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Folklore Husbandry and a Philosophical Model for the Design of Captive Management Regimes

Keeping reptiles and amphibians is an activity enjoyed by many hobbyists worldwide and is also undertaken by zoos, museums, research organizations, and other professional animal care facilities. The United Kingdom pet trade alone consists of over 500 species of reptiles and amphibians (Tapely et al. 2011), including the importing of 100,000 individual reptiles (Rayment-Dyble 2004). Imports into the European Union include many CITES-listed species and therefore many species of conservation concern (Auliya 2003). Furthermore this trade has seen a continuous increase in both numbers and species diversity of animals as the private keeping of such animals has notably gained popularity over the last 10–20 years (Auliya 2003; Barten 2006; Mader and Mader-Weidner 2006; Tapely et al. 2011; Varga 2004; Wilson 2005). From the perspectives of animal welfare and conservation it is important to develop appropriate husbandry regimes so that these species thrive in captivity, and ideally these would be based on some form of empirical data (Arbuckle 2009; Hosey et al. 2009; Kaumanns et al. 2000; Swaisgood 2007; Wiese and Hutchins, 1994).

There has been a steady stream of both published and unpublished studies that have provided data relevant to the husbandry of captive animals, though these vary greatly in quality and detail (Fidgett 2005; Hosey et al. 2009). The herpetocultural literature is no exception to this general trend, but the level of research interest tends to be somewhat lower than in certain other groups, particularly mammals (Anderson et al. 2008; Arbuckle 2009; Hosey et al. 2009). Some recent changes including the creation of Herpetoculture section in *Herpetological Review* are a step in the right direction and should help to fuel studies allowing keepers to develop an evidence-based approach to husbandry.

It should be noted however that such an evidence base is only of benefit if it is consulted and integrated into captive management plans. Unfortunately, it is often the case, both in professional and private contexts, that evidence-based husbandry is not used for a variety of reasons including lack of information, a belief (either explicit or implicit) that experience is a better guide than research, and lack of encouragement or ability (real or perceived) to pursue such an approach (Arbuckle 2010; Clauss et al. 2003).

The aim of this paper is to draw attention to the problem of folklore husbandry for exotic animals, specifically reptiles and amphibians, and to encourage professional and amateur keepers alike to strive towards applying evidence-based methods to their husbandry routines.

What is folklore husbandry and why does it matter?—The term "folklore husbandry" was coined by Arbuckle (2010) to refer to "methods or supposed 'best practices' [which] become established without proper evaluation, often justified simply because 'it has always been done that way' or for otherwise unknown or poorly substantiated reasons." In essence, it refers to the widespread practice in many professional institutions and among many private keepers of doing things by tradition and/or uncritically accepting anecdotal husbandry information.

KEVIN ARBUCKLE
Institute of Integrative Biology, Biosciences Building, University of Liverpool, Crown Street, Liverpool, U.K., L69 7ZB
e-mail: k.arbuckle@msn.com

An important point is whether this actually matters. After all, many species have been kept successfully for many years and often bred using methods that fit the definition of folklore husbandry. Indeed, this may be the primary reason why such methods have been so widely adopted. It is likely that some folklore husbandry methods will prove to be suitable once they have been properly evaluated. Nevertheless there is an inherent issue in that they have not been adequately tested and so should not be blindly accepted as the best nor the only possible solution. Unfortunately that is how folklore husbandry methods are often portrayed, particularly among private keepers (de Vosjoli 2007).

What can result are dogmatic assertions of the "correct" way of doing things that hamper the further development of methods via condemnation of different practices (de Vosjoli 2007). This is an attitude that is to be discouraged on at least two grounds. Firstly, it is problematic to take any current situation and proclaim it to be the best one possible. This is particularly true for the care of reptiles and amphibians, which is still in a stage of frequent development, as it can directly lead to a decrease in motivation to continue to improve husbandry. In fact the basic natural history and ecology of many commonly kept species are poorly known, reducing further our certainty that a given approach is the best one. Secondly, the successful maintenance of a given species is a matter of degree. One method may give good results but another may confer even better results or improved welfare standards. The idea of encouraging a diversity of husbandry practices is not new, and is in fact a key aspect of de Vosjoli's (2007) "multifactorial model of herpetoculture," although he does not explicitly highlight the benefits of such a philosophy to continual methodological improvement.

