Determining number of feedings per day for young wild mammals being hand-fed substitute milk formula

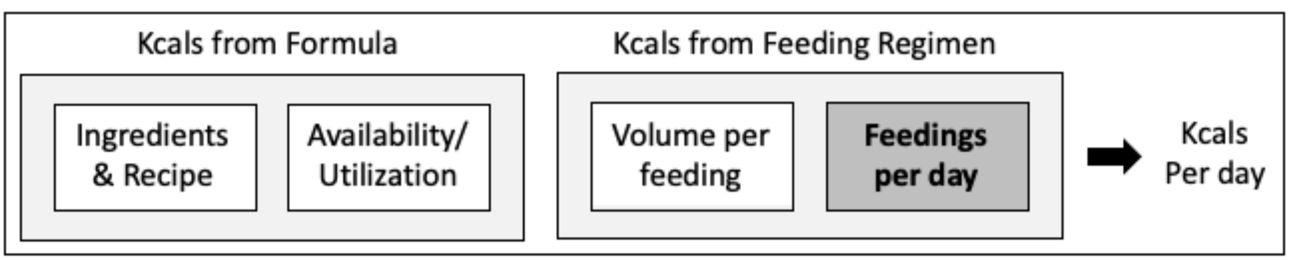
Allan Casey
WildAgain Wildlife Rehabilitation, Inc.
Evergreen, CO

Abstract

A common question facing wildlife rehabilitators is estimating how many feedings of a substitute milk formula per day will result in a healthy, growing and thriving animal. A search and review of sources, ranging from scientific research papers and publications to more informal social media postings, provides various suggestions. Unfortunately, many of these sources provide widely varying instruction, little consensus, and very sparse references, which prompts a questionable level of confidence in the information. As such, this often conflicting and incomplete information provides little help in making an independent determination of the approximate proper number of feedings to be provided per day. Fortunately, with a few pieces of basic information that the rehabilitator should have at hand, and some simple math, this number can be estimated fairly easily as described in this paper. Part 1 presents the mathematical equations used to calculate an estimate for feedings per day. Part 2 discusses the derivation of a critical variable in the equation that has been empirically derived specific to young wild animals in rehabilitation. Lastly, Part 3 presents several specific examples to illustrate the straightforward use of the equations. [Note: For readers not interested in the detailed math, the examples in Part 3 provide an easier way to arrive at the estimate for feedings per day.]

Introduction

Since the number of feedings per day is only one of several determinative variables that collectively yield the daily intake of energy as measured in kcals[1], all of the critical variables should be recognized and viewed in a logical context. The following diagram (not meant to be an equation) conceptually depicts the primary variables in their simplest form, which are then discussed below.



As shown above, there are two primary sources that form the basis of kcals provided per day when using a substitute milk formula. While not the subject of this paper, the first source is the formula itself, comprised of

[1] To avoid any confusion, this paper discusses energy requirements expressed as kcals, which equals one thousand "small" calories. A small calorie is the energy required to raise 1 gram of water 1 degree Celsius. Most all dietary references and uses of the term "calorie" actually refer to "Calories", or kilocalories, or kcals, or the amount of energy required to raise 1 kilogram of water 1 degree Celsius. For example, packaging for a single Oreo™ cookie indicates approximately 140 Calories (also read as 140 kcals or 140,000 calories.)

the ingredients and recipe used, and then further influenced by the availability and utilization of those nutrients. An overview of how to calculate the kcals provided in the formula itself is discussed later. The second source is how that formula is administered through the feeding regimen, comprised of the volume fed per feeding and then coupled with the number of feedings per day. A brief discussion of determining volume per feeding is provided later, accompanied by an in-depth discussion of estimating the optimum number of feedings per day, which is the primary subject of this paper.

This paper is subject to a few caveats:

(1) It appears that many rehabilitators base their formula recipe composition, preparation method, feeding technique, and feeding regimen primarily on personal experience and informal, qualitative methods. Those factors, as well as assessing the overall health of the animal, are certainly essential to consider since they affect decisions, practices and success. This paper, however, offers an additional quantitatively based approach to formula construction and feeding regimen, including determining an estimate for feedings per day.

