

UNIVERSITÀ DEGLI STUDI DI PADOVA
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Owl Monkeys' Husbandry: an overview of captive
management techniques focused on *Aotus* species

Relatore/Supervisor
Prof. Giorgio Marchesini

Laureanda/o /Submitted by
Marianna Polito
Matricola n./Student n.
2033619

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ABSTRACT

The management of wild species in captive setting, like Zoos or Sanctuaries, has always been challenging both in terms of Animal Welfare and Human Safety. We sometimes find ourselves faced with animals kept in very poor conditions and inadequate environment that don't allow a life worth living. To avoid this, and promote a safe place in which animals can perform their natural behaviour, is fundamental to establish a list of specific requirements and techniques to enforce, in order to ensure the wellbeing of those animals kept outside their natural habitat. Of course, to do that, the main difficulty is to recreate a balance between the animal nature and the captive environment created for each. In this way the starting point for a good management is setting the needs of a species from which develop a husbandry tailor-made protocol, without forgetting the safety for the personnel working in the facility.

The purpose of this thesis is to collect and illustrate the main techniques to be put on practice for the captive management of Owl monkeys.

Owl monkeys, commonly named night monkeys, are nocturnal haplorrhine primates belonging to the genus *Aotus*, inhabiting the tropical forests of central and South America. They are social animals, with large eyeballs and an excellent olfactory apparatus to move in the dark, widely distributed from Panama to the North of Argentina.

According to the species biology and behaviour, the building of adequate enclosures in terms of space and permanent furniture together with the administration of enrichments and appropriate feeding techniques allow to ensure and improve their Welfare in captivity.

In addition to the literature review, in this thesis is reported a practical example of applied husbandry techniques and behaviour monitoring of the Owl monkey's species from Alturas Wildlife Sanctuary in Costa Rica.

INTRODUCTION

The genus *Aotus*, containing several species of Owl monkeys also referred as night monkeys, is still one of the least studied and of which we have less knowledge despite the fact these neotropical primates are widely distributed throughout Central and South America. The main reason is their nocturnal activity pattern, unique among New World Monkeys, which makes wild populations studies more challenging.

It is therefore necessary a combination of research methods, including both field and captive settings observations, aimed to integrate the current understanding of the species in every aspect. Keeping these animals in captivity, however, involves the establishment of tailored protocols based on species needs.

The purpose of this thesis is to catalogue the main husbandry techniques applied to the *Aotus* species complex in a captive setting, like zoos, sanctuaries or behavioural observation centres. The precautions on the captive management of these specimens enable to improve the welfare of owl monkeys outside their natural habitat, ensuring their well-being.

In order to develop the correct requirements for the genus is crucial to begin from an accurate analysis of the species biology and natural behaviour expressed in the wild.

1. SPECIES PROFILE

1.1 Taxonomy: species diversity

Owl monkeys belong to the genus *Aotus* which in turn is enclosed in the Aotidae family of the haplorrhine suborder. Originally, a unique species *Aotus trivirgatus* with relative subspecies was included in the genus, but subsequently to the taxonomic researches carried out by Philip Hershkovitz in 1983 the species classification has been improved. The American biologist has consolidated the presence of nine species of owl monkeys split into two groups depending on morphological differences (neck coloration), karyotypes and susceptibility to *Plasmodium falciparum* (Hershkovitz,1983). Four species belong to the grey-necked group (*Aotus lemurinus*, *A.brumbacki*, *A. trivirgatus*, and *A.vociferans*), while the other five are grouped in the red-necked one (*Aotus nancymae*, *A. miconax*, *A. nigriceps*, *A.*

infulatus, and *A. azarae*). Beside phenotypical features, a geographic distinction claims the species distinction, with the gray-necked group localized north to the Amazon River and the red-necked grouped spread along the southern side. Later primatologists have questioned this system supporting the discovery of two new species possessing a different combination of karyotype, phenotype and molecular data.

Because of this, the number of species and subspecies within the Genus is still debated and controversial due to the morphological similarity of sibling species and limited phylogenetic evidences; but currently 11 separate species are recognized: *Aotus lemurinus*, *A. zonalis*, *A. griseimembra*, *A. jorgehernandezi*, *A. brumbacki*, *A. trivirgatus*, *A. vociferans*, *A. miconax*, *A. nancymae*, *A. nigriceps*, and *A. azarae* (Fernandez-Duque, 2023).

1.2 Biology and Ecology

To better address the requirements for the *Aotus* species in captivity, it is crucial to understand their fundamental biological information and their interaction with native ecosystems. This includes habitat distribution, feeding habits, social structure and reproduction as well as key features of the behaviour expressed in the wild. All these facts provide an overview of owl monkeys' characteristics that distinguish them from other New World Primates.

1.2.1 Habitat and Distribution

Wild populations of Owl monkeys are found across the huge geographic area covering nine states (Argentina, Bolivia, Brazil, Colombia, Ecuador, Panama, Paraguay, Peru and Venezuela) from Panama to northern Argentina, inhabiting a great variety of ecosystems. Since the range is very wide and diverse, groups of individuals occupy many different altitudes from sea level (Caribbean and Pacific coasts) to 3300 m.a.s.l. (Andean cordillera).