In addition to the ideological disadvantages noted above, folklore husbandry can also incur time and financial costs that are of more practical concern. As an example of the former is the removal of beaks from avian prey or the chopping of foods for herbivorous species. These are time-consuming methods that are used with some regularity but their benefits have always simply been assumed by those who perpetuate their use. As an aside, recent research by Plowman et al. (2008) has shown that chopping foods provides none of the perceived benefits and is actually contraindicated in some situations. This is a good example of a folklore husbandry claim perceived as beneficial for numerous reasons, but that on investigation turned out to be false. Application of the results of Plowman et al. (2008) should alleviate the time cost of food preparation for keepers, and in a professional setting where "time is money" should also present a financial saving.

Furthermore it is clear that some folklore husbandry claims, if refuted, would also provide a direct financial cost saving. Arbuckle (2009) found that providing a gut-loading diet with the aim of adequately supplementing calcium was not a successful

approach. However, although supported by a review of previous studies his experimental results did not permit statistical evaluation of this, and therefore require further work to provide concrete evidence. If it does prove to be accurate however, dusting with a relatively cheap supplement may give better results than the use of a specific gut-loading diet, many of which are relatively expensive.

Hopefully, I have now shown that it is important to be aware of folklore husbandry, and to adopt a more evidence-based approach to the care of exotic animals such as reptiles and amphibians. I will now provide some more examples of folklore husbandry that require investigation and also highlight a few studies that have evaluated such claims. I will then offer some guidelines in the form of a framework for establishing a husbandry regime. Finally, I will attempt to encourage dissemination of the basic ideas contained here with the aim of improving husbandry practices in both professional and private collections.

Some examples of folklore husbandry.—Examples of folklore husbandry are ubiquitous and in many cases are so deeply ingrained that they may not be instantly recognized as such. Nevertheless it might be useful to highlight a few of these so that a better idea of what the subject encompasses can be gained. These are somewhat dominated by nutritional examples, and this reflects both my own background and also that captive feeding appears to be a particularly prominent area of research into animal husbandry. Many examples have not been directly examined and the current availability of data to test them is variable. They represent potential for future directed studies and include a wide range of claims.

Do nutritional products such as supplements and "complete" diets that are marketed in a species-specific fashion give better results than equivalent products marketed in a more general way? Given that the nutritional requirements for reptiles and amphibians are for the most part extrapolated from domestic animals (Allen and Oftedal 1994; Baer 1994), the existence of species-specific marketing raises suspicion as to whether any genuine benefit to these products exists. Studies directed at evaluating whether the performance of a given species is better with products marketed for them than others would provide key information to guide which option to use.

Do particular livefood species represent a better staple diet than others? It is a long held belief that locusts are a better staple prey than crickets, and feeder cockroaches have recently become somewhat of a vogue food item that is touted for a high nutritional value. However, despite much published data on nutrient compositions of various invertebrate prey (Finke 2002; Nijboer et al. 2009; Oonincx and Dierenfeld 2011) the relative benefits in practice have rarely been tested. It is an important step to know the composition of a given prey item, particularly compared to another prey item, but in itself this provides no measure of how an animal will perform on that diet. It has previously been highlighted that direct comparison of prey composition to recommended nutrient intake is notable by its absence from most studies (Arbuckle 2009). Furthermore, there are little or no data on nutrient digestibilities for most reptile and amphibian species currently kept, despite the importance of this information for relative assessment of prey species. It is clear that much information is lacking to answer this question with confidence, but many folklore husbandry claims are made apparently without reference to those data that do exist.

Does the substrate influence general activity level or natural behaviors such as burrowing? Despite the almost unanimous use of substrates in enclosures, there has been surprisingly little research investigating whether a particular choice is better than any other. There is a plethora of anecdotal evidence available on the issue. For instance I have used a mix of sand, soil, and a few bark chips in an attempt to create a substrate mimicking the reported natural soils of the Plains Hog-nosed Snake (*Heterodon nasicus*). Following the change from newspaper to this substrate I noticed an apparent increase in activity and some burrowing behavior. However, like most such reports this represents a purely untested anecdote. Similarly, based on ecological observations and successful results of the entire husbandry regime used, Bennett and Thakoordyal (2003) strongly recommend the use of deep substrates for burrowing in Savannah Monitor (*Varanus exanthematicus*) enclosures. They particularly advocate soil but mention that others can be used, though the former "is easily the best." While I would personally agree with this last comment, it would be useful to have data from a comparison of various options, providing a direct evidence base to complement the natural history observations.

