Non-invasive Methods for Nutritional Research at the Jersey Wildlife Preservation Trust

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ABSTRACT

This poster/paper presents a review of nutritional research at the Jersey Wildlife Preservation Trust (JWPT). JWPT is an international conservation organization working to save animals from extinction. At present JWPT does not employ a full-time nutritionists and yet in recent years at least 16 species have been the focus of nutritional research, a list which includes reptile, birds and mammals. Research on nutrition is carried out both as problem-solving exercise (in relation to ill health or apparent infertility) and as part of ongoing programs to improve animal husbandry .The aims have been to enhance nutritional quality and palatability and to stimulate natural foraging behavior. As JWPT is dealing with captive breeding programs for highly endangered species, the emphasis is on non-invasive research methods. Techniques involve direct observation to record intake rates and food preferences, weighing feeds and collecting remains to determine intakes, fecal analysis, and using inert makers to study gut passage time. These methods are simple to use and minimize stress and disturbance to the animals. A nutritional handbook detailing the dietary regimes in use has also recently been revised. As well as nutritional content, dietary regimes at JWPT also include environmental and behavioral enrichment components, natural foodstuffs, forage and browse, and dispersed feeding systems for group-living animals to reduce competition over food.

INTRODUCTION

One of the challenges which zoological institutions face when housing and maintaining exotic animals is providing them with an adequate diet. There are a number of factors that need to be taken into account when designing diets. These include: knowledge of the animal's diet composition and foraging behavior in the wild, knowledge of the functional anatomy of its digestive tract, knowledge of dental morphology and adaptation to the natural diet, knowledge of the bases on which animals select particular food items, and an understanding of the implications that foraging and diet selection have for social behavior [Hume and Barbosa, 1993; Leus and Macdonald, 1995]. This is a tall order, given our lack of knowledge about many exotic species. It is compounded by the fact that even when these factors are known, devising suitable substitutes for a wild diet is hard. For example, we may know that 75% of a wild primate's diet is fruit, yet feeding 75% fruit in captivity may provide a very different intake in terms of nutrients, since fruits produced commercially for consumption by humans (and thus readily available as components of zoo diets) are so different from wild fruits.

Given the increasing numbers of species which are threatened in the wild, there are many ways in which zoological institutions can contribute to conservation. Maintaining viable populations of threatened species in co-ordinated and managed breeding programs is just one example. In order to sustain these populations the goal of zoo feeding programs must be to provide nutritional support for all stages of life, including egg development, gestation, lactation, and early postnatal growth [Oftedal and Allen, 1996] .Dietary deficiencies may result in increased susceptibility to disease, reduced fertility, reduced neonate viability, sub-optimal yolk or milk production, retarded growth and physical deformities. Deficiencies in diet presentation may result in obesity, stereotypies, or increased aggression.

It is clear that an understanding of the nutrition of exotic animals is vital to their well- being and our ability to maintain them successfully in captivity, yet animal nutrition is a new and relatively unexplored field. Part of the problem is a lack of facilities in zoological institutions and a lack of expertise. There is thus a strong need to develop nutritional studies and departments in zoological institutions. For example, there are only nine nutritionists currently employed in zoos in North America, fewer in Europe and none in Britain.

The Jersey Wildlife Preservation Trust (JWPT) is an international conservation organisation whose remit is to save animals from extinction. At present JWPT does not employ a full-time nutritionist and yet in recent years at least 18 species have been the focus of nutritional research, a list which includes reptiles, birds and mammals.

Research on nutrition is carried out both as a problem-solving exercise (in relation to ill-health or apparent infertility) and as part of ongoing programs to improve animal husbandry. Studies carried out to solve problems tend to focus on assessing nutrient quality of the diet, whereas the husbandry work is more oriented to food presentation methods and behavioral and environmental enrichment involving food, and feeding and foraging techniques. The aims are to enhance nutritional quality and palatability and to stimulate natural foraging behavior.

As JWPT is dealing with captive breeding programs for highly endangered species, and in some cases holds the only captive populations of certain species in existence, the emphasis is on non-invasive research methods. Thus animals are not separated from their usual social groupings, normal routines are disturbed as little as possible, and most assessments are done indirectly through weighing food remains or analysing feces.

This paper gives a review of recent nutritional research undertaken at JWPT with the aim of showing that even a small zoological institution, without professional expertise in nutrition or appropriate laboratory facilities, can still undertake nutritional studies the results of which lead to enhanced standards of dietary provision.