Considering that Owl monkeys are arboreal species living in the high canopy of trees, the habitat type exploited includes various kind of tropical forests (primary, secondary and

remnant tropical forests), as well as deciduous, subtropical dry forests or gallery forests developed along rivers.

Evidences of the presence of groups has been reported both from natural and anthropogenic areas, that indicates the adaptability of the genus to lower quality environments resulting from habitat loss.

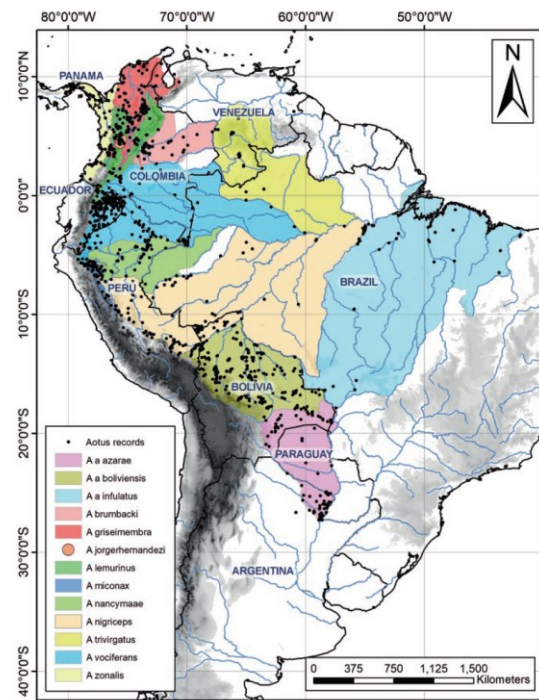
The discrepancies of vegetation, climate and resources availability within the range leads to the evolution of many species associated to specific geographical regions set by natural boundaries and their related environmental conditions.

The Owl monkey's species distribution was confirmed through a review of the distribution maps collected by the IUCN Red List, the "All the World's Primates" website and the "Biomodelos" program of Colombia's von Humboldt Institute. The results of the research showing detailed distributions for each individual species are as follows (Fernandez-Duque, 2023) (Fig. 1):

- *Aotus azarae* (including three subspecies *A. a. azarae*, *A. a. boliviensis*, and *A. a. infulatus*): found in Argentina, Bolivia, Brazil, Paraguay and Peru, from the Atlantic coasts to the Andes;
- *Aotus brumbacki*: endemic to central Colombia;
- *Aotus griseimembra*: found in northern and central Colombia and northwestern Venezuela;
- *Aotus jorgehernandezi*: a single individual was sampled from Los Nevados National Park, Colombia;
- *Aotus lemurinu*: found from northern Colombia into Ecuador, along Andes;
- *Aotus miconax*: endemic to northern Peru, along the eastern Andean cordillera;
- *Aotus nancymae* and *Aotus nigriceps*: distributed from western Brazil to Peru, at different altitudes;
- *Aotus trivirgatus*: found mainly in Brazil, Venezuela and a small portion of Colombia;

- *Aotus vociferans*: widely distributed in the Amazonian forests of Brazil, Ecuador, Colombia up to the Peruvian Andes;
- *Aotus zonalis*: found in Panama and Colombia, both on the Pacific and Caribbean coasts;

Fig. 1 Geographic distribution of Owl Monkeys species throughout South America (Eduardo Fernandez-Duque, 2023)



1.2.2 Morphology: focus on visual and olfactory specializations

Aotids are classified as small size monkeys: an adult individual ranges from 0.7 to 1.5 kg of body mass, with slightly variations according to species differences. Based on observations on wild and captive populations there is no significant sexual dimorphism in terms of phenotype or relative body size and weight. One characterizing feature of the species is the long but not prehensile tail, with an estimated length similar to the body one; while the forelimbs are shorter than hind limbs. Their dense coat is of various shades of grey and brown whereas the fur is pale yellow on the ventral aspect of the body. The globular head is marked by three black stripes that run vertically along the face which frame the “hypertrophied” brown eyes. As the etymology of the name *Aotus* suggests (from the Ancient Greek, *a-otus*, “without-ears”) the small and round pinnae of the ears are hidden in the fur (Fernandez-Duque, 2023).

To cope with their nocturnal activity, owl monkeys developed specific anatomical adaptations allowing the locomotion through the forest in dim light conditions.

From a morphological point of view is evident that their eyes have evolved to enable a greater sensitivity to light compared to diurnal primates. The large size and spherical shape

are associated with a larger corneal diameter to increase light photons collection. Moreover, the proportion between photoreceptors of the retina layer is not equal, since the number of cone cells (photopic function) is far below the one of rod cells (scotopic function); this rods dominance implies a poor colour vision in favour of an efficient visual system in low-light (Fernandez-Duque, 2023).