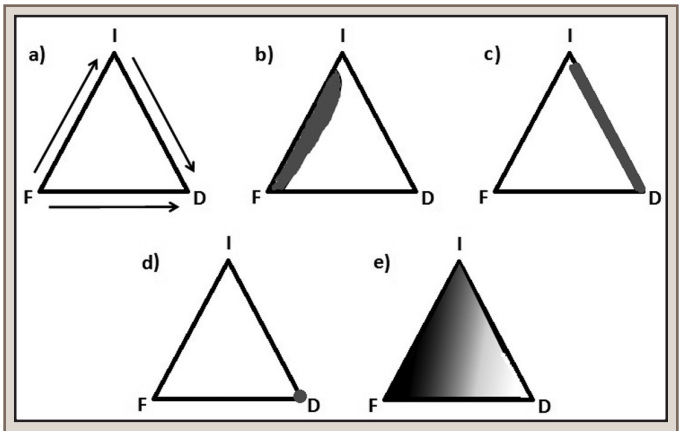

FIG. 1. The FID model of husbandry design. a) Basic model showing arrows representing the directions we should be aiming to move in. b) Shaded area indicates the range of most current designs. c) Shaded area indicates a range of good designs. d) Filled circle represents the ideal design. e) Darker shading indicates higher density of anecdotal evidence. See text for further details. F = folklore husbandry, I = integrated husbandry, D = direct evidence-based husbandry.

Is environmental enrichment necessary for reptiles and amphibians, and if so which form should it take? Enrichment is strongly advocated as a strategy to improve the welfare of captive animals (Swaisgood 2007), but specific considerations for reptiles and amphibians are lacking from most treatments of the subject. The general aim of many enrichment strategies is to increase activity or to encourage natural behaviors (Hosey et al. 2009). The latter aim is probably responsible for the idea that creating naturalistic enclosures promotes good welfare through environmental enrichment (Fàbregas et al. 2011). However, often such benefits are assumed rather than empirically tested. Some notable exceptions exist including Hurme et al.'s (2003) demonstration that an enrichment feeding device for dendrobatid frogs resulted in increased activity, but unfortunately such studies are not the rule. On the basis of natural history observations, Rosier and Langkilde (2011) examined whether the provision of a climbing structure is beneficial to a lizard that regularly climbs off the ground (*Sceloporus undulatus*). In contrast to what might be expected, these authors found no effect on a variety of welfare and behavioral measures. Their study highlighted the non-intuitive nature of providing enrichment, particularly to animals that

are phylogenetically distant from humans. It is a good example of why folklore husbandry claims should be properly tested, not simply accepted because they "make sense."

Can we take information on natural food groups and convert these straight to a captive diet? In other words, if we know that an herbivorous reptile naturally eats 50% leaves, 30% fruit, and 20% other vegetable matter, can we replicate these proportions in captivity? In this example, it is particularly important to note that, although providing some fruit would probably be acceptable, it would be unwise to uncritically make up 30% of the diet with it. One concern is that fruits more than many other plant parts are highly seasonal (Jordano 2000), and so either the absolute amount or the specific fruits eaten or both are likely to vary considerably over the year. This is very different from a constantly high proportion of fruit in the diet. Furthermore, the nutritional content of the food is more important that the "package" in which the nutrients are given to the animal. Schwitzer et al. (2008) highlighted the fact that domesticated fruits, those cultivated for human consumption and taste buds, have a very different nutrient composition to those found in the wild. It seems that wild fruits are actually more similar to cultivated vegetables. Since it is unlikely that most keepers will be able to source the wild fruits that form the natural diet of their animals, it appears as though substituting at least some of the fruit with vegetables in captivity would be preferred. It is likely that further scrutiny of simple "cut and paste" methods will reveal other cases where amendment is needed. This is a case of a partially evidence-based approach but with some aspects remaining under the umbrella of folklore husbandry.

How should we develop husbandry regimes?—With such a spectre hanging over our heads, how should we design our husbandry regimes so as to ensure the best approach we can? Because we must look after our animals now, we don't have the luxury of waiting for a full evaluation of every technique we use and thus we must act with imperfect knowledge. It is certainly true that the reason so many folklore husbandry claims exist is because we simply do not currently have the information to test them—in many cases we have to reserve ourselves to using such methods if we are reasonably confident they will be effective.

The goal should be to implement each part of a given animal's care with the best information available. This can be conveniently divided into three levels of increasing reliability: folklore, integrated, and direct evidence-based husbandry. The former has already been described and so needs no more definition here. Before discussing the other two approaches I should emphasize that although they are discrete categories, any given regime will undoubtedly incorporate all three. Despite the negative light under which I have cast folklore husbandry, as previously mentioned it is prevalent due to the fact that it works (at least to some degree) in many cases. It thus has a place in husbandry regimes when no better information exists as it can represent a conservative approach providing its limitations are borne in mind.