NON-INVASIVE METHODS FOR NUTRITIONAL RESEARCH USED AT JWPT

The second edition of JWPT's Dietary Manual published recently contains detailed descriptions of the feeding regimes currently in use [Courts, 1995]. Lists of items, however, provide insufficient information with which to evaluate the nutritional adequacy of the diet fed, and no information at all about what the animals are actually consuming. More detailed investigation is necessary and numerous research projects have been conducted at JWPT to determine this information more precisely (see Table 1). The ideal situation would be to monitor the intake of individual animals. However, for the evaluation to be valid it is essential that the animals are behaving normally and separating animals for the purpose of a study would likely cause stress, which in turn may affect appetite and hence intake. Thus, with the exception of normally solitary animals (e.g. aye-ayes), all the animals were studied in their usual social groupings.

TABLE 1. Recent nutritional studies at the Jersey Wildlife Preservation Trust

Species	Common name	Type of study	Reference
Pteropus livingstonii	Livingstone's fruit bat	Diet evaluation 1	in progress
Daubentonia madagascariensis	Aye-aye	Diet evaluation 1	Ashbourne, 1994;
		Chemical analysis	Sterling et al., 1994
Hapalemur griseus alaotrensis	Alaotran gentle lemur	Diet evaluation 1	Fidgett et al., 1996
		Chemical analysis 1	Fidgett et al., 1996
		Chemical analysis 2	Fidgett, 1995
		Gut passage time	Cabré-Vert & Feistner, 1995
Lemur catta	Ring-tailed lemur	Gut passage time	Cabré-Vert & Feistner, 1995
Varecia v. variegata	Black & white ruffed lemur	Gut passage time	Cabré-Vert & Feistner, 1995
Varecia v. rubra	Red ruffed lemur	Gut passage time	Cabré-Vert & Feistner, 1995
Callithrix geoffroyi	Geoffroy's marmoset	Diet evaluation 1	Price, 1992
		Chemical analysis 2	Price, 1992
		Gut passage time	Price, 1993
		Diet evaluation 1	in progress
Callithrix a. argentata	Silvery marmoset	Gut passage time	Price, 1993
		Diet evaluation 1	in progress
Saguinus b. bicolor	Pied tamarin	Diet evaluation 1	in progress
Saguinus oedipus	Cotton-top tamarin	Gut passage time	Price, 1993
Leontopithecus rosalia	Golden lion tamarin	Gut passage time	Price, 1993
Leontopithecus chrysopygus	Black lion tamarin	Diet evaluation 1	in progress
Callimico goeldii	Goeldi's monkey	Gut passage time	Price, 1993
		Diet evaluation 1	in progress
Geronticus eremita	Waldapp ibis	Diet evaluation 1	in progress
Rhynchopsitta pachyryncha	Thick-billed parrot	Diet evaluation 1	French, 1995
Amazona versicolor	St. Lucia parrot	Diet evaluation 1	Fidgett & Robert, 1993
		Diet evaluation 2	Fa & Cavalheiro , in press
Iguana spp.	Herbivorous iguanas	Diet evaluation 3	Brice, 1995
Cyclura spp.	Herbivorous iguanas	Diet evaluation 3	Brice, 1995

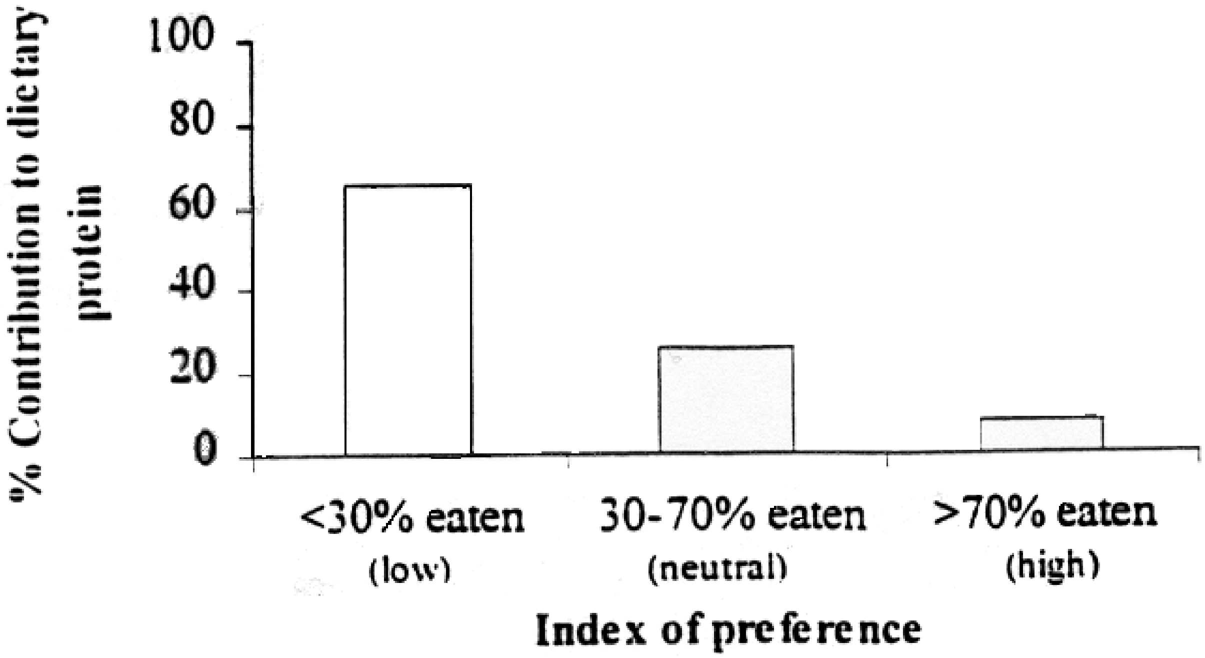
Key: Diet evaluation 1 - analysis of feed and remains, assessment of palatability; Diet evaluation 2 - focal animal sampling of intake; Diet evaluation 3 - literature review and survey; Chemical analysis 1 - analysis of plant material; Chemical analysis 2 - analysis of faeces; Gut passage time - measurement of gut transit time