(2) This paper only deals with young, healthy, normal developing wild mammals. This includes demonstrating regular and steady weight gain, appropriate level of physical activity, normal postural adjustments and social interactions, and expected fur development. Additionally, this paper only deals with young mammals that are on full strength formula as provided by the rehabilitator. It does not address or include that initial time period during which an incoming animal is being stabilized, hydrated and being fed a dilute formula concentration. Nor does it address or include that time period when small amounts of solids may be added to the formula, or that may be provided in the enclosure for shredding or eating. Additionally, it does not address animals under inordinate stress, such as recovering from severe injury or disease.

(3) Conclusions drawn in this paper are based on data founded on reasonable estimates of certain values (either from scientific literature or empirical derivation) and should be regarded as guidelines in helping to determine a defendable estimate for number of feedings per day.

PART 1 - Feedings per day – the basic math

Simply stated, feedings per day equals the animal's daily energy requirement (kilocalories, or kcals) divided by the amount fed (kcals) at each feeding. Depicted as a simple equation, it looks like this:

$$approximate\ feedings\ per\ day = \frac{daily\ kcal\ requirement}{kcals\ per\ feeding}$$

For example, if the daily kcal requirement is 10, and 2 kcals are fed each feeding, then based on the equation, the daily number of feedings equals 5. Simple math, yes, but in this equation, we first need to know how to determine (A.) the daily kcal requirement and (B.) the proper number of kcals to be fed at each feeding.

Determining the daily energy (kcals) requirement

If the body weight (BW) of the animal is known, then a straightforward equation provides the daily kcal requirement to be fed. These daily requirements, by body weight, are also summarized in the table below, and are calculated from the following equation:

$$daily\ kcals = BW(kg^{.75})\ (k)\ (f)$$

where:

BW = weight in kilograms (kg) raised to the exponential constant of .75 (Rubner, 1883)
(k) = constant based on mammalian clade (eutherians = 70; marsupials = 49)
(f) = a multiplier to account for energy expenditure above basal resting rate = 2.1 (explained in Part 2)

In this equation, BW multiplied by the clade (i.e., from a common ancestor) constant (*k*) yields a kcal requirement for basal resting rate, usually defined as a state of sleeping or resting. Energy is expended only for life-sustaining functions such as respiration, blood circulation, digestion and thermal maintenance in normal environmental temperature range. For a more in-depth explanation of this constant, refer to the reference list at the end of this paper.

The value for (f) is used as a multiplier to estimate the quantity of kcals required for additional energy needs (above the basal metabolic requirement). This can include such things as physical activity, body growth (tissue deposition and organ development), recovery from illness or injury, and environmental stress (e.g., risk of predation, food/water deprivation, and temperature extremes). This value has been empirically derived for hand-fed young mammals in rehabilitation being bottle/oral syringe/tube fed and is estimated at **2.1**. (See Part 2 below for the empirical derivation methodology.)

As an example, to determine the daily kcal requirement of a 60-gram mammal (non-marsupial):

$$(60^{.75})\ (70)\ (2.1) = 17.8 \text{ daily kcals}$$

For ease, these values for daily kcal requirements are provided in that table below for a range of body weights. Additional weights can be calculated using the equation above.

BW (grams)	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**150**	**200**	**250**	**300**
Eutherians	*4.6*	*7.8*	*10.6*	*13.1*	*15.5*	*17.8*	*20.0*	*22.1*	*24.2*	*26.1*	*35.4*	*44.0*	*52.0*	*59.6*
Marsupials	*3.3*	*5.5*	*7.4*	*9.2*	*10.9*	*12.5*	*14.0*	*15.5*	*16.9*	*18.3*	*24.8*	*30.8*	*36.4*	*41.7*

Daily Energy Requirement where the value for k (physical activity level) = 2.1.

TABLE 1 – Calculated Daily Energy Requirement (kcals)

Determining the number of kcals per feeding

Assuming the recipe of the milk substitute formula has been closely matched to mother's milk in terms of appropriate nutritional composition (e.g., proteins, fats, carbs, kcals, etc.), then another straightforward equation provides the number of kcals provided at each feeding:

$$kcals\ per\ feeding = (m)\ (v)\ (u)$$

where:

(m) = kcals per cc of milk substitute formula
(v) = volume of formula (cc's) provided per feeding
(u) = formula utilization factor (est. 92.5%)

If not already known, the kcal/cc value for any substitute milk formula recipe can be calculated very easily using a specifically designed calculator found on WildAgain Wildlife Rehabilitation's website at www.ewildagain.org in the nutrition section of the site. It contains independent lab test results for most of the commonly used powdered milk replacers. It can also accommodate other products specified by the user. Once the ingredients and proportions are input, the calculator provides the kcal/cc value for the formula. This value, approximating metabolizable energy (ME), is calculated using the general Atwater factors of 4 kcal/g protein, 9 kcal/g fat, and 4 kcal/g used for human-grade foods to convert the gross energy (GE) values from the lab to ME values.

