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A Comparative Multi-Zoo Survey Investigating the Housing and Husbandry of *Callimico goeldii*

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Abstract: Callimico (*Callimico goeldii)* are members of the callitrichid family, and a species of conservation concern managed within the European Association of Zoos and Aquaria (EAZA) ex situ program. They benefit from extensive 'Best Practice' guidelines developed by the Callitrichid Taxon Advisory Group (TAG), but there are gaps in species-specific knowledge and captive management research. A survey was created to understand and evaluate current housing and husbandry within EAZA collections holding callimico. The questionnaire allowed collation of details including enclosure size along with prevalence of mixed species exhibits, use of UV-B lighting, enclosure complexity and enrichment routines. Responding collections represented 44% of the current callimico holders, with the results allowing comparative analysis of current practice against the guidelines and considering previous research. Significant positive differences were discovered between minimum recommended enclosure dimensions, including total enclosure volume, 32 m^3 ($p < 0.001$, median = 100) and height, 2.5 m ($p < 0.001$, median = 3) versus EAZA's minimum recommended dimensions. Encouragingly, no significant difference in complexity was found between on and off exhibit housing, but the results suggest that being housed in a mixed species exhibit offers a more complex environment for callimico ($W = 405.5$, $p < 0.005$). The responses revealed overall good practice, although a disparity was noted in the provision of UV-B lighting and the prevalence of enrichment. Observational research focusing on spatial use, preference and behavior is recommended to complement husbandry guidelines. Reference of the survey findings to welfare indicators could determine the effect of current housing and husbandry on callimico welfare.

Keywords: Goeldi's monkey; callitrichid; captive management; welfare; enclosure complexity

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1. Introduction

It is essential that zoos provide captive environments that recognize the physical and behavioral needs of the animals in their care. Husbandry guidelines can support such provision, but, for some taxonomic groups, the recommendations are generalized to the whole family group rather than considering species-specific differences. The EAZA Best Practice Guidelines for Callitrichidae [1] are one such set of guidelines providing wide ranging support to optimize the housing, husbandry and nutrition of the callitrichid family. They are continually reviewed and cover an extensive range of housing and husbandry information gained from both field studies and research but are not always able to provide species-specific advice. They are tasked with providing information for those of the 62 species and subspecies held in captive care, including Goeldi's monkey or callimico (*Callimico goeldii*). Found in fragmented populations in the Amazon basin of Brazil, Bolivia, Peru and Colombia, callimico live sympatrically with red-bellied (*Saguinus labiatus*) and saddleback tamarins (formerly *Saguinus fuscicollis*, now reclassified *Leontocebus fiscicollis*), occupying a dietary niche in the understory of secondary and bamboo rainforest [2]. These groups can range from a breeding pair to larger groups of up to ten that include multiple

males and females, with a dominant breeding pair and occasionally a second breeding female [3,4]. Callimico are omnivorous, with a varied diet that includes fruit, invertebrates, small vertebrates such as frogs and, unusually for primates, fungi [5]. Increased levels of threat, including deforestation, are coupled with a continuing decrease in the in situ population [4], leading to their management under the European Association of Zoos and Aquaria (EAZA) ex situ program (EEP), supported by the Callitrichid Taxon Advisory Group (TAG).

While a gap in knowledge does not equate to poor husbandry, understanding captive environments can enhance welfare and offer a species an opportunity to thrive [6]. Provision of suitable housing by zoos is a result of legislative requirements with industry standards for European zoos set by EAZA [7], which are then evaluated through welfare audits [8]. The callitrichid best practice guidelines make recommendations for enclosure areas that are accessible for 80% of waking hours throughout the year, including a minimum total area of 32.5 m^3, minimum height of 2.5 m and floor space for internal and external enclosures of 3 m^2 and 10 m^2, respectively [9]. Porter [10] calculated a home range of 150 ha for a Bolivian study group of callimico, five times more extensive than the sympatric tamarins observed during the same study, although Rehg's north Brazil study [11] reported a maximum range of 59 ha for the species. In the context of free ranging exhibits, it was suggested that no callitrichid enclosure can be too large [12]. Vertical spatial use in situ by callimico is reported to range from terrestrial foraging of insects and mushrooms [4] to higher levels of the canopy to retrieve fruit, recorded at more than 25 m [13]. However, Ferrari [14] made clear that there is still a need for greater knowledge of this species.

Recommendations can be useful in collection planning, but enclosure size may be less important than complexity for primates [15]. Although there appears to be a paucity of specific research for callitrichid enclosures, considering the presence and dimensions of internal components can be important in understanding both useable space available and the utilization of those components or zones by the occupying species [16–18]. The creation of a varied and complex environment may be instrumental in not only increasing usable dimensions within an enclosure but also promoting natural behavior. Cotton top tamarins (*Saguinus oedipus)* were found to exhibit higher levels of natural behaviors in a more naturalistic and complicated enclosure that emulated a rainforest [19].