Regarding olfaction, all species of the *Aotus* genus possess a large olfactory bulb, approximately as big as their brain, and a functional vomeronasal organ on which they rely on for foraging and intra-specific communication.



Fig.2



Fig.3



Fig.4

Fig. 2,3,4 Morphology of Owl monkeys.

(Right and left pictures: Wisconsin National Primate Research Center website)

(Central picture: Fernandez-Duque,2023)

1.2.3 Nutrition and Feeding Ecology

Researches carried out on wild population faecal samples have shown that night monkeys are primarily frugivores, a feeding strategy highly dependent on the abundance and seasonal availability of fruit found in large crown-trees. A great variety of fruit represents the preferred choice to gain energy, followed by flowers, nectar and leaves of the corresponding plants during periods of fruit shortage (winter or dry season). A portion of fruit species contains good concentration of fats and non- structural carbohydrates, while flowers and leaves are the main source of fibres and proteins (Cruz et al., 2019). The primary diet is often

supplemented with large insects, like orthopterans or moths, and spiders which are usually active throughout the night. Competition with other primates for shared resources is extremely reduced thanks to Owl monkey's nocturnality; even other nocturnal species, such as bats, do not provide significant source of competition (Wright, 1989; 1994). Accordingly to their foraging habits, owl monkeys play a fundamental role in the dispersion of several plant seeds throughout the forest contributing to the reforestation process in tropical ecosystems.

1.2.4 Conservation Status

Because of the wide range of distribution of owl monkeys and the additional difficulties related to the nocturnal lifestyle and arboreal behaviour, field studies on abundance are very challenging. According to the Red List of IUCN *Aotus* spp. wild populations are experiencing a declining trend, even though not all of them are endangered. As reported in the Red List: *A. azarae*, *A. nigriceps*, *A. trivirgatus*, and *A. vociferans* are categorized as Least Concern; *A. brumbacki*, *A. griseimembra*, *A. lemurinus*, and *A. nancymae* as Vulnerable; *A. miconax* as Endangered; *A. zonalis* as Near Threatened; and *A. jorgehernandezii* is not classified due to Data Deficiency (IUCN, 2021).

The main risk factors are represented by habitat loss, illegal trafficking and hunting. Forests fragmentation due to anthropogenic activities, such as crops and farms creations (many of which are illegal) or infrastructures building, lead to a reduction of available habitat for owl monkeys as well as increasing road killings and power lines deaths. Furthermore, according to indigenous negative beliefs on owl monkeys, considered as "witchy monkeys", the hunting of these species is constantly growing aggravated also by illegal pet trade.

The historical background of the genus showed a use of specimens as models for biomedical research, aimed to investigate and test antimalarial vaccines, HIV drugs and ophthalmological trials; all this in an illegal and uncontrolled manner that brought to a decrease of wild owl monkeys population density, especially in the tri-border area between Brazil Colombia and Peru.

Nowadays all *Aotus* species are included in the Appendix II of the CITES (Convention on International Trade of Endangered Species of Wild Fauna and Flora, 2020) signed in 1975, which regulates their trading and possession. Unfortunately, illegal trade of owl monkeys is still present across Central and Latin America, representing an alarming threat for the conservation of the genus.

Over the years, however, many conservation projects have been launched to improve the current knowledge and preserve wild populations. Among these, the DuMond Conservancy of Florida (USA) examines the largest captive colony of owl monkeys and promotes educational campaigns for the conservation of the species since 1986, while the “Owl Monkey Project” began in Argentina in 1996 focusing on the observations and tracking of wild *Aotus azarae* through radiotelemetry (Fernandez-Duque, 2023).

1.3 Natural Behaviour

1.3.1 Nocturnality and activity budgets

The unique nocturnal activity pattern of Owl monkeys is the focal point to understand their natural behaviour in depth and learn how to deal with these species in captivity. All the eleven *Aotus* species are strictly nocturnal, make exception for *Aotus azarae* that shows a form of “cathemerality” by being active also during the day. Results from captive populations studies conducted under seminatural conditions demonstrate peaks of locomotor activity at dawn and dusk (after sunset from 6pm to midnight and from 4 am to 6 am before the sunrise), during the portion of the night when the moonlight has a higher intensity, allowing both cons and rods to function. Actually, there is a strong positive influence of moonlight on the activity level of owl monkeys as well as a direct proportion with environmental temperature (Fernandez-Duque, 2012).

While they are active, owl monkeys spend most of the time travelling in search of food resources to eat by moving quadrupedally through the canopy of trees. The remaining portion of the night is allocated to rest and only a small amount is dedicated to social

interactions as shown in the graph comparing different field studies on activity budgets over the years (Fig. 5).