In the rehabilitation community, as supported by much of the literature, volume per feeding seems to have standardized at about ≈5-6cc/100gr of body weight for most mammals, except for lagomorphs fed at ≈10cc/100gr of body weight. Said another way, the animals are fed ≈5-6% of body weight in cc's of formula, and ≈10% of body weight in cc's for rabbits.

The value for (*u*) is a factor used to account for the fact that the full ME in the formula, as calculated, is less than 100% available for digestion and utilization by the animal, due to a number of factors. These include the quality of the ingredients used in the recipe products (e.g., powdered milk replacers), user imprecision in product measurement and combination, and an incomplete understanding of solubility issues. While the general Atwater factors assume a much higher degree of digestibility and utilization, the American Association of Feed Control Officials (AAFCO) use modified Atwater factors for most pet foods, in recognition of those ingredients that do not meet human-grade standards. The modified factors are 3.5 kcal/g protein, 8.5 kcal/g fat, and 3.5 kcal/g, which are roughly 85% of the values of human-grade foods. For purposes of this paper, a value for (*u*), of a formula utilization factor, was selected at 92.5%, which is the midpoint between the standard and modified Atwater factors.

Continuing with the example of the 60-gram mammal (non-marsupial) from above, for a formula containing 1.27 kcals/cc, and being fed 3 cc's per feeding, and incorporating the value for (*u*) of 92.5%, the result is:

$$kcals\ per\ feeding = (m)\ (v)\ (u)$$

$$3.52\ kcals\ = (1.27)\ (3)\ (.925)$$

Determining the number of feedings per day[2]

To complete the example of the 60-gram mammal above, and using those values calculated for that animal, the number of feedings is calculated as shown below:

$$approximate\ feedings\ per\ day = \frac{daily\ kcal\ requirement}{kcals\ per\ feeding}$$

$$approximately\ 5\ feedings\ per\ day = \frac{17.8\ kcals\ per\ day}{3.52\ kcals\ per\ feeding}$$