Integrated husbandry is the most common form of evidence-based husbandry and was the view detailed in Kaumanns et al. (2000). It involves integrating the existing ecological and, more generally, biological information on a given species, and assimilating this into a husbandry plan that attempts to mimic nature. This has important benefits in that such information is available for many species, albeit the quantity and quality will vary widely. However, it suffers from two main constraints.

Firstly, as highlighted above care must be taken to ensure that it is the important parts of the information that are replicated. There is no sense in providing a diet with the same set of food groupings as the natural diet if the nutrient composition is vastly different. Similarly, providing light for many species is not as important as providing the appropriate quality of light to enable biosynthesis of vitamin D in the skin.

Secondly, there may be differences between captive animals and their wild counterparts that impact the husbandry methods used or the evaluation of such methods. The captive environment differs from the natural habitat, and different species will not necessarily respond to this in the same way (Mason 2010). Although such differential responses to captive stressors are perhaps unsurprising, other effects of short- and long-term periods in captivity have been noted that are less intuitive. Captive animals have been shown to diverge from their wild counterparts in behavior (Guyon 2009; McPhee 2003), physiology (Studier and Wilson 1979), and even morphology (Moore and Battley 2006; Moss 1972; O'Regan 2001), all of which might have implications for the application of field-collected data to captive management.

Integrated husbandry is an excellent way of introducing an evidence-based approach to captive management, especially since data are far more abundant than for direct evidence-based husbandry. It can also act as an information platform from which hypotheses for direct empirical studies can be based. However, it does have some limitations which should be recognized and we should not accept it as the be-all-and-end-all of husbandry methods.

Direct evidence-based husbandry on the other hand represents the gold standard. It involves empirical examination of methods used and ideally their alternatives. An ongoing example of this is work on the use of ultraviolet B (UVB) lamps to create an appropriate lighting regime in captivity. It is beyond the scope of this paper to offer a thorough discussion of the issue, but comparisons of the light output of different bulbs currently in use (Schmidt et al. 2010) combined with a field study on exposure that is used to provide guidelines in captivity (Ferguson et al. 2010) is a commendable endeavor.

Although forming a discrete category of information, direct evidence-based husbandry often follows folklore and integrated husbandry by using them to generate hypotheses. For instance, a direct study might aim to evaluate a folklore husbandry claim or might be designed to test whether a particular integrated strategy does indeed offer the benefits it proposes in captivity. Once empirically examined, such methods can then be discouraged or elevated to the direct evidence-based category.

The main limitation of this approach is the time and financial resources necessary to investigate each technique, and as a result data from direct studies are lacking for most methods currently in use. With time and effort however, we can increase the proportion of any given husbandry regime that results from a direct evidence-based approach.

The FID model.—I have divided husbandry methods into three discrete categories, but emphasized that these categories will often combine in various proportions to result in the complete husbandry regime. This perspective can be represented by a simple visual model, consisting of a ternary diagram with folklore (F), integrated (I), and direct evidence-based (D) husbandry at separate corners (Fig. 1). In this case each corner represents 100% use of that principle.

The strategy illustrated by the FID model is an attempt to push our husbandry regimes as far as possible in the direction of the arrows (Fig. 1a). In no case should we try to move towards F but the ultimate goal is to use a regime that is as close to D

as possible. If we are close to F then we should look at moving towards either I or D (the side ID represents an evidence-based approach). If we are close to I then the preferred direction would be towards D.

In many cases it is useful to talk about a range of possibilities for the reasons highlighted earlier. Most current designs lie near the side FI (Fig. 1b). This is largely due to the fact that often there are few direct data to rely on, but where this applies we can still attempt to move towards I. Similarly we can denote a range of good approaches which lie along or close to side ID, those which are heavily evidence-based (Fig. 1c).

The ideal scenario would be to have perfect knowledge of the best option (or range of options) to use, and this would lie on corner D (Fig. 1d). Unfortunately this ideal situation is unlikely to be fully realized, certainly for most species and in the near future. However, just because this hypothetical scenario represents 100% direct evidence-based husbandry does not imply that an integrated approach should not apply. As discussed above many direct evidence-based methods are and will be a result of formal tests of integrated methods in captivity. It is not the case that the former will overturn all integrative (or even folklore) husbandry methods, but might often confirm them such that they receive more support and are thus elevated to the status of direct evidence-based.

Finally, it is worth discussing where anecdotal evidence enters this framework since it has not been explicitly covered here. The reason for this is that anecdotal evidence cannot be allocated to any discrete category and often arises in part from two or even all three categories described here. Nevertheless it is possible to make some comments on its distribution since anecdotes are not expected to occur evenly through the parameter space in the FID model. Anecdotal evidence is expected to be most prevalent near F, showing a decreasing presence through I and declining to zero at the ideal point on D (Fig. 1e).