Dietary Evaluation by Weighing Feeds and Remains

The method most commonly used to evaluate a diet is relatively simple, although time-consuming. Trials are run over a period of time (usually 7 days or more to encompass the range of foods fed), during which all the food items offered to the study animals are weighed at the time of preparation. All food remaining at the end of a feeding period is carefully collected and also weighed. Some means of compensating for changes in moisture content must be used, and this is achieved either by drying feed and remains samples to a constant weight in a drying oven or through the use of a dummy or control feed to mimic the climatic conditions experienced. Although the first method is more accurate, it can often prove impractical for large volumes of food and in the instance of large bamboo stems fed to Alaotran gentle lemurs 'control' values for moisture loss in forage were used instead [Fidgett *et al,* 1996]. Reconstituted weights, subtracted from original weights fed, produce an estimate of feed intake. These values are then averaged over the length of the diet trial. As Oftedal and Allen [1996] point out, the nutritional composition of the diet is typically estimated from data on the nutrient composition of individual items in the diet and is therefore only as accurate as the data upon which the estimate is based. For many of the nutrition studies at JWPT, a software program Animal Nutritionist [N-Squared Computing, Silverton, Oregon] has been used. Its own database of 1500-plus food items can be added to with relative cases, although care must be taken to ensure the correctly units are used, particularly when the use of conversion factor is required. Hence from weighing feeds and collection of remains, through the use of Animal Nutritionist, it is possible to arrive at an estimate of nutrient composition. Comparisons between the intake of different groups are made on the basis of total group body weight, rather than by the number of animals in each group.

Despite being labour-intensive, this technique has been the main one used to evaluate diets and the species' diets examined include Geoffroy's marmosets, aye-ayes, Alaotran gentle lemurs. St. Lucia parrots and thick-billed parrots. This method is also being used with Waldrapp ibis and Livingstone's fruit bats (Table 1).

The data provide an estimate not only of what is being fed, but, more importantly, what is being consumed. A comparison of the two may reveal whether nutritional inadequacies apparent in the diet consumed result from the animals' choice of food items, or are because the diet provided is inadequate. Price [1992] found the diet of Geoffroy's marmoset at JWPT to be deficient in protein and other vitamins and minerals. A simple index of preference. whereby food items were categorised into low, neutral or high palatability according to the percentage eaten, suggested that the problem of low protein content in the diet offered was compounded by the low palatability of feed items high in protein concentration (Fig. 1).



There is also the issue of appropriate standards by which to judge the adequacy of a diet. In the study described above, the marmosets' diet was compared to requirements established by the National Research Council for New World monkeys [NRC, 1978]. It should be noted however, that these values are those calculated for *Cebus* monkeys and no comparable data exist for callitrichids. Inevitably this is the case for the majority of exotic species in captivity and these limitations should be borne in mind when using requirement models.