Field studies for callimico have provided much of what is known about the species' natural ecology, spatial use and activity budgets [11,13], while the majority of studies conducted ex situ predominantly consider reproductive [20] and health issues [21] as well as phylogeny [22] and their use within medical research [23]. Previous comparative multi-zoo husbandry studies have been successful in identifying key areas for further research [24,25] as well as associating health with poor enclosure design [26,27]. The use of mixed species exhibits and provisions such as ultra-violet (UV-B) lighting have been highlighted as areas of interest to the EEP coordinator. The focus of this study is a survey to understand and evaluate the current housing and husbandry practices across EAZA collections. We aim to investigate enclosure size for the species held in collections across Europe by group size and mixed species exhibits as well as exploring enclosure provisions and considering enclosure complexity.

2. Materials and Methods

Following endorsement from the EAZA Callitrichid Taxon Advisory Group (TAG) and ethical approval through University Centre Sparsholt, a Google Form© questionnaire (Supplementary Materials S2) was sent by the EEP coordinator for the callimico to zoological collections within EAZA (n = 87). Participants were able to answer as little or as much as they were able to and were able to attach taxon advisory reports, photographs and further information. Most surveys were automatically recorded though Google Forms©; the remainder were submitted using a converted PDF form. The questionnaire was composed of 8 question sections of varying length relating to housing, features and routines used within the collections and mixed question styles, incorporating tick boxes, short and long

answer questions. The questionnaire could be completed by any staff with day-to-day knowledge of the callimico enclosures and husbandry.

Following collation of descriptive statistics for the callimico population, the enclosure size data were calculated to provide measurements for total space (m^3), floor space for internal, external and total area (m^2) as well as for height (m), allowing direct comparison to those recommended by the best practice guidelines. Where a range of height measurements were provided, an average was taken. Groups in separate enclosures within a zoo were treated independently. The guidelines are specific about the recommendations relating to areas used for 80% of waking hours [9]. Callimico are diurnal; in the absence of specific waking hours noted within collections, a 12 h waking/sleeping pattern was adopted in line with previous literature [28] and applied to enclosures where restriction of access between enclosures was detailed. Additionally, where a collection specified that access between enclosures was temperature-dependent, climate charts for the locality of the collection were considered to understand the percentage of access provided. Enclosures where dimensions for height were unavailable, including for 'free range' settings, and where access was irregular or required physical movement of the callimico were not included in the total space calculations.

It was possible to calculate the volume for all but three of the enclosures. The range of space available for the callimico for 80% of their waking hours was wide, from 10 m^3 to 1485 m^3; this latter collection was not used in calculations for the cubic area as it was close to four times larger than the next largest area at 480 m^3; its inclusion skewed the results. To determine the deviation in enclosure sizes from that recommended by EAZA (32 m^3) [29], a non-parametric 1-sample sign test was utilized. Indoor enclosures, where specified, were similarly analyzed, although a 1-sample *t*-test was used to compare outdoor enclosure space to determine if there was a significant difference between the mean and the recommended outdoor floor space (10 m^2).

The data for enclosure size (m^3) were used to examine if there was a correlation between the size of enclosures and the number of callimico housed, with 24 enclosures housing single species and 15 mixed species exhibits. Where other callitrichids were present in the enclosure, they were included in the occupancy data as their spatial needs are covered under the same guidelines as callimico. A further test was run for mixed species enclosures to understand any significance when other callitrichids were not accounted for. Associations between number of callitrichids and size of the exhibit were tested using a Spearman's correlation for both single and mixed species exhibits.

Height measurements were non-parametric when checked for normality ($p < 0.05$); a 1-sample sign test was conducted to check the median against the EAZA-recommended height of 2.5 m. To understand the impact of allowing free access within enclosures, the data encompassing measurements for total volume (m^3) and total floor space (m^2) were also examined with a 1-sample sign test.

A non-parametric Mann–Whitney test was conducted to establish if there was a difference between the size of single species exhibits of callimico and those housing multiple species. A note was then made of each type of substrate, furnishing and plant element recorded by each respondent, with an equal single score allocated to each type of feature. If the exhibit housed mixed species, a single score was also added for this, with no account made for the number of animals. Because there was an uneven number of on and off exhibit enclosures, a Mann–Whitney was conducted using the total score for each enclosure to ascertain if there was a difference between on and off exhibit complexity and to examine whether there was a difference between the complexity of exhibits that housed callimico only or included mixed species. A further Mann–Whitney test enabled further comparison of complexity between callimico-only and mixed species enclosures. In this instance, each type of species was allocated a single score; again, no allowance was made for the number of species.