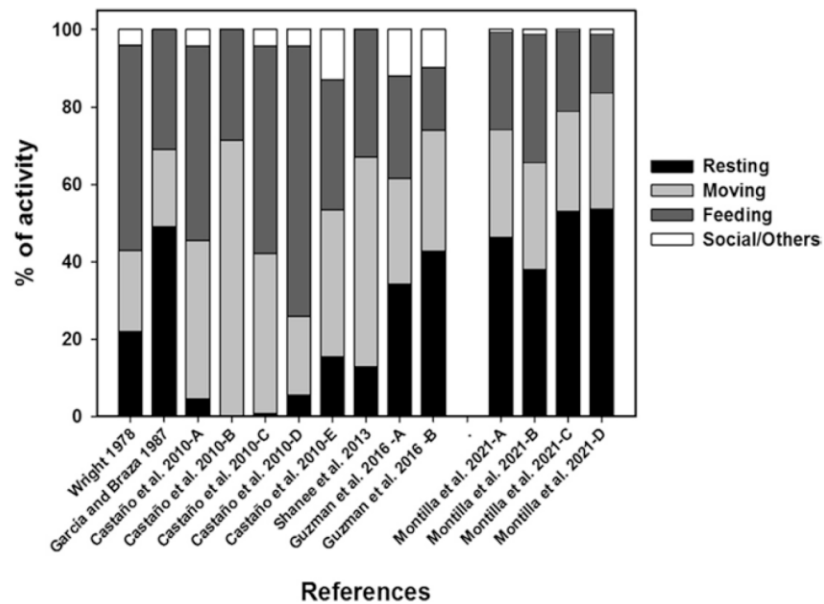


Fig. 5 Activity budgets of Owl Monkeys, a comparison between different studies (Montilla et al., 2021).

1.3.2 Social Structure, Reproduction and Parental Care

As described by E. Fernandez-Duque in his literature collection “the social organization of a species is determined by the size and composition (age/sex classes) of a social unit” (Kappeler, 2019). Compared to large social groups formed by several monkey’s species, the typical social unit among owl monkeys is rather small made up of a heterosexual adult pair (one reproducing adult male and one reproducing adult female), a single infant and several subadults of various age not necessarily related with the other group members. The size home range inhabited by a single-family group is about 4 to 10 ha (Wartmann et al., 2014) and it may overlap with that of adjacent groups. Territorial behaviours have been observed in nature, often ended in aggressive intergroup encounters including vocalizations, chasing, wrestling, stiff legged jumping and piloerection (Wright, 1994). The dynamicity of the group composition in the wild is conferred by “floaters”, which disperse from natal groups after

sexual maturity achievement (around 3 years old) to form new family groups or replace one sex of an existing pair.

Another peculiarity of *Aotus* genus, is their monogamous mating system that stands out among primates. Within a social group, the adult reproductive pair mate exclusively with one another for one or more reproductive season, as evidenced by data collected in captivity. They reproduce once a year giving birth to a single infant after a gestation period of 117-159 days depending on the species (Wolovich, Evans et al., 2008; Fernandez-Duque et al., 2011). The care of the offspring is shared between adult female and male (biparental care), however during the period after the first week of life the adult male plays a crucial role in the carrying of the infant and food sharing; this example of cooperative breeding it has been studied both in wild and captive owl monkey's populations (Fernandez-Duque, 2012).



Fig. 6 Owl monkeys (*Aotus azarae*) social group. (photo credit: Dr. Margaret Corley, Owl Monkey Project, Formosa-Argentina)

1.3.3 Communication

The nocturnal lifestyle that characterizes the *Aotus* Genus has had a substantial influence on the communication system of these species, which is based on chemical signalling rather than visual cues. To fit their nocturnal habits, conspecifics rely mainly on scent marking and vocalizations according to the different context.

Intra-group communication occurs through a combination of olfactory, auditory and visual signals specifically addressed to recognize group members and for the coordination of group movements across the home range.

Owl monkeys possess specialized apocrine and sebaceous scent glands localized at the base of their tail (large subcaudal gland) and on the sternum (sternal and pectoral glands) that vary in size depending on the species; their secretions are chemically distinct therefore necessary for individual recognition. "Urine washing" is another common behaviour

performed by owl monkeys to mark the territory and consists in urinating on their hands and feet in order to spread the smell while moving between branches (Wright, 1981).

Tactile interactions are displayed mostly through huddling (resting in contact with another individual) and tail-twine (tails overlapping) which confers a form of thermoregulation as well as social bonding. Additionally, allogrooming has been observed in adults and dependent infants, but also during pair formation between mates in captivity (Wolovich and Evans, 2007).

Beyond this, visual signals and facial expression seem to be of little consequence in respect to the other forms of communication listed above.

2. ANIMAL WELFARE IN CAPTIVITY

2.1 Animal Welfare: definition and applications

To better understand the animal requirements in captivity, is necessary to investigate the meaning of Animal Welfare and its implication for Husbandry.

In the past, the term has been widely used to describe only the physical health of animals as criterion for their well-being; however, this interpretation did not consider their emotional status. Thus, a complete definition of Animal Welfare must include both the state of animal's body and mind, and the extent to which its nature is satisfied (Hewson, 2003). All these physical, affective and natural living aspects experienced by an animal in relation to living conditions are interrelated and must be regarded as essential to ensure the optimal welfare.