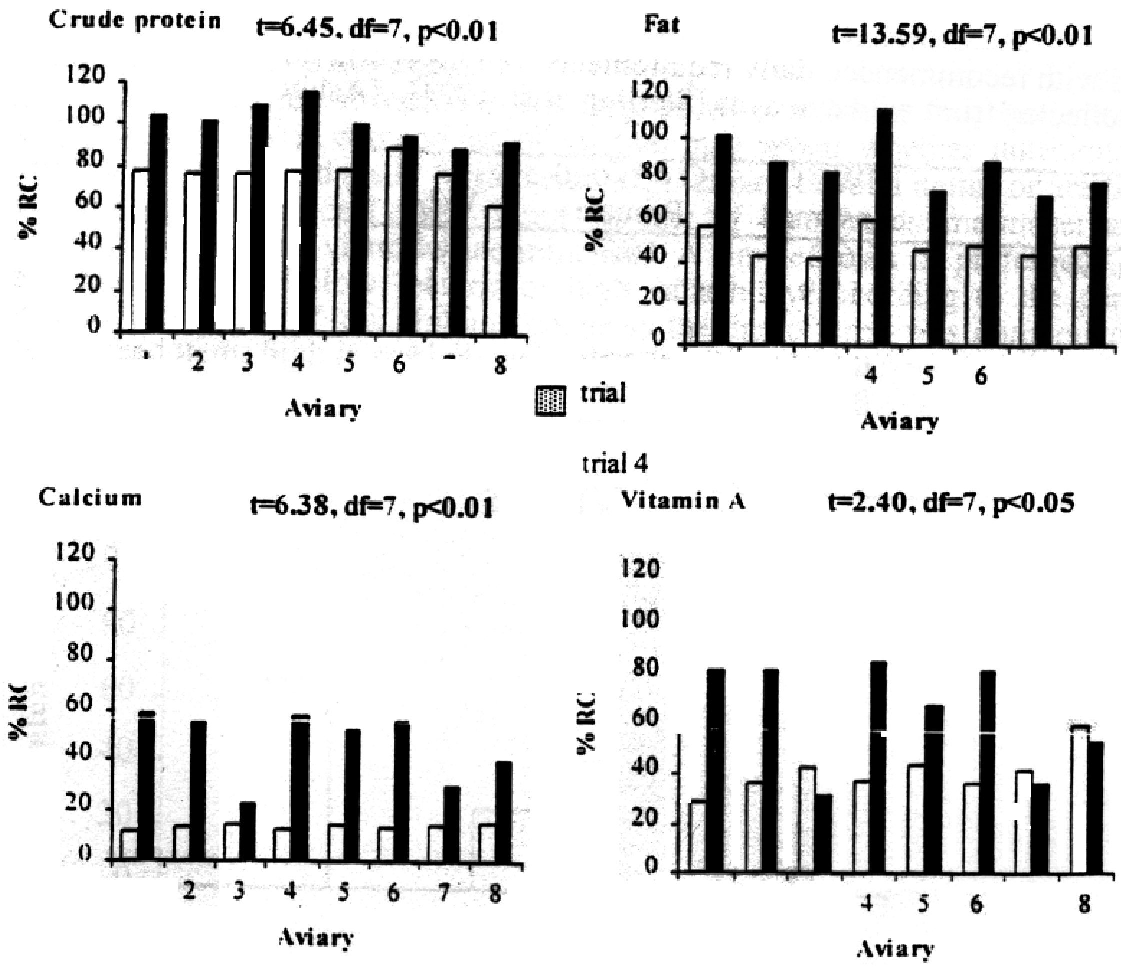
A preferable situation is when comparisons can be made between captive diets and data collected from animals in the wild. The majority of field studies of feeding ecology have tended to focus on the proportion of time that animals spend feeding on different food types, rather than their actual intake rates because the latter are often very difficult or impossible to obtain. In addition, it is only rarely that food samples are collected and analysed for actual nutrient content. Sterling [1993] was able to collect these data for aye-ayes, mainly because of the low dietary diversity of the species in the wild. Intake rates and food composition combined to give nutrient intake which could then be compared with data available for captive aye-ayes [Sterling et al., 1994]. It was found that nutrient intake in the captive aye-ayes at JWPT resembled that of wild aye-ayes during the cold-wet season, although fat content, vitamin A and Fe levels were noticeably lower in captive animal diets and vitamin E substantially higher [Sterling *et at.* 1994]. This is in marked contrast to the interpretation had aye-ayes been compared to established requirements for Old World monkeys [NRC, 1978], as shown by the examples of selected nutrients presented in Table 2. Captive diets cannot hope to recreate the physical content of wild diets, but instead strive to emulate the chemical composition using appropriate substitutes. The study above found that many items fed in captivity mirrored foods eaten in the wild (e.g. fat content of commercially grown nuts resembled that of *Canarium* nuts while waxmoth larvae and mealworms had a similar fat content to invertebrates consumed by wild aye-ayes [Sterling *et at,* 1994]).

T ABLE 2. The mean concentration of selected nutrients in the diet consumed by aye-ayes at JWPT, compared with recommended daily requirements for Old World nonhuman primates [NRC, 1978] and data collected from wild aye-ayes [Sterling et al, 1994]. [Ashbourne, 1994]

Nutrient	JWPT consumed	Old WorldPrimate	Wild
Crude protein (%)	6.2	16.7	11.5
Fat(%)	15.9	-	51
NDF (%)	1	-	35.8
Calcium (%)	0.091	0.555	0.14
Phosphorus(%)	0.112	0.444	0.7
Vitamin A (IU/kg)	720	13900	2518
Vitamin E (IU/kg)	14.8	55.6	2.9