Descriptive statistics were used to show the variety of mixed species and to record enclosure components and the use of enrichment and training. When examining the

prevalence of UVB lighting, reference was made to UV Index maps [30,31] to differentiate regions as Northern and Southern within the responding collections.

3. Results

A total of 39 surveys were received, representing 44% of EAZA collections holding callimico: these surveys were representative of 43 exhibits. The population included five solo males housed in mixed species exhibits, while 30% of the enclosures contain callimico pairs, 18.6% of which were mixed sex pairs, not all breeding, with the remainder being sibling pairs. Further groups, including family ensembles, ranged from three to eleven individuals. These included 50 males with an age range of 1 to 23 years, with an average age of 9 years, while the 39 females had a similar range of 1 to 22 years (average of 9 years), with a further 15 infants under the age of 1 year, not all of whom were sex-determined. The median group size was 3 with a mode of 2.

3.1. Enclosure Size

A 1-sample sign test revealed a significant positive difference ($p < 0.001$ median = 100) between the EAZA-recommended minimum size of 32.5 m^3, with thirty-one collections shown to be housing callimico in enclosures greater than the recommended size and eight not achieving this (Figure 1). A further 1-sample sign test between the recommendation and data, which included the full area of the enclosures available if there was free access, showed a significant difference ($p < 0.001$, median = 111) and reduced the number of collections not meeting the minimum recommendation to four.

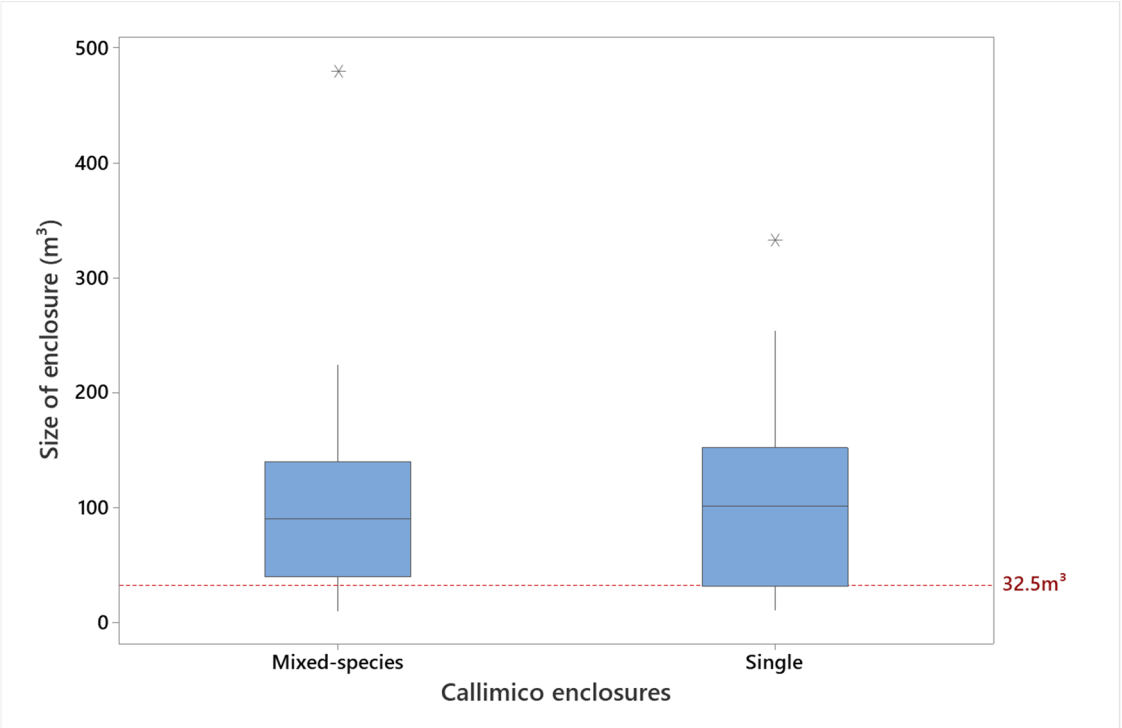

Figure 1. Size of mixed species exhibits v the single callimico exhibits. The recommended size (32.5 m^3) is delineated in red. * denotes the large outlying enclosure sizes data.

When comparing single-species exhibits of callimico and those housing multiple species, a similar median (90 m^3 for mixed species and 101 m^3 for single-housed callimico) and similar ranges (40–140 m^3 for mixed species and 32–120 m^3 for single-housed callimico) were found, with both types of exhibits having similar minimum-sized enclosures of 10 m^3 and 10.35 m^3, respectively, with larger enclosures observed in the outlying data for each

exhibit (480 m^3 and 333 m^3, respectively). A Mann–Whitney test confirmed no significant difference ($W = 302.50$, $p = 0.952$) between the size of both types of enclosures (Figure 1).