The enforcement of the Animal Welfare Act (AWA) in 1966 has provided a new perspective on the welfare concept, defining the correct code of practice for the use and treatment of animals under human care, with the purpose of improving the life of animals in captivity and avoid suffering. The same principle is also shared in the Five Freedoms written by Francis Brambell in 1965, which highlight the minimum living standards to fulfil basic animal needs as well as promoting positive emotional status and allowing the expression of natural behaviours.

2.2 Assessing Animal Welfare

The definition of Animal Welfare underlines the articulation of this concept into three areas of concern: the basic health and functioning of animals, their affective state and the ability to express natural behaviour (David Fraser, 2009). Each sphere presents a different view on what should be emphasized as criterion for the evaluation of welfare, defining distinct scientific approaches for its assessment. Scientists that based their research on basic health and functioning of animals focus on mortality and injury rates detected in animals, while an assessment developed on animal's mental state identifies signals of fear, pain or distress as indicators of poor welfare. Finally, a natural living approach is established on species specific natural behaviour performed, along with animal motivation and right of choice. An effective welfare assessment should include valid and reliable indicators directly observed in animals, encompassing both behavioural measures and physiological parameters to accurately evaluate the animal's condition and, if required, adjust the management practices.

All different value-based approaches have contributed to significant improvements for animal welfare in captive settings, related for example to housing models, use of enrichments and animal handling procedures. Is therefore useful a combination of all three assessment methods and the balanced implementation of different criteria in order to provide a tool to take care of animals in a comprehensive manner (David Fraser, 2009). For this purpose, collaboration between zoos and other institutions enables the exchange of information and recommendation about husbandry techniques and related species welfare indicators.

2.3 Behaviour in captivity: development of abnormal behaviours

Nowadays Animal Welfare is of primary importance and the implementation of the standards to maximize it is a priority for zoos and other facilities where animals are kept for most of their life.

Unlike in nature, in captive settings animals are subjected to restrictions that influence their behavioural repertoire and sometimes compromising their well-being. Captivity poses in

different ways a source of stress, some linked to husbandry procedures, which may lead to the development of abnormal behaviours that have adverse consequences on animal's physical and mental health. The appearance of abnormal behaviours in a captive setting, which deviate (qualitatively and quantitatively) from the ones performed by the species in the natural habitat, often provides an indicator of poor welfare resulting from a suboptimal environment to which animals are exposed. Nevertheless, it cannot be used as absolute indicator for assessing animal welfare since is not reliable in every context; to make an example, the display of abnormal behaviours can be associated with a clinical disorder unrelated to the captive environment (Lutz et al., 2022). Considering this, their assessment and evaluation, held by trained staff, are crucial to eliminate or at least reduce the determining stressors, while the identification of risk factors is the basis for establishing preventive measures to block their appearance at first.

Stereotyped behaviours are the most frequently detected in captive environments and what is observed is a clear repetitive pattern of actions or movements with no apparent purpose. The occurrence of these stereotypies in primates has been studied and further classified into motor stereotypies involving the whole body such as pacing, swinging, rocking or flipping, in contrast self-directed behaviours include hair pulling, self-clasping and eye-poking. Leading causes are identified as a combination of both intrinsic and extrinsic factors, which may be associated with the biology of the species as well as stress and lack of stimulation posed by the environment (Robinson and Weiss, 2023).

In the following chapter are listed all the applicable techniques to enhance animal welfare and prevent situations of distress in captivity.

3. HUSBANDRY GUIDELINES FOR CAPTIVE OWL MONKEYS

Addressing species needs is essential to improve animal welfare in controlled environments. Captive facilities adopt specific husbandry measures suitable for the species housed, in accordance with standards established by laws regulating the keeping and care of animals. International or regional associations, like WAZA (World Association of Zoos and Aquariums)

or EAZA (European Association of Zoos and Aquaria), provide guidance and support for the management of animals under human care facilitating the cooperation between institutions to set up and enforce the highest welfare standards.

Concerning the *Aotidae* family many of the animal care principles to follow are in common with other New World Primate's species and are grouped within the collection drafted by the Global Federation of Animal Sanctuaries (2013).

In this thesis are reported only the husbandry guidelines that refer to the management of Owl monkeys in zoos and sanctuaries or different structures for behavioural observations where animals are kept in semi natural conditions; are therefore excluded laboratories for biomedical research on primates, where individuals are kept in indoor cages.

3.1 Housing requirements

Captive environments differ significantly from natural habitats and may lack some key elements crucial to stimulate species-typical behaviours. In the wild, primates have access to much larger home ranges than what is feasible in captivity, hence it is necessary to resemble to the greatest extent possible the natural conditions to which animals are accustomed. To achieve this, facilities should set up tailored protocols to meet basic needs of each species according to their biology; these protocols define all the requirements to respect and the practices to enforce regarding enclosure type and size, permanent furnishing, social housing and environmental parameters. The main housing standards for Owl monkeys are discussed below in more detail.