(-) value not known

Having established the diet provided and ingested, and compared it with a suitable standard, it is possible to recommend revisions, and all of the studies described resulted in changes to the pre-existing dietary regimes. In one instance the effectiveness of successive revisions was measured using the same methodology. St. Lucia parrots at JWPT had suffered high mortality, from gout in young birds and arteriosclerosis in the older birds [Fidgett and Robert, 1993]. The additional factor of poor reproductive performance in recent years prompted a dietary evaluation. A major concern was that the disease problems indicated a diet too rich in protein and fat. However, the dietary analysis demonstrated that both these components were in fact present at concentrations lower than recommended requirements [Baer and Ullrey, 1986]. Other nutrients, notably vitamin A and calcium, were extremely deficient. Changes to the diet were recommended and implemented and included the use of cheese and soya beans. Both of these items proved to be extremely palatable to the parrots and, as a consequence, protein and fat levels increased dramatically in a subsequent trial, although vitamin A and calcium levels were not significantly improved. Further revisions included reducing the use of cheese and adding parrot pellets. Matched pair t-tests compared the original diet with the final revision and found significant increases in the four nutrients of interest [Fidgett and Robert, 1993], as is shown in Figure 2. An equally important revision involved the timing of food presentation; first thing in the morning the parrots were now given the nutritionally important items (e.g. the parrot pellets), and fruits etc. were fed late, to reduce the opportunity for the birds to feast on fruit at the expense of obtaining adequate nutrition from the pellets.



DIETARY EVALUATION BY FOCAL ANIMAL OBSERVATIONS

While attending to the animals' welfare, evaluating the diets of species in their natural groupings is an unreliable means of estimating their individual intakes. It relies on the assumption that every animal in a group eats an identical amount and that no single animal eats all of one food item. Factors such as age, sex, grouping, dominance status and breeding origin may affect food choices made by individuals and direct behavioral observations made at feeding times can provide valuable information about these choices. One such study has been carried out at JWPT on St. Lucia parrots [Fa and Cavalheiro, in press]. During anyone feeding session, focal animal observations were made of a single bird within a pair. The time, food type and number of pieces ingested or rejected were recorded, as were any aggressive interactions. The typical weight of a food item being offered was also measured, in order to calculate intake from number of pieces ingested. It was found that diet diversity and food intake was higher for females than males, and wild-born birds consumed less but ate a wider variety of foods than captive-born ones. Birth origin effects were confounded by the fact that all the older birds were wild born, representing the founder population. Within paired birds, females were more aggressive towards their mate, which may have influenced lower feeding levels observed for males, although single males also ate less, [Fa and Cavalheiro, in press]. The results from this study suggest that it is not possible to make generalisations that satisfy optimal diet requirements because of the considerable individual variation found.

This type of study provides much more detailed information about individual preferences than can normally be obtained from calculating intake simply by the 'leftovers' technique described above. The effect of dominance can have important implications for an individual's dietary intake and attempts to ensure equal access to all include feeding groups more food than is actually required and scattering the food over a large area or in more than one dish. Nevertheless, short of separating animals at feeding times it is extremely difficult to guarantee that every animal will obtain its 'fair' share.

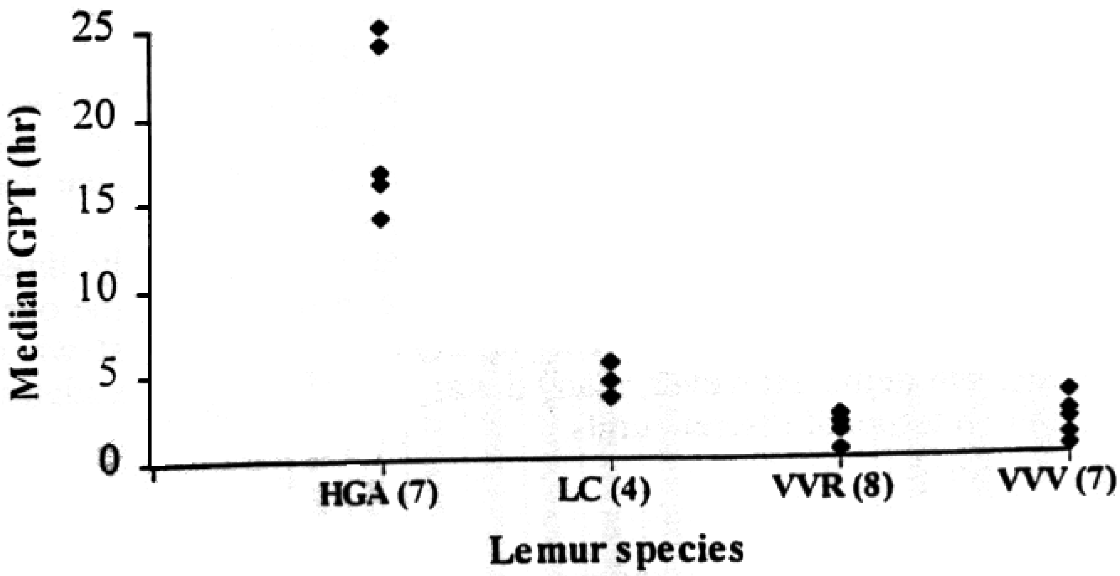
One problem with the focal animal sampling method is that it is extremely time-consuming; observing only one animal per feeding session will require a long period of time over which to establish a reliable data set if group size is large. This method also works best when intake can be measured in terms of discrete items. However, many dietary items, such as exudates, browse and forage, are not quantifiable in terms of discrete units.