Height

A significant difference was revealed by a 1-sample test when comparing the median against EAZA's recommended height for enclosures of 2.5 m ($p < 0.001$, median = 3), with five enclosures meeting the recommended height, twenty-seven exceeding it and six enclosures less than the recommended height (Figure 2).

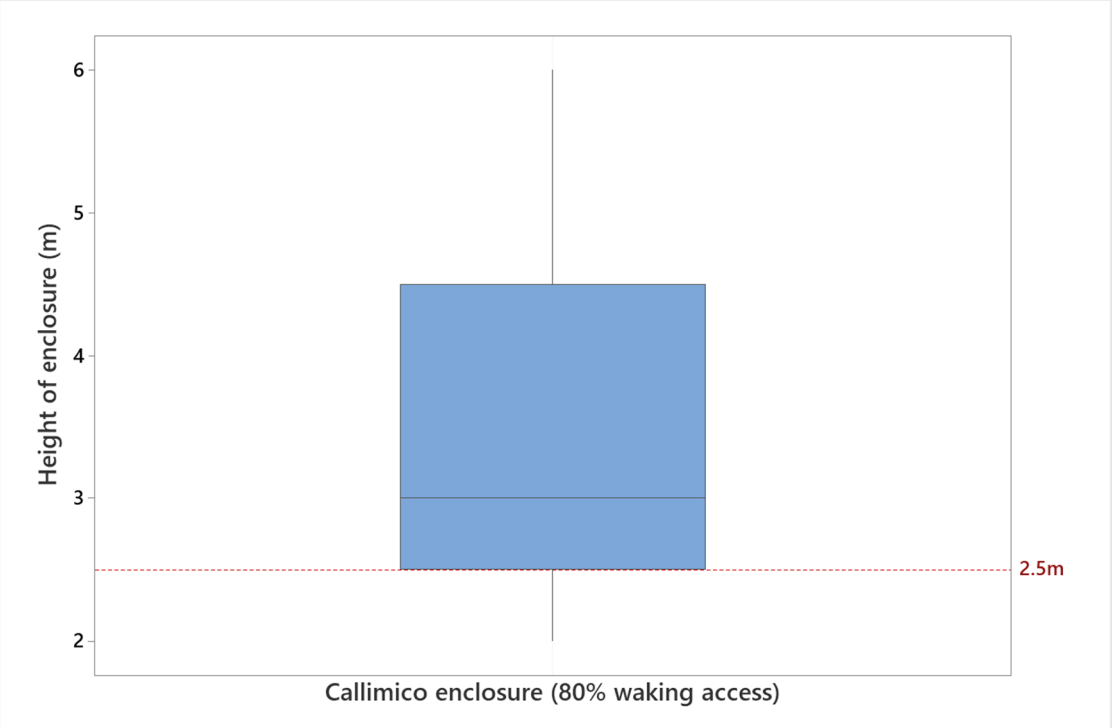

Figure 2. Height in callimico enclosures to which there is access for 80% of waking hours, with the median shown at 3 m; the range runs from 2 m to 6 m, with the majority of enclosures having a height between 2.5 and 4.5 m, exceeding the recommended 2.5 m shown on the line.

3.2. Mixed Species Exhibits

Of the 43 enclosures considered, 17 of them housed callimico alongside a variety of species, with mammals being most represented (Table 1), with 57% of these being Callitrichidae. Of these enclosures, four housed a single male callimico.

Table 1. Species held in mixed exhibits with callimico.

	Species	Enclosures Holding These Species in Mixed Exhibits with Callimico
Birds	Grey-winged trumpeter (*Psophia crepitans*)	3
	Green-cheeked parakeet (*Pyrrhura molinae*)	1
	Sun bittern (*Eurypyga helias*)	1
	Black-tailed trogon (*Trogon melanurus*)	1
	Brazilian tanager (*Ramphocelus bresilius*)	1
	Golden conure (*Guaruba guarouba*)	1
	Palawan peacock (*Polyplectron napoleonis*)	1

Table 1. *Cont.*

	Species	Enclosures Holding These Species in Mixed Exhibits with Callimico
Primates	White-faced saki (*Pithecia pithecia*)	2
	Pygmy marmoset (*Cebuella pygmaea*)	5
	Cotton top tamarins (*Saguinus oedipus*)	1
	Bearded emperor tamarin (*Saguinus imperator subgrisescens*)	1
	Common marmoset (*Callithrix jacchus*)	2
	Geoffroy's marmoset (*Callithrix geoffroyi*)	1
	Red-handed tamarin (*Saguinus midas*)	1
	Golden lion tamarin (*Leontopithecus rosalia*)	1
	Golden-headed lion tamarin(*Leontopithecus chrysomelas*)	1
Other Mammals	Two-toed sloth (*Choloepus didactylus*)	4
	Azara's agouti (*Dasyprocta azarae*)	4
	Red rump agouti (*Dasyprocta leporina*)	1
	Lowland paca (*Cuniculus paca*)	1
	Rock cavy (*Kerodon rupestris*)	1
	Mixed banded armadillo (*Tolypeutes matacus*)	1
Reptiles	Red foot tortoise (*Chelonoidis carbonaria*)	2
	Green iguana (*Iguana iguana*)	1
Amphibians	Smooth-sided toad (*Rhaebo guttatus*) (cockroach control)	1

Note: bold entries represent other callitrichid species.