3.1.1 Space and enclosure design

The first step in designing an enclosure for Owl monkeys is to define the space allocated to the housed specimens, considering both the horizontal and vertical dimensions that determine its overall size. The quantity of space provided is as essential as its quality to enable animal's freedom of movement and preserve their physical and mental health. Given the arboreal attitude of *Aotus* species, the development of an appropriate three-dimensional space is

highly important to satisfy climbing behaviour. While the primary enclosure is represented by an open space environment, an indoor shelter may be present in some facilities to guarantee year-round protection against adverse atmospheric conditions or to separate and move animals when required. According to group size and composition the minimum outdoor enclosure space required is approximately about 20.9 sq. m (4.6m x 4.6m) with minimum height of 3.7 m for a pair of night monkeys, and a supplementary 2.8 sq. m must be added for each extra individual. On the other hand, indoor rooms if present, must comply with a minimum size of 9.3 sq. m each per pair of specimens (with 2.3 sq. m more for each additional individuals) and a recommended height of 2.43 m (Global Federation of Animal Sanctuaries, 2013). The exhibit perimeter must be properly delimited by fences made of chain link, welded wire or woven wire mesh (minimum mesh size 25.4 mm x 25.4 mm) firmly anchored to the ground or to concrete blocks; electric fencing, correctly signed, can be used in conjunction with traditional methods, but not as primary containment. The enclosure can be covered with a roof or closed with a fence, but it can also be an open-top design; in this case, the upper part of the vertical wall, roughly the 30%, is composed of non-climbable material like smooth poured concrete. Moreover, wet moats barriers are not advised to be used as a single escape preventive approach (Global Federation of Animal Sanctuaries, 2013).

Enclosure and transfer doors must be designed to ensure the safety of both animals and staff, consequently guillotine doors are not recommended because of the high risk of injury and mechanical failure. To avoid owl monkeys escape, access to the enclosure must be carefully controlled through a lockable double-door system of entrance. All outdoor enclosures should feature a natural substrate that reflects the native environment, which may include soil, sand, grass, leaf litter or other natural materials. Whereas indoor shelters are built with concrete floor, including a fluid drainage mechanism, and equipped with bedding material such as shredded paper or wood shavings.

Diversity and complexity of the enclosure should be supplied using natural and artificial permanent furniture, that offer further stimulation for animals and, if changed regularly, improve dynamicity of the captive environment. The essential equipment for Owl monkeys inside the enclosure includes: shelters and nesting boxes, climbing structures and platforms,

feeders and other structural devices. Fresh vegetation plays an important role in mimicking the wild habitat along with offering shades and structures to support natural locomotion; therefore its use shall be favoured to create a stimulating environment. The precautions to be observed in this case concern the choice of plants (with relative seeds, fruits and flowers) which are non-toxic and non-harmful for the species. Shelters and nesting boxes, natural or artificial, must be provided in quantities that are proportioned to the group size, ensuring adequate availability for the optimal utilization by all individuals. These are placed in different locations throughout the enclosure giving owl monkeys the possibility to hide from conspecifics or protect themselves from wind and precipitations. Further permanent components to include are climbing structures of varying shape and complexity, which develop both in the horizontal and vertical plane to allow a complete exploration of the environment. Based on their construction material, furniture are categorized as either natural (e.g. branches, bamboo) or synthetic (e.g. fake rocks, ropes); however they must be durable and enable effective sanitation (Global Federation of Animal Sanctuaries, 2013) . All the elements present inside the enclosure have to satisfy behavioural needs of the species and with the same importance also prevent any kind of danger for animals and personnel.

3.1.2 Light, Temperature and Humidity

In captive settings, outside the habitat of the species, all the environmental parameters must be controlled regularly and kept within the optimal range for the species housed, especially for indoor enclosures where they can be artificially regulated.

Appropriate lighting should be designed to align with the species' circadian rhythm, thereby supporting their psychophysical well-being. Owl monkeys adapt the duration of their active period to the moonlight intensity, if kept only indoors this should be take into consideration with rooms equipped with windows or skylights to permit natural light ingress, or supplemented with artificial lighting to achieve desired light levels. Otherwise, in outdoor enclosures the light cycle is determined by the environmental one hence is not required the provision of additional systems. A specific note must be made for structures located in

northern regions where light is limited during the winter months. In such cases, it is important to implement systems that provide adequate lighting to ensure the well-being of owl monkeys.

Owl monkeys inhabit mostly tropical areas associated with a warm and humid climate, but they can also reach high altitudes and consequently lower temperatures; in fact, the fur of owl monkeys has evolved to deal with these temperatures discrepancies and ensure correct insulation. They can tolerate temperatures up to 35°C, although it is better to maintain it between 21°C and 29°C indoor, below or above this range thermoregulatory systems such as heated or cooled areas or proper ventilation and air conditioning must be provided. Indoor humidity should not exceed 80%, the preferred range is between 40% and 70% to prevent fungi proliferation (Global Federation of Animal Sanctuaries, 2013).

