (SM), lone female (LF), sub-adult female (SF), females with cubs of the year (COY) and females accompanied by yearlings (YF) compared the average dietary content proportion of each category to the population sample. AM 2/TTL, SM 2 vs TTL, LF 2 vs TTL, SF 2 vs TTL, COY 2 vs TTL, and YF 2 vs TTL compared the average dietary content proportion from two individuals randomly selected from each of the categories against the sample population. AM 2 vs AM, SM 2 vs SM, LF 2 vs LF, SF 2 vs SF, COY 2 vs COY, and YF 2 vs YF compared the average dietary content proportion from the two individuals randomly selected to the category average. \* The average dietary proportion had no food category: other.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| N | Sex & Stage | χ² | DF | p-value |
| 64 | AM | 15.80 | 4 | 0.003 |
| 24 | AM 2 vs TTL | 37.17 | 4 | 0.000 |
| 24 | AM 2 vs AM | 13.39 | 4 | 0.010 |
| 47 | SM | 19.39 | 3\* | 0.000 |
| 17 | SM 2 vs TTL | 8.49 | 3\* | 0.037 |
| 17 | SM 2 vs SM | 3.30 | 3\* | 0.348 |
| 218 | LF | 4.36 | 4 | 0.359 |
| 21 | LF 2 vs TTL | 18.35 | 3\* | 0.000 |
| 21 | LF 2 vs LF | 30.37 | 3\* | 0.000 |
| 84 | SF | 2.41 | 4 | 0.661 |
| 12 | SF 2 vs TTL | 16.42 | 3\* | 0.001 |
| 12 | SF 2 vs SF | 15.04 | 3\* | 0.002 |
| 72 | COY | 1.05 | 4 | 0.902 |
| 17 | COY 2 vs TTL | 38.59 | 4 | 0.000 |
| 17 | COY 2 vs COY | 27.27 | 4 | 0.000 |
| 13 | YF | 28.92 | 3\* | 0.000 |
| 3 | YF 2 vs TTL | 34.97 | 3\* | 0.000 |
| 3 | YF 2 vs YF | 47.99 | 3\* | 0.000 |

Figure 4. The p-value of a Chi-squared test comparing the difference between the average dietary content proportions in different categories of brown bear fecal samples. Sub-adult male (SM), lone female (LF), sub-adult female (SF), and females with cubs of the year (COY) compared the average of total category dietary content proportion against the sample population average. SM 2 vs TTL, LF 2 vs TTL, SF 2 vs TTL, and COY 2 vs TTL compared the average dietary content proportions of the fecal samples from the two individuals randomly selected from each category against the sample population average. SM 2 vs SM, LF 2 vs LF, SF 2 vs SF, and COY 2 vs COY compared the average dietary content proportion of the fecal samples from the two individuals randomly selected against the category average.

**Discussion**

To preface my discussion, it should be mentioned that my results could have potentially looked differently had I divided the diet categories (berry, insect, vertebrate, vegetation, other) into lower taxonomic levels for analysis, e.g., dividing insects into *Formica* spp., *Camponotu*s spp., etc.

For general analysis of bear fecal sample, the data shows that ~ 10% (N=49, p=0.964) of the original sample size was sufficient to obtain a reliable estimate of the proportions of fecal dietary food items on the population basis. However, for more directed analysis, i.e., questions that seek to understand the diet of subcategories based on different sex and season, a greater number of fecal samples are needed. This is reinforced by evaluating male bears in both mating and berry season and female bears during the mating season. All of these categories require a larger sample size as they proved to be significantly dissimilar from their respective overall category sample population at 40% (N=17, p=0.009), 30% (N=21, p=0.011), and 10% (N=11, p<0.000). Based on these analyses, a sample size for each category to obtain a reliable estimate of the proportions of fecal dietary food items would be as follows: mating = 15, berry = 35, male = 11, male & mating = 21, male & berry = 28, female = 39, female & mating = 22, and female & berry = 28. So for a reliable estimate seeking to understand the diet of brown bears categorized based on sex and season, a sample size of 99 fecal samples would be necessary.

However, by comparing categories and individuals with each other and the total sample size I found another method for evaluating the overall sample size needed to obtain reliable population dietary analyses. I found that randomly choosing two male sub-adults and collecting only their fecal samples would provide a fecal sample analysis not significantly different from the total male sub-adult population (p=0.348). However, none of the other categories showed this relationship, so this appears to be more a lucky pull from the data more than a useful trend. More useful is that the dietary content proportions of LF (p=0.359), SF (p=0.661), and COY females (p=0.902) were all not significantly different from the overall sample population. Based on this analysis, I suggest that the most efficient category to use as a proxy sample population to obtain a reliable estimate on the population diet, would be the COY female category, as it has the smallest sample size at 72 fecal samples.

Based on my results, I recommend that for broad brown bear dietary questions, a fecal sample population of only 49 samples is necessary. For more precise questions that will seek to divide the population sample, 99 samples are recommended with a ~25% of the samples falling in each of the following categories: male & mating, male & berry, female & mating, and female & berry.

The diet analysis results, as previous papers have shown, exhibit great diet differences between seasons (Stenset et al. 2016). The seasonal shift is mainly related to the availability of berries, as in the berry season, 57% of the diet is berries. Vertebrates do not have a large impact on the diet as it did in other studies as free-ranging sheep are not prevalent in the study site (Dahle et al. 1998). However, I suggest that this study should be repeated with data from more years.

Another aspect for future consideration, is comparing the categories of mating, berry, male, male & mating, male & berry, female, female & mating, and female & berry to the population category. I compared the decreasing sample size in each category with the original category sample size; however, comparing it to the population could add new insight.

The categories of AM, SM, LF, SF, COY, YF were not systematically decreased and statistically compared like the previous categories were. It may be that the COY sample size could be reduced even further and be used in place of the recommended 49 fecal sample for broad brown bear dietary questions.

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