3.3. Enclosure Resources

Although differences in complexity were noted between collections, there was no significance in the complexity between 'on' and 'off' exhibit enclosures in EAZA collections ($W = 733.5$, $p = 0.63$). When examining the differences between whether an exhibit housed mixed species or only callimico, no significance was noted in the complexity of the environment ($W = 492$, $p = 0.55$). A further test, which accounted for each individual species in a mixed species exhibit as an element of complexity, found significance when compared to callimico-only enclosures ($W = 405.5$, $p < 0.005$) (Figure 3).

UV-B lighting use was reported by 59% of responding collections (see Supplementary Materials S1 for details of lighting systems and cycles). The survey revealed that 15% of collections where callimico are indoors at least 80% of their waking hours do not use UV-B lighting in internal enclosures (Figure 4); the majority of these zoos were in the northern area of the EAZA region.

The use of multiple substrates was reported, with 69% of 'on exhibit' enclosures, whether internal or external, using two or more substrates within the exhibit, while this is only recorded in 5% of 'off exhibit' enclosures. These figures are not directly comparable as not all responding collections record a separate 'off exhibit' enclosure. Planting in some form was used in 97% of 'on exhibit' enclosures, although less than half of the enclosures identified as 'off exhibit' had planting. Of those collections with planting, 90% was permanent. Three collections reported using planting in pots and hanging baskets, while two used artificial planting. A variety of furnishings were recorded across the collections. Natural branches were the most common feature in both 'on' (97.4%) and 'off' exhibits (77.8%), whether external or internal. Details for ropes and branches showed a variety of diameters, with the range for ropes from 1 to 10 cm and for branches a wider range of 1–30 cm.

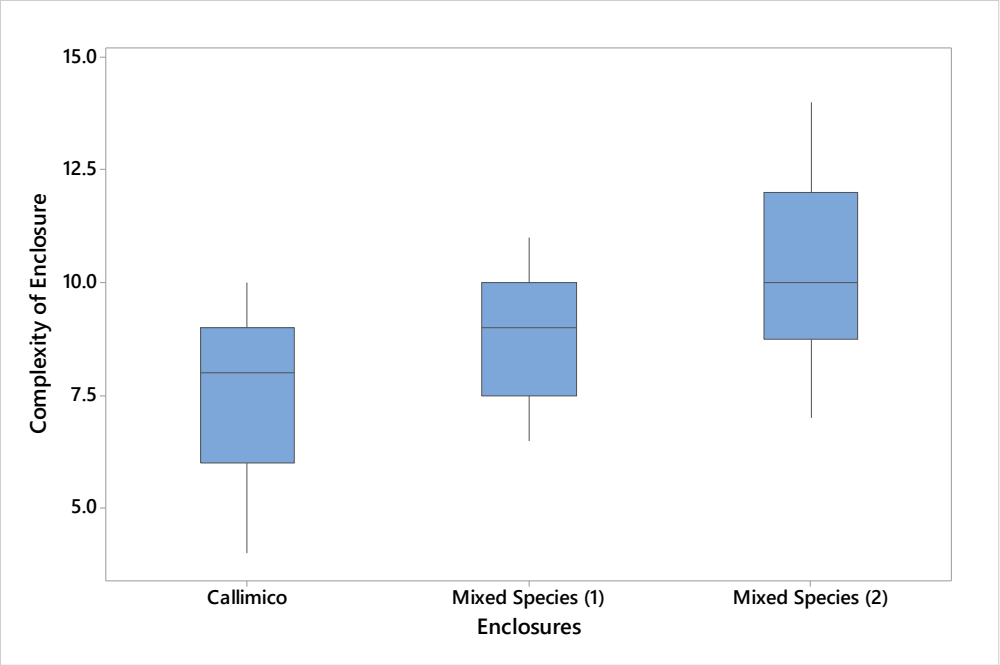

Figure 3. Boxplot suggesting increased complexity in enclosure environment when callimico are housed with mixed species. 'Callimico' refers to the complexity of exhibits housing this species only, 'Mixed Species (1)' allocates the presence of mixed species within the environment as an element of complexity. Mixed Species (2) includes each individual species housed within the exhibit as an element of complexity.