3.1.3 Social housing

Social housing has frequently been advocated as a strategy to improve psychological welfare of captive animals. As described in the Social structure, Reproduction and Parental Care paragraph of this thesis, wild Owl monkeys are socially and sexually monogamous, living in closely bound groups of two to five individuals including an adult pair and several juveniles. It is thus crucial to attempt to recreate this social structure even in a captive context, with the objective of preserving the species' natural behaviour and providing the appropriate social stimulation they require. However, adhering to these housing criteria is not always possible or simple, mainly due to social conflict within the breeding pair which normally separates after a period between three and seven years. To get through this potential difficulty, a captive behavioural study was conducted at OMBRR (Owl Monkey Breeding and Research Resource, University of South Alabama), aimed to observe the success of owl monkeys pair formation and find alternative housing possibilities. Results show that the highest pairing success occurs with opposite sex pairs (82% rate of success), determining the preferred choice of socialization for adult owl monkeys. Conversely, iso-sexual pairing has been less successful, with a rate of 62% for female-female pairs and 40% for male-male pairs, suggesting a different housing approach when the optimal one is unfeasible (Williams et al.,

2017). Before and during the process of pair or social group formation is essential a careful monitoring of the interactions between the specimens and the behaviours displayed by each, to detect excessive aggressiveness and interrupt the trial.

Zoos often design mixed-species exhibits that house compatible animals belonging to the same habitat and sharing the same ecological niche; this is done to add complexity to the environment and provide additional social stimulation. This strategy can be applied also to the *Aotus* genus with precautions, as for example they cannot be housed together with Old World primates. It is necessary to consider the nocturnal behaviour of Owl monkeys, ensuring they are housed with other primary nocturnal species to avoid creating conditions of mutual disturbance. For this reason, the assessment of species combinations must include evaluation of potential injuries, hierarchy problems and disease transmission, together with the integration of measures to separate animals if needed. In the Primate Report 64 (2002), multiple examples of mixed-species exhibits involving Owl monkey species are illustrated; among these notable is the Dortmund Zoo where a pair of adult owl monkeys (*Aotus trivirgatus*) are kept with several individuals of Giant anteater (*Myrmecophaga tridactyla*) and Two-toed sloth (*Choloepus didactylus*), or the case of the Frankfurt Zoo which houses together specimens of *Aotus azarae* with Larger hairy armadillos (*Chaetophractus villosus*) and Two-toed sloths (Schwibbe and Ziegler, 2002).

It is important to note that if more than one owl monkey's family group is housed in the same facility, visual and auditory barriers must be introduced to prevent stressful situations, since in nature intergroup encounters are rare. Barriers can be made of one material or in combination, including concrete, rocks, water (waterfalls as auditory barrier also) and thick vegetation (Global Federation of Animal Sanctuaries, 2013).

3.1.4 An example of Owl monkeys housing at DuMond Conservancy

The DuMond Conservancy for Primates and Tropical Forests, founded in 1990 in Miami (FL, USA), is a research and conservation centre dedicated to expanding the knowledge and raising awareness about nonhuman primates inhabiting American tropical forests. The Monkey Jungle area where the institute is localized, hosts a large colony of captive Owl

monkeys, of more than 50 individuals for the majority of the species *Aotus nancymaeae*, arrived at the centre after a period spent in biomedical laboratories. Here, owl monkeys' pairs or family groups are housed in outdoor enclosures surrounded by the natural environment and properly separated from each other by vegetation. Welded mesh pens are of cylindrical or square shape with following dimensions: 2.44 m x 2.44 m and 3.05 m x 3.05 m; ensuring enough space to perform a great variety of natural behaviours otherwise restricted in a laboratory setting. Enclosures are supplied with nest boxes to rest during the day, and series perches and branches for climbing and jumping through (Fernandez-Duque, 2023).

The goal of the DuMond Conservancy is to provide opportunities to conducting behavioural studies on captive owl monkeys, integrating these findings with field research with the purpose of enhancing the welfare of the specimens and educate the public.

3.2 Enrichment

A successful husbandry protocol must include a well-designed enrichment program tailored to the specific needs of the housed animals, with the goal of enhancing their quality of life under human care. Enrichment provides animals the opportunity to be stimulated through various means, promoting the expression of their natural appropriate behaviour. The implementation of effective enrichments strategies contributes to the improvement of welfare across multiple parameters, including reduction of stress and abnormal behaviours along with the increase physical activity, use of the environment and positive social interactions.

Enrichments are categorized into distinct classes based on their type and function, generally applied in combination or inter-changed frequently.

The first category is that of physical environmental enrichments which includes all the structural components present in the enclosure that make it resemble the wild habitat, as well as artificial devices which animals can interact with; the primary intent is to prevent boredom by encouraging locomotor activity and the exploration of surrounding environment. Besides permanent elements, further items like fresh branches, wood or PVC

platforms, ladders, ropes and hammocks are optimal furniture for species belonging to the genus *Aotus*, especially if their position can be regularly altered to provide new enclosure configurations (Burgess, AAZK Suggested Guidelines for Primate Enrichment).