Gut Passage Trials

Gut passage times are typically measured using an inert marker that is mixed with the food and passes unaltered through the gut. The time taken for this marker to appear in the feces provides an estimate of gut passage (transit) time (GPT). Many factors interact to affect GPT , including the composition of the diet, and the individual's health and any medical treatment (Krombach *et al,* 1984, Crissey *et al,* 1990). Therefore GPT can provide an additional means of measuring the impact of dietary changes and can also be used to provide baseline data for monitoring healthy digestive function. If the marker were mixed with the food for an entire group it would be necessary to house individuals separately in order to obtain measurements from them. This is clearly undesirable for social species and so a method using individual dosage was used, with chromium oxide (Cr203)' an inert green powder, as a fecal marker [Price, 1993]. Small cubes of bread were soaked in condensed milk to which the Cr2O3, marker had been added. The primates initially tested readily ate the bread and marker in this form and the green color was easily detectable in feces. The main advantage however was that the marker could be administered by hand to known individuals even while they were in a group, without the need to separate them from their usual cagemates.

No significant difference between species in GPT were found from a selection of closely related New World monkey species maintained in the collection at JWPT. Overall, healthy individuals from five species (Geoffroy's marmosets, silvery marmosets. *cotton-top tamarins, golden lion tamarins. Goeldi monkeys), all had average GPTs of* 4.5 *hr [Price.* 1993]. *Since all the animals in the study received the same diet, it was perhaps not surprising that this was the case, although there are considerable differences between their diets in the wild. Data such as these provide a baseline for investigating species differences in response to dietary manipulations. for example the addition of gum to the diet [Price.* 1993].

A similar study was conducted with captive lemurs (black and white ruffed lemurs, red ruffed lemurs, ring-tailed lemurs and Alaotran gentle lemurs) and significant differences between genera were found [Cabre-Vert and Feistner, 1995] .Hapalemur had the longest mean transit time of 18.21 hr, followed by Lemur (4.75 hr) and Varecia with just 1.70 hr (Fig. 3). These differences are likely to be related to the feeding ecology in the wild. Hapalemur is exclusively folivorous [Mutschler et a1., submitted] and has a relatively simple digestive tract [Tattersall, 1982], although it appears to have a slightly enlarged caecum acting as a site for hindgut fermentation, allowing it to process large amounts of fibrous food. In contrast Varecia are primarily frugivorous [White, 1989], and since fruits consist mainly of simple sugars they are easy to digest. Lemur lies somewhere inbetween, feeding on a more fibrous diet than Varecia, but without the extreme folivory of Hapalemur.