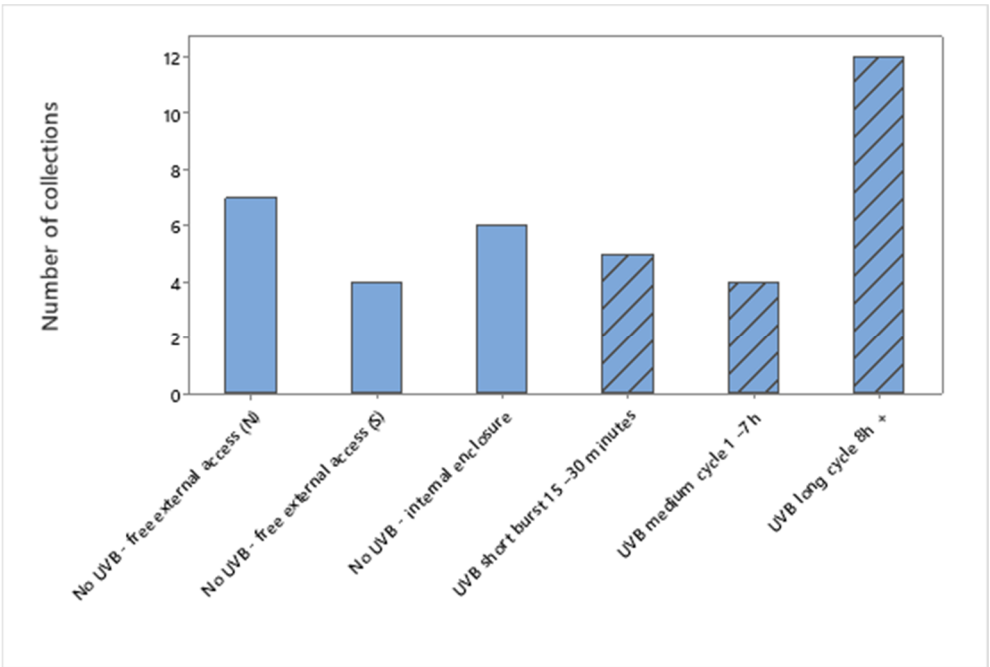

Figure 4. Prevalence of UV-B lighting in EAZA callimico enclosures. The plain bars show collections not using UV-B systems, whether they have free external access and if so if they are considered to be in a northern (N) or southern (S) climate. The hatched bars are collections using UVB within enclosures on varied cycles.

3.4. Enrichment

While 12% of zoos reported that they do not offer regular enrichment to their callimico, 53% of those that responded do so as part of the daily routine, two doing so twice daily, with a wide range of food-based enrichment protocols used as well as olfactory, social, environmental and cognitive enrichment. Specific examples, where provided, are noted in Table 2; 95% of the collections used invertebrates as food-based enrichment, with over half using vegetables, fruit or gum, with seasonal, natural branches also reported by three collections as being a source of foraging enrichment.

Table 2. Examples of enrichment currently being provided for callimico in EAZA collections.

Category	Types of Enrichment	Number of Collections Currently Using This Enrichment
Nutritional	Gum feeders, such as drilled logs	6
	Gum on branches	4
	Faux 'turf' mats for invertebrates	3
	Forage boxes/bags/tubes	14
	Hanging cartons/cages/baskets	5
	Pinecones	2
	'Kong' toys	3
	'Kebab' sticks	3
	Scatter feeding	4
Sensory	Herbs/herbal tea bags	4
Cognitive	Puzzle feeders	4

3.5. Training

A quarter of the respondents left the details for training blank or stated that they do not carry out training, while a further three zoos use handfeeding for close visual inspection. The remaining 66% of collections confirmed that they conduct some training with their callimico; four collections stated that this was completed on a regular weekly basis. Types of training reported were predominately for weighing, with additional training reported as crate training, general checkups/medical, general target training and recall.

4. Discussion

With reference to EAZA's husbandry guidelines, the results revealed a wealth of good housing and husbandry practices, with many collections exceeding recommendations in accommodation space and height [9]. The responses also suggested that many zoos use furnishings in an endeavor to meet the guideline's suggestion that exhibits should reflect natural habitat complexity. A diversity of enrichment was also recorded. Group sizes within the collection necessarily fluctuate with the breeding program, but the population is reflective of the variety recorded in situ [10], although the social structure is more typical of captive populations rather than the socially flexible troops observed in the wild [32]. No callimico were housed alone; solo males were housed in mixed species exhibits with other callitrichid species.

However, nearly one fifth of housing did not meet the requirements for either volume or total floor space despite the latter allowing for flexibility in enclosure design. While the lowest height of regularly accessed enclosures, 2 m, did not meet the recommended minimum, a previous study recorded callimico showing a preference for height use at 1–2 m despite the enclosure providing scope for double that range [33].