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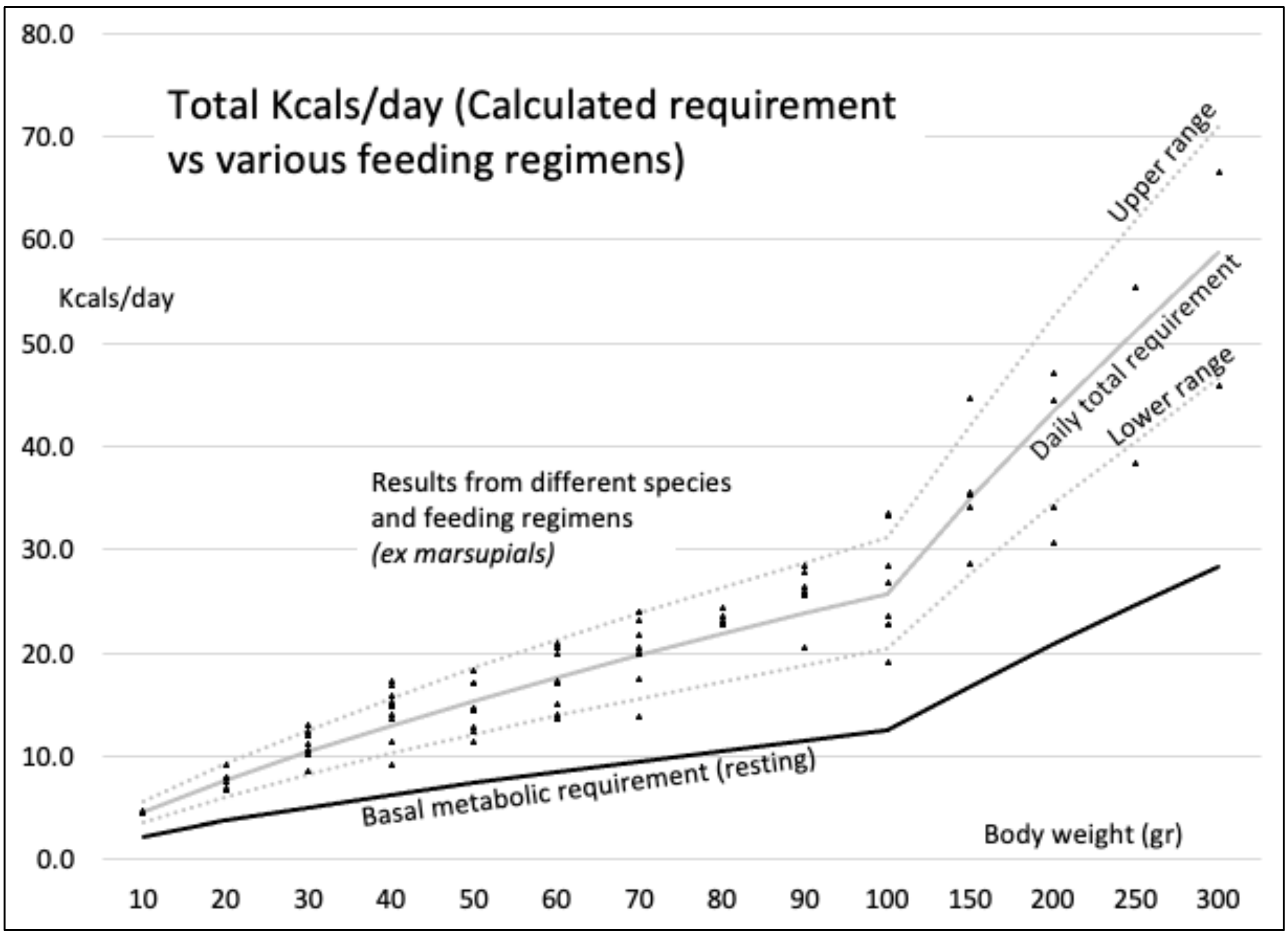
[2] While this section estimates number of feedings per day, it does not address the timing or frequency of those feedings. Considering the stomach capacity discussion above, it is advisable to most evenly space the feedings during a 24-hour period to allow appropriate time intervals for sustained satiety and adequate digestion prior to the next feeding. For example, when five feedings per day are indicated, many rehabilitators space them 4 hours apart, beginning around 6 am and concluding at 10 pm. When more feedings per day are indicated, say 6 or more for neonates, night feedings are generally required. All of this to suggest not attempting to compress 5 feedings per day into a short time period of 6-8 hours, for example, which often results in GI upset, discomfort, and can even prompt genital nursing of litter mates.

The use of the term “approximate” in the equation above is intentional. The actual number of correct feedings per day likely ranges from 4-6, depending on any number of factors and circumstances. These could be related to the animal’s rate of growth and development, rehabilitator practices, as well as considering the inherent imprecision in the equations resulting from the use of certain estimated values. Nevertheless, this calculation serves as a reasonable guideline and starting point when estimating the correct number of feedings per day.

To further illustrate this point, the following chart shows the data of the species and feeding regimens from all of the rehabilitators that provided data for the analysis described in Part 2 below. As shown, few of the data points consistently fall exactly on the value for the required daily kcals, but rather fall in an acceptable range above or below that line. Notable are some of the outlier data points from the ranges, which should encourage further examination as to possible under or over-feeding during the day. Under feeding could certainly lead to stunted growth and insufficient organ development, whereas chronic overfeeding can often result in GI upset and distress.