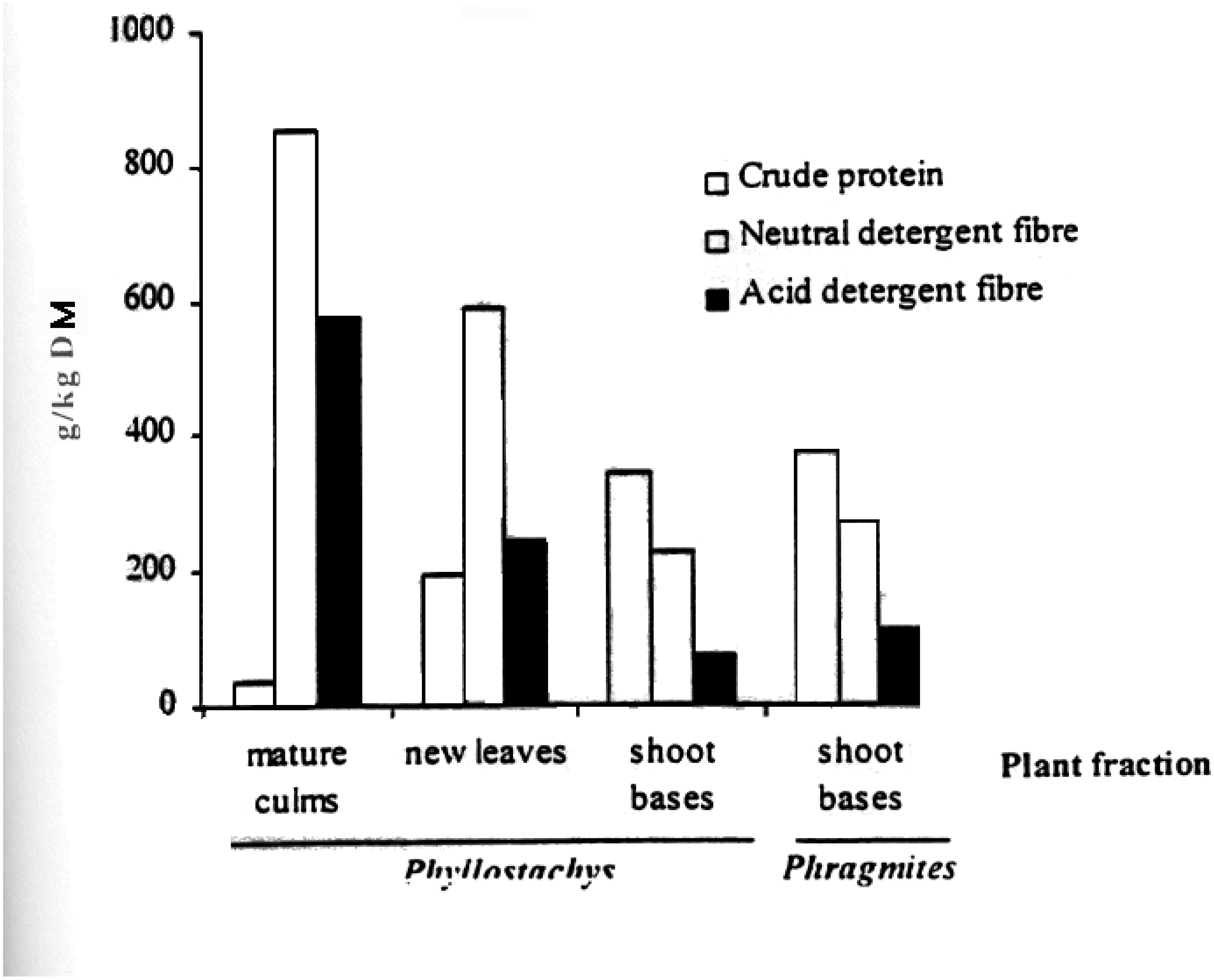
could be calculated by continuing to check the feces and/or by using more sophisticated methods to detect the dye, rather than just the simple visual methods used here. However, the data produced form the basis for interspecific comparisons and could assist the investigation of the effects of dietary changes (eg the inclusion of different or more forage/fibre in Halpalemur diets)

Chemical Analysis of Feces and Foodstuffs

Chemical analysis of feces and food stuff is a non-invasive technique because it does not involve the animal directly. Access to these techniques has relied on external collaborations, since JWPT does not possess the relevant expertise or analytical facilities: with the University of Bristol (Geffory's marmosets-feces, Price, 1992] and the University of Aberdeen (Alaotran gentle lemurs-feces and forage items, Fidgett, 1995, Fidgett et al, 1996]. Fecal analysis during the diet trials of the marmosets found mean digestibilities for dry matter, protein and fat were 84%, 92% and 87% respectively [Price. 1992]. Therefore, although the animals were apparently receiving insufficient protein in their diet according to published NRC requirements [NRC, 1978], the protein was in a readily digestible form.

Fecal samples collected from captive and wild Alaotran gentle lemurs provided an opportunity to compare their composition. Given that the sample sizes were small (n=4) and exact intake of the wild lemurs is unknown, interpretation of the results is limited. Nevertheless fecal samples from wild lemurs contained much higher levels of undigested fibre and less protein than samples collected from captive gentle lemurs [Fidgett, 1995].

All studied members of the genus Hapalemur are highly folivorous, having diets containing more than 85% bamboo [Wright 1989]. However, Alaotran gentle lemurs are restricted to a habitat where bamboo is not present and instead papyrus and reeds dominate its diet [Mutschler et al., submitted]. These forage items are not readily available at JWPT and so bamboo species are substituted. When offered bamboo stems as forage, gentle lemurs were extremely particular in their choice of plant fractions, selecting new plant growth (leaves or shoots), over mature clums (stems) and existing leaves. When whole apical shoots were fed, the lemurs were even more selective, stripping away fibrous shoot sheaths, biting off a section about 10-15 cm from the tip and eating only the base of this section. Only after these sections had been removed from all the shoots offered did the lemurs return to forage on the remainder of the shoot. High selectivity for shoots and leaves has also been observed in wild gentle lemurs [Mutschler et al, submitted]. Nutrient composition data for bamboo have been published, although in the limited context of a very different consumer, the giant panda [Dierenfeld et al, 1982]. Chemical analysis of the fractions consumed by the Alaotran gentle lemurs showed that the plant parts selected had relatively high concentrations of crude protein and low fibre content (Fig. 4). Further, the composition of the bamboo tips mirrored that of shoot bases collected from the common reed Phragmites, collected in Jersey but known to be a staple constituent of the diet of wild gentle lemurs. Analyses of the composition of wild Phragmites and other wild plant food species are underway and will be used to determine suitable substitutes for the captive gentle lemurs.