The results showed that, when total usable space, both by volume and floor area, was considered, it had the effect of reducing the number of zoos not meeting the minimum guidelines. Some collections responded that free access was temperature-dependent, with the restrictive trigger temperatures warmer than the examples provided in the guidelines, which suggested that external access is allowed in some collections as low as 5 °C and 0 °C [9]. Callimico may exercise the choice to avoid inclement weather [34], but decreasing the effect of the seasons and lower temperatures in external enclosures could be an option

to increase usable space and consequently spatial choice. Marwell Zoo has trialed 'smart heaters' [35], potentially offering a cost-effective way to increase available space.

Examination of overall differences between single species and mixed species enclosure size found the average of both types of enclosure at 90 m^3 to be almost three times that of the minimum recommended size. However, we are unable to comment on usable space for callimico within these enclosures, and the comparisons do not take into account the spatial needs of other species, other than where there are other callitrichid species within an enclosure. Although previous studies examined space utilization within mixed exhibits [33,34], how these needs overlap or impact those of callimico was not in the scope of this research. While no significant difference was revealed between exhibit size for callimico-only enclosures and those housing mixed species, it appears that the mixed species environment may offer greater complexity. It should be noted that the calculation for complexity based on the answers provided was very simplified, merely recording how many different elements there were within an enclosure. The study did not allow for density, quantity or quality of furnishings or planting to be compared. Complexity of an environment may alleviate restricted size [36], while control and choice within an environment can benefit welfare [37]. Understanding possible differences in 'on' and 'off' exhibits is important; all enclosure areas should offer similar complexity regardless of whether they can be viewed by visitors [38]. This is particularly important in a species such as callimico that may exhibit a nervous disposition [27] or whose use of an enclosure may be influenced by the weather [32]. The potential benefits of mixed species exhibits include social enrichment, education for visitors and cost effective, larger enclosures [34,39,40]. This may be reflected in their use by 40% of responding collections, although longevity and success were not examined. The use of toads for pest control was interesting; cockroaches, for example, can pose a health hazard as hosts for *Prostenorchis elegans,* an intestinal parasite [41], although the guidelines mention cockroaches for opportunistic feeding [42]. Research focused on spatial use in mixed species exhibits could complement earlier literature and may contribute to supporting their success.

A wide variety of UV-B lighting was recorded, with cycles differing even for similar bulbs. Inconsistent use of UV-B lighting may be a cause for concern. Callitrichid species have limited ability to absorb vitamin D in their diet, a lack of which can result in poor health, including metabolic bone disease; the need to supplement their environmental source of UV-B is an area identified for future research [16,42,43]. Provision of UV-B at 59% was slightly higher than that noted in previous research (51.7%) [27], although 15% of the exhibits in this study did not have an environmental source of UV-B, double that noted by Cabana et al. [27]. Of these, the majority were located in the north of the EAZA European region, where the UV index rarely increases above 6 and during the winter season is often much lower; for example, in the United Kingdom [44], it is significantly less than for callimico's equatorial-range countries. Access to an outside enclosure and natural sunlight in these northern areas may not be adequate as a source of UV lighting [45]. UV provision should take into account how an enclosure is used, which fell outside the scope of this study. Placement not undertaken in conjunction with known patterns of enclosure use could potentially limit effectiveness of UV-B, particularly if it is on for limited cycles during the day. [46]. Conversely, excessive UV-B exposure can have negative health implications [42,46,47]. The current literature around the use of UV lighting in animal enclosures is dominated by herptiles, which considers appropriate provision of UV based on an animals' natural ecology, their behavior and habitat use, which is categorized as a Ferguson Zone [46]. Accordingly, UV provision considers the dense understory of the callimico 's natural habitat [46].

A higher use of planting was recorded than that found by Cabana et al., who reported planting in 81% of callitrichid enclosures. While density of planting was not examined, it can be a constructive way to allow callitrichids to hide, considered as an important choice in reducing stress [27]. Planting can also enhance aesthetics for visitors [15,48], increase access and usable space in enclosures [9,49], stimulate natural foraging behavior

and offer sensory enrichment [19,50]. Less than half of 'off' exhibit enclosures recorded the use of planting despite the importance of maintaining complexity and free movement where possible between enclosures [38,51]. Planting was also reported as being difficult in some mixed species exhibits due to the destructive nature of some inhabitants. The use of hanging baskets or replaceable potted plants, used in some collections, may offer a solution [9,50]. As callimico are noted to forage terrestrially [13], it was encouraging that 69% of 'on' exhibit enclosures, whether internal or external, use two or more substrates, although this is only recorded in 5% of 'off' exhibit enclosures. Provision of substrates increases complexity of exhibits, offering a manipulative surface that can promote natural behavior and extend feeding periods through planned scatter feeding and opportunist feeding of invertebrates [9,50].