Note that anecdotes are still expected to be moderately common even in regimes that use a high degree of integrated husbandry, this is a result of the limitations of such an approach highlighted above. Note also that I do not regard them as equivalent to folklore husbandry, despite a strong relationship between them. This is because although they share many similarities, a single piece of anecdotal evidence can be influenced by both folklore and evidence-based methods. In contrast, by definition a folklore husbandry technique is not a result of any evidence-based approach, neither direct nor integrated.

Finally, and in common with folklore husbandry, although we should aim to move away from anecdotal evidence it is not necessarily a bad thing in all cases. For instance, where better approaches are lacking an anecdotal observation can steer the keeper away from poor practices. Furthermore, anecdotal observations can also provide new hypotheses for further examination and in that sense can contribute to development and improvement of husbandry regimes.

A call to action.—I hope that the ideas presented above can be used to improve professional and private captive management regimes. However, this is only likely to happen if they can stimulate new research and implementation of that research. In this vein, I rely on two (non-mutually exclusive) groups of people for this: researchers and keepers.

Researchers with an interest in animal husbandry and welfare should focus on evaluating folklore husbandry claims and providing a direct evidence base for use by keepers. Aside from such direct studies, reviews of the biology and particularly the ecology of a given species would also be useful, if written from a practical perspective aimed at informing husbandry. Such reviews can provide a good background for integrated husbandry regimes and can give recommendations for further studies. Given the practical nature of such research, I believe that the workers involved have a responsibility to make their studies available to those who can apply their findings, wherever possible. The best study on animal husbandry is useless if keepers cannot read it.

Keepers have a responsibility to share their knowledge and ideas. This should not be a problem since it is the sharing of information that leads to folklore husbandry in the first place. However the important point is that keepers should foster an attitude of awareness of different perspectives on husbandry, particularly folklore husbandry. With an understanding of the different categories of methods and their limitations keepers can evaluate the reliability of any information received.

When disseminating information keepers should make an effort to explain why a particular method is done, not simply pass it on in a manner that promotes parroting of poorly substantiated claims. Finally, it is also the responsibility of keepers to retain an open (but critical) mind to new methods. Trying new methods is the only way we can ultimately improve our husbandry practices, particularly if these represent at least a partially evidence-based approach. This is what we as keepers should continually strive to do, for the benefit of all concerned.

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HERPETOCULTURE NOTES

SQUAMATA — LIZARDS

***AMEIVULA ABAETENSIS*. DRINKING BEHAVIOR.** Many reptiles have morphological adaptations (Sherbrooke et al. 2007. Zoomorphology 126:89–102) and behavioral strategies (Al-Sadoonet al. 1999. Saudi J. Biol. Sci. 6:91–101) for the acquisition of water in the environment, with documented cases of convergent adaptations for species in arid environments (Comanns el al. 2011. Beilstein J. Nanotechnol. 2:204–214). *Ameivula abaetensis* is a diurnal lizard species, endemic to the sand dune habitats ("restinga") along the Brazilian coastline. The geographic distribution of the species extends from the north coastline of Bahia State in Salvador Municipality, to Santo Amaro de Brotas Municipality in Sergipe State (Dias et al. 2002. Copeia 2002:1070–1077). Previous research by Santa-Rosa et al. (2012. Bol. Mus. Biol. Mello Leitão 29:53-63) suggested that the ingestion of *Byrsonima microphyla* fruits by *A. abaetensis* may be an important source of water in restinga habitat during the dry season. This note reports drinking behavior in *A. abaetensis*.

Two independent groups of *A. abaetensis* were kept in captivity during the period of 28 February to 25 April 2009 (N = 8), and 20 to 27 October 2012 (N = 6). The specimens were collected during field activities, in the sand dunes habitat in Restinga do Abaeté, Salvador, Bahia (12.9283°S, 38.3358°W; datum WGS84), and they were kept in captivity for behavioral observations (license nº 31047-1/SISBIO). The climatic and structural conditions of captivity (terrarium with dimensions 100 x 100 x 100 cm) were very similar to those found in the natural microhabitat inhabited by the species (Dias and Rocha 2004. J. Herpetol. 38:586–588; Dias et al. 2005. J. Herpetol. 15:133–137; Dias and Rocha 2007. Braz. J. Biol. 67:41–46), but the specimens were kept sheltered from direct sunlight. For the first group, we provided fruit (*B. microphyla*) and water for sustenance in shallow containers. For the second group, we provided small beetles and water. For