PART 2 – Energy Expenditure Multiplier – Derived from Rehabilitation Data

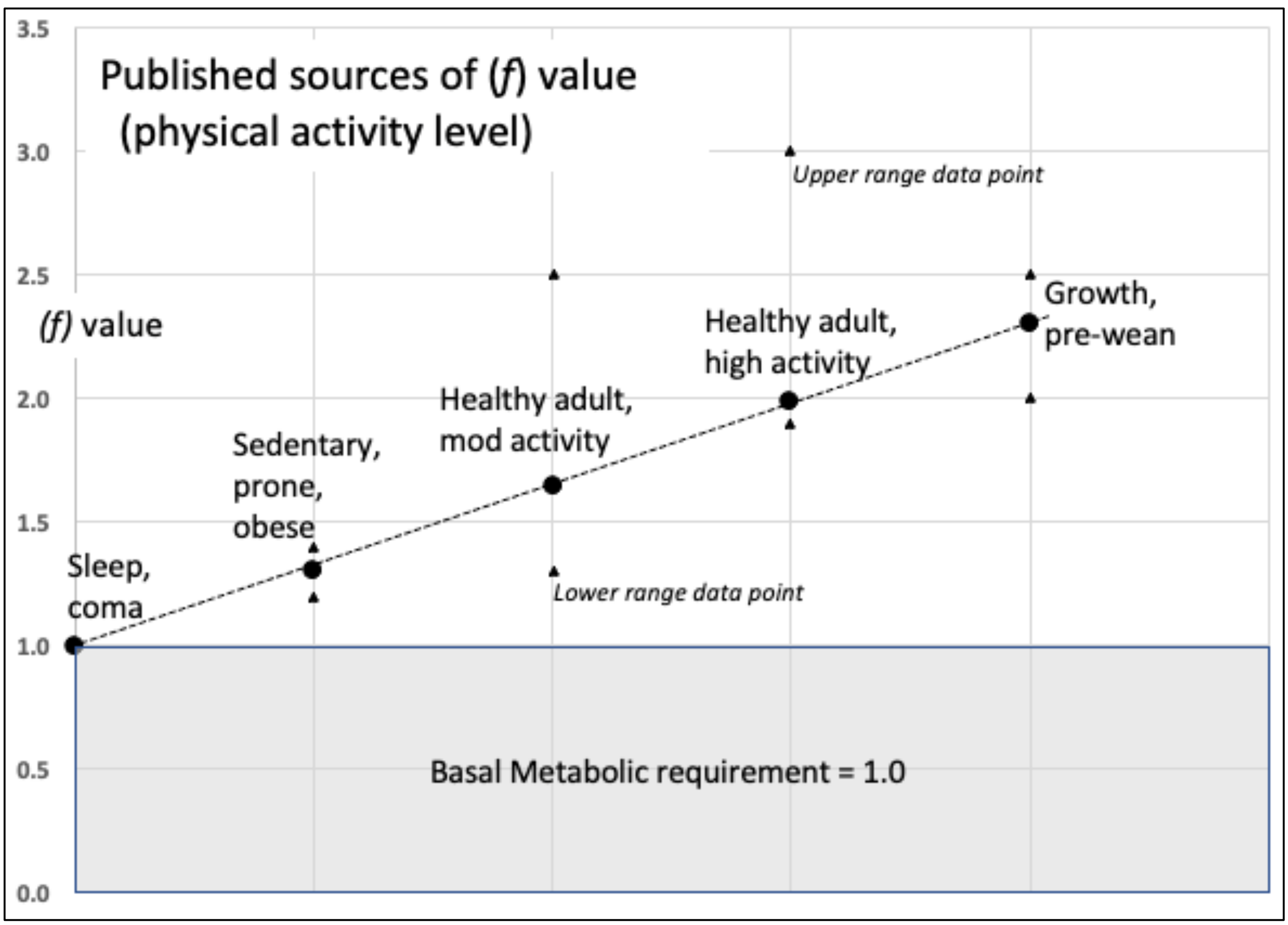
The daily kcal requirement to be fed can be easily calculated using the previously discussed equation:

$$daily\ kcals = BW(kg^{.75})\ (k)\ (f)$$

However, the accuracy of the calculated result is **highly** dependent on the value used for (*f*). How do we determine the correct value to use in the calculation?

Literature search

During the literature search on this topic, values for (*f*) were included in 14 different sources. Again, this value is a measurement of the additional daily kcal requirement above the basal metabolic requirement. The average values from the literature are graphed below (along with upper and lower range values) for various states of activity. The chart indicates a value for (*f)* of 1.0 in a sleeping or comatose state – simply maintaining the minimal life processes such as respiration and cardiac function. The (*f*) value for a healthy adult engaged in moderate activity is 1.64, indicating that an additional 64% of daily kcals above the basal metabolic requirement is needed to sustain that level of activity without any change in body weight. At the right side of the chart, it shows that a young, pre-wean animal undergrowing normal growth and development rates has an (*f*) value of 2.3, indicating an additional 123% of daily kcals above the basal metabolic requirement.



Based on the chart shown above, it is apparent that a young and growing animal requires a higher percentage of kcals than a mature adult engaged in high physical activity. And the literature suggests the (*f*) value to be in the range of 2.0 to 2.5, with a weighted average of 2.25. So, is that the correct number? How were those published values obtained or derived? Is there an alternate way to determine that number based on actual experience from a number of rehabilitators over many years working with a variety of species?