A wide range of furnishings were recorded, with all the collections supplying nest boxes, important in managing stress in callitrichids [9,27]. Natural branches were the most common feature reported, often ranging from 1 to 30 cm, reflecting a natural habitat [10]. Ropes were also reported as a common feature in exhibits, offering pathways through enclosures that increase usable space and access within the enclosure [9,18], although it is worth noting that their natural counterpart, vines, are less commonly used in situ [10]. One collection reported regularly changing the branches within the enclosure, simulating the variety and changing pathways of a natural environment [9]. Anatomically appropriate provision and placement of furnishings may stimulate natural locomotory behaviors that complement callimico anatomy; a preference for branch size and orientation has been demonstrated in field with small branches regarding the predominate substrate used, although vertical trunks and bamboo culms supported the species' characteristic trunk to trunk leaping locomotion [13]. Ex situ observations also suggested a preference for angled branches [33]. Future studies on enclosure complexity as a factor in behavior and space use should consider the size and orientation of furnishings, which may be essential for both behavioral and physical fitness [38,52].

A variety of enrichment techniques were employed by those collections that reported using enrichment; these were mainly nutritional enrichment, including foraging boxes, suspended feeding devices and artificial foraging turf. The use of herbs for olfactory stimulation and changing the environment to offer new places to use and hide were also detailed. While food-based foraging enrichment can be a simple and cost-effective method of promoting species-specific food processing, activity budgets and spatial use [53–55], it was noted that 61% of reported food enrichment used fruit. With a recent study revealing awareness of potential health benefits in removing cultured fruit from primate diets [56], there may be positive welfare implications in reviewing its prevalence in enrichment [49]. Callimico are not obligate gum feeders, although it forms part of their opportunistic diet in the wild [5] and is important to the behavioral and physical needs of captive callitrichids [42]. This study did not examine daily nutritional provision, but gum was only reported as a component of enrichment by 69% of zoos, although it can be an easy and effective method of promoting positive welfare [57]. One collection reported that fecal consistency improved following the introduction of gum enrichment. While a quarter of the respondents did not provide details of training, it was clear that collections that do train their callimico use it to assist routine and medical husbandry, potentially mitigating stress [58] and complementing other forms of enrichment through social human animal interaction [59,60]. While none of the responding zoos specifically recorded the provision of social enrichment, 40% of the enclosures contained mixed species whose social complexity may also provide enrichment [34]. Replicating the social structure of in situ callimico can be challenging in captivity, but it is essential that social welfare is addressed by housing animals either with conspecifics or with other species, such as other callitrichid species, that can allow for interaction and cognitive stimulation reflective of their natural environment [61]. Social interaction can provide a rewarding and pleasurable experience [62,63] and can occur between callitrichid species [64]. Encouragingly, no callimico were housed alone in the responding collections.

The study has provided a snapshot of current EAZA zoos revealing that callimico benefit from large, often complex enclosures, but its scope, without reference to observations, does not allow conclusions to be drawn about the welfare of the inhabitants. Restricted space need not infer poor welfare [17,65]; future research could employ enclosure use studies to identify how callimico use structural components and overall space. Evidence of preference within an exhibit can inform use and placement of furnishings or species-specific enrichment. Comparative observations may also be able to reveal appropriate activity budgets for the species for which the literature shows disparity [13,33,42] but could influence guidance on space use. Case studies have potential in identifying any influence that demographics or personality may have in the use of enclosures [61] and also consider callimico response to zoo visitors [51].

5. Conclusions

The snapshot of current housing and husbandry created by the survey demonstrates a high level of compliance; the guidelines clearly provide a wealth of information relating to the captive care of callimico. Choice and control are essential to promote positive welfare within a captive environment. Enhancing the complexity of enclosures and species-appropriate husbandry can achieve this and potentially mitigate factors that may be more difficult to address, such as enclosure size or access. Drawing on current practice within EAZA collections, this can include the use of planting and increasing or moving natural branches within enclosures, or the varied and regular use of enrichment to increase natural movement and behaviors. These can be cost-effective and simple to use. Ongoing research may identify more effective use of technology such as heaters to increase space use and appropriate UV-B lighting. Further research has been identified to provide more species-specific information through observations to understand spatial use and the effect of captive variables on callimico as well as using the comparative information from this survey in examining welfare indicators. The potential to translate this research to other callitrichid species may offer an opportunity to complement the existing guidelines. Suitable enclosures and optimum husbandry can promote welfare for captive callimico. Understanding the current provision and building upon best practice offers the opportunity to provide high levels of welfare that not only support the aims of the EEP but encompass the behavioral fitness of the species.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/jzbg5010005/s1. S1: UV Lighting reported in Housing and Husbandry Survey for Callimico 2021; S2: Callimico goeldii Housing and Husbandry Survey 2021.

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