Diet Evaluation by Review and Survey

Herbivorous iguanas rely on hindgut fermentation to digest plant material, of which foliage is the principal component. The process of microbial fermentation that takes place in the hindgut is temperature dependent and so to be maintained successfully in captivity these highly specialised lizards require not only specific nutritional considerations, but also that factors such as lighting and temperature are appropriate. Poor reproductive success in two species of herbivorous iguana, rhinoceros and West Indian iguanas, at JWPT prompted a review of the literature for information on feeding and lighting requirements. A survey of the captive management regimes used by 30 major institutions that hold these genera was also conducted [Brice, 1995].

Information from the wild suggests that the diets of herbivorous iguanas are composed predominately of relatively indigestible plant material (78% of all plant matter consumed by *C. carinata* was leaf material, [Auffenberg, 1982]). However, less than half of the 16 institutions that replied to the survey offered natural forage to their iguanas and all but one fed fruit (Table 3).

A further recommendation based on field observations is that captive iguanas be fed a limited number of items on a daily basis in order to maintain the throughput of digesta [Brice, 1995]. It is more commonly the case that animals are fed only a few times per week.

T ABLE 3. Brief summary of food groups represented in diets fed to two iguana species, from the responses of 16 institutions surveyed, [Brice, 1995].

	Fruit	Root Vegetables	Leafy Vegetables	Natural Forage	Supplemen
No.Collections	15	11	16	6	15

DISCUSSION

This paper has reviewed a variety of nutrition projects carried out at the Jersey Wildlife Preservation Trust. We have demonstrated that even a relatively small zoological institution, without specialist nutritional expertise or the necessary laboratory facilities, can, nevertheless, undertake studies of nutrition in exotic species which enhance the captive management of those species.

This paper has emphasized diet evaluation in terms of nutrient quality. However , devising a diet of optimum nutrient content is of little benefit if the animals do not eat it and so palatability has been an important consideration in these studies. But providing a good diet that is readily eaten by the animals is not sufficient if distribution or social effects inhibit or limit adequate intake by certain individuals. Although not covered in this review, the presentation and distribution of food needs to be considered in parallel with diet formulation, to ensure that all individuals have equal, or near equal, access to food resources, and that monopolisation of feeding sites or preferred food items does not occur. Finally, since finding and consuming food may occupy a substantial proportion of daily activity in the wild, simply providing a good diet, well distributed to ensure equal access to all, may still not be sufficient if the animals consume their daily energy intake in an extremely short time period. Thus behavioural and environmental enrichment is an extremely important component of providing captive exotics with appropriate nutrition. For example, at JWPT the invertebrate component of the aye-ayes' diet (mealworms, waxmoth larvae, Eudicella larvae, etc.) are presented in sections of bamboo so that the aye-ayes have to employ natural foraging methods (digit tapping, gnawing, use of the 3rd or 4th digit for extraction) to access their prey [Carroll and Beattie, 1993]. Marmosets are provided with gum in artificial gum trees, so that they have to gnaw to access the gum, as they would in the wild, and lion tamarins are provided with bromeliads and provisioned, leaf-litter-filled foraging boxes so that they can forage naturally. In this way both dietary and behavioural considerations are met. These aspects are especially important for animals destined for reintroduction, although they should be an important component in the formulation of dietary regimes in general.

Although in some cases artificial or pelleted diets may be adequate in terms of nutrient quality, at JWPT a wide range of natural foods are also given, so that, although some dietary components may form a daily 'core', many other items vary on a daily basis, providing variety and stimulation. Forage and scatter-feeds are regular components of the diets of many species, reptiles, birds and mammals.

Many of the diets fed to exotic animals in captivity have been devised from 'lore' handed down, based on the belief that diets of the approximate foods eaten in the wild will be adequate for the majority of zoo animals -"monkeys have been fed fruits and vegetables, carnivores slabs of meat, and insectivores trays of mealworms without regard to nutritional composition" [Oftedal and Allen, 1996, p.109]. However, dietary evaluation often presents a very different picture, and assessing actual nutrient quality allows the formulation of diets which are more nutritionally appropriate for the species in question. Since an increasing number of exotic animals are also of conservation concern, a greater understanding of wild animal nutrition will enhance our ability to care for them appropriately in captivity. The field of exotic animal nutrition is thus an important growth area for the future, and one in which zoological institutions can play a leading role.

CONCLUSIONS

Non-invasive techniques of diet evaluation (analysis of feed and remains, focal animal sampling to measure intake, gut transit time, and chemical analysis of plant parts and feces) can be successfully employed, in the absence of specific nutritional expertise or laboratory analytical facilities, to provide information leading to the improvement of diets fed to captive exotic animals.

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