Empirical derivation based on rehabilitator's experience

As part of the research for this paper, data was gathered from multiple, experienced rehabilitators from around the U.S. to build a data set to see if the value for (*f*) could be determined by empirical observation. This also required developing a methodology to analyze the data once it was collected.

First, a way to calculate (*f*) from the data collected was needed. Based on the equations discussed earlier, it is known that:

$$daily\ kcals = BW(kg^{.75})\ (k)\ (f)$$

Another way to arrive at daily kcals is by examining a successful feeding regimen:

$$daily\ kcals\ = (m)\ (v)\ (n)\ (u)$$

where:

- *(m) = kcals per cc of milk substitute formula*
- *(v) = volume of formula (cc's) provided per feeding*
- *(n) = number of feedings per day*
- *(u) = formula utilization factor (est. 92.5%)*

Therefore, if both of these equations yield the same value for daily kcals, then both equations are equal, such that:

$$BW(kg^{.75})\ (k)\ (f) = (m)\ (v)\ (n)\ (u)$$

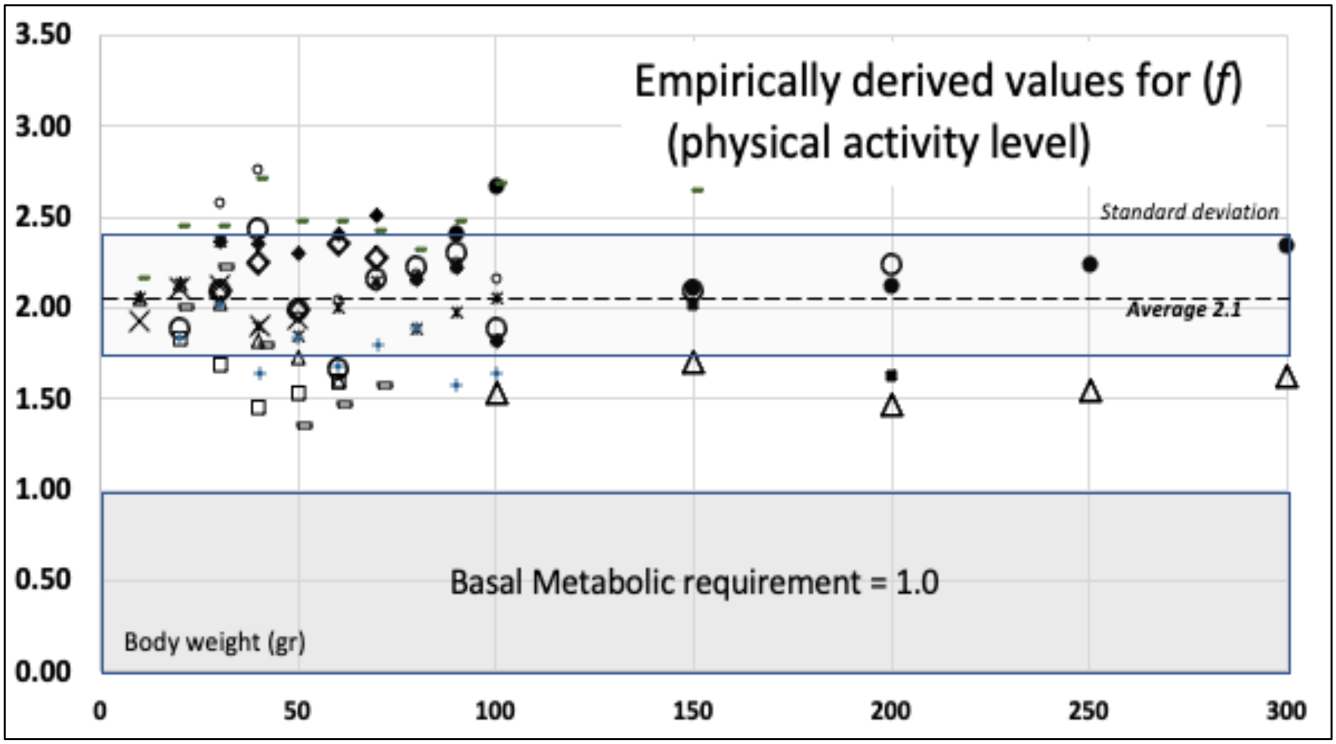
Further, if the task is to solve for the value of (*f*), then the equation can be restated as follows:

$$f = \frac{(m)\ (v)\ (n)\ (u))}{BW(kg^{.75})\ (k)}$$

At this point, the data that is needed from each rehabilitator, for a given species, is their feeding regimen (kcals/cc in their formula; cc's fed at each feeding; number of feedings per day) for a given body weight of the animal.

Data was collected from 7 different rehabilitators, from 6 different states (CA, CO, CT, KY, ME, VA), with an average experience level of 18 years (ranging from 10 – 35 yrs.), averaging approximately 145 animals per year (ranging from 25 – 300) and representing 11 different species. Over that collective time period, that data set represents over 125,000 animals.

The following chart is a scatterplot of the (*f*) values calculated from the collected data. The average of the values is 2.1 with a standard deviation of .3 (range of 1.8 – 2.4). This compares to the literature that presents an average value of 2.25.



Based on the above discussion, it appears that a reasonable value for (*f*) exists in the range of 2.0 to 2.5, with an average of 2.25 based on the literature search, and an average of 2.1 based on empirical derivation from actual substitute milk formula diets and feeding regimens as provided from a group of experienced rehabilitators working with an array of species.

PART 3 – Illustrative Examples of Calculating Feedings per Day

From Part 1 above, feedings per day is equal to kcals per feeding divided by the daily kcal requirement:

$$feedings\ per\ day = \frac{daily\ kcal\ requirement}{kcals\ per\ feeding}$$

To simplify the math, the daily kcal requirement is precalculated and shown in Table 1 above. Therefore, the remaining task is to calculate kcals per feeding, using the following:

$$kcals\ per\ feeding = (kcals\ per\ cc)\ (cc's\ per\ feeding)\ (.925)$$

Following are four examples illustrating how to perform the calculation.

Example 1 – Fox squirrel weighing 50 grams, fed a formula containing 1.27 kcals per cc, and fed 2.5 cc's per feeding. How many feedings per day?

$$feedings\ per\ day = \frac{15.5\ (from\ Table\ 1\ above)}{(1.27)(2.5)(.925)} = \mathbf{5.3}$$

This calculation suggests the estimated number of feedings in the 5 – 6 times per day is appropriate.

Example 2 – Raccoon weighing 150 grams, fed a formula containing .69 kcals per cc, and fed 9.0 cc's per feeding. How many feedings per day?

$$feedings\ per\ day = \frac{35.4\ (from\ Table\ 1\ above)}{(.69)(9.0)(.925)} = \mathbf{6.2}$$

This calculation suggests the estimated number of feedings in the 6 – 7 times per day is appropriate.

Example 3 – Cottontail weighing 50 grams, fed a formula containing 1.35 kcals per cc, and fed 5.0 cc's per feeding. How many feedings per day?

$$feedings\ per\ day = \frac{15.5\ (from\ Table\ 1\ above)}{(1.35)(5.0)(.925)} = \mathbf{2.5}$$

This calculation suggests the estimated number of feedings in the 2 – 3 times per day is appropriate.

Example 4 – Opossum (marsupial) weighing 40 grams, fed a formula containing .90 kcals per cc, and fed 2.0 cc's per feeding. How many feedings per day?

$$feedings\ per\ day = \frac{9.2\ (from\ Table\ 1\ above - marsupial)}{(.90)(2.0)(.925)} = \mathbf{5.5}$$

This calculation suggests the estimated number of feedings in the 5 – 6 times per day is appropriate.

Conclusion

A considerable amount of time and energy is spent throughout the rehabilitation community researching, constructing, debating and feeding different substitute milk formula recipes. However far less time appears to be spent discussing an appropriate number of feedings per day, and how to reasonably estimate that daily amount. Following the relatively easy math in this paper, coupled with known information about the animal (weight, formula recipe, feeding regimen), the approximate number of feedings per day that will satisfy the acceptable number of daily kcals can be readily calculated.

Author

Allan Casey is a co-founder of WildAgain Wildlife Rehabilitation, Inc. in Evergreen, CO and has been a licensed rehabilitator since 1986. He has researched, published and presented on a wide range of wildlife rehab related topics including nutrition, rehab regulations and numerous aspects of rehab practice, tools and techniques. He holds BBA and MBA degrees; worked in corporate finance for 25 years; and has assisted over 200 nonprofit organizations with initial state and federal tax-exempt flings, strategic planning and organization development.

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