Social enrichments instead focus on the creation of affiliative interactions between conspecifics or other animals housed together, in the case of mixed-species exhibits. Those kinds of stimuli are essential for the well-being of Owl monkeys, which are social primates by nature and live in small monogamous family groups; this social structure, if practicable, should be replicated in captivity to support cooperative behaviours. Animal training can serve as an additional source of social enrichments, facilitating bonding between animals and caretakers while reducing fear and aggression. Moreover, it is a technique to conduct voluntary medical procedures or other routine practices. However, implementing a training program for Owl monkeys is extremely challenging, primarily due to their nocturnal activity, which makes more complicate its execution.

One of the most widely employed categories is represented by nutritional enrichment, a technique to present animals with food in a creative and variable manner. The first approach to achieve this is to set up a constant rotation and renovation of food items offered; secondly, animals are engaged in foraging activities aimed to promote species-specific behaviours. Food may be delivered within containers such as cardboard boxes or tubes, hidden among leaves, suspended on hanging structures, or provided in a frozen form during hot weather. In addition to the examples mentioned above, perforated PVC pipes and puzzle feeders are food-based enrichments commonly used for owl monkeys' species with the purpose of favouring manipulation and prolong the time of food consumption.

Puzzle feeders also fall under the group of cognitive enrichments due to their capacity to promote mental stimulation, since they required effort to find or get out the food they contain. This category includes enrichment strategies that involve problem-solving tasks intended to develop and enhance animals' cognitive skills, particularly for primates like Owl monkeys.

The last remaining class to be analysed groups together visual, olfactory, auditory and tactile stimuli into the broader category of sensory enrichments, which encompasses several modalities able to activate the sensory system of animals and elicit a behavioural response.

Among these, olfactory enrichments are essential components in the development of an enrichment plan for Owl monkeys, as they rely extensively on olfactory cues for spatial navigation and communication. The realization of these enrichments involves the spreading of various scents throughout the enclosure branches and structures to stimulate monkey's sensory engagement; fragrances used in captivity should be mainly of natural origin, including conspecific scents, flowers, fruits and similar flavours. A research study carried out at the DuMond Conservancy for Primates and Tropical Forests (Miami, USA) tested the effect of various dried herbes (sage and rosemary) and spices (cinnamon and nutmeg) on fifteen adult pairs of captive *Aotus nancymaae*. Outcomes demonstrated positive response to all scents, observed through sniffing and increased exploratory behaviour, along with reduction of stereotypies frequency following the exposure to cinnamon. This leads to the conclusion that olfactory enrichments should be widely incorporated into captive facilities housing Owl monkeys, as they provide significant opportunity to improve their welfare and natural behaviour (Woerle et al., 2020). In contrast visual enrichments are not usually employed for these species since they do not provide adequate stimulation in the dark while night monkeys are active.

Additional sensory enriching activities can be afforded by offering tactile stimuli through objects with diverse textures, such as soft toys, egg cardboards, towels or brush heads.

To conclude, in order to ensure animals well-being is crucial to design the most suitable enrichment plan for the specimens housed, giving the animals the opportunity to choose and considering all the safety and viability aspects related to its establishment.

3.3 Dietary management

To ensure animals' freedom from hunger and thirst while promoting the expression of normal feeding behaviours, captive facilities are responsible for the creation and administration of an appropriate and balanced diet that meets species nutritional needs, adhering to veterinary protocols for any special health requirements. Designing a diet requires deep knowledge of gastrointestinal anatomy and feeding ecology of the species; field observations of wild individuals are a powerful tool to improve the learning about their

feeding habits and find out preferred food items. When creating a diet, veterinarians and nutritionists shall consider not only the species dietary requirements, but also the size, age, life stage and health conditions of each individual housed, in order to address subjective needs and guarantee animals' welfare.

Literature suggests that a correct diet tailored for Owl monkeys, in accordance with their frugivore strategy, consists of 65% to 75% of fruit, flowers, seeds, buds, sap of various plant species and insects, on which they can naturally forage on; moreover, fresh browse should be offered on regular basis to provide a correct amount of leaves included in the diet. The alternation of diet types increases food variability and keeps animals' curiosity high; due to this in combination with fresh products, the diet may also include a percentage of commercial pellets formulated for New World Monkeys (e.g. LabDiet, Mazuri) containing all the nutrient components and supplementations required (Global Federation of Animal Sanctuaries, 2013). Because wild fruits are not always available or difficult to obtain in captivity, the nutrients derived from them are often substituted with other food elements, such as vegetables that are both palatable and readily accepted by owl monkeys. Zoos and sanctuaries must cope with feasibility and costs of dietary management, providing always good quality food and in a correct amount for all specimens. Recent findings have shown that feeding more naturalistic diets to primates is beneficial both for the mental and physical state of animals by decreasing the frequency of diseases, abnormal behaviours and aggression, while improving digestive tract health (Robinson and Weiss, 2023).

Equally important is the timing and method of delivering the diet to animals, in such a way that their natural feeding behaviour and habits are respected. In the specific case of *Aotus* spp. due to their nocturnal lifestyle, food is provided once daily prior to sunset, ensuring sufficient availability during owl monkeys' active phase. Additionally, food should be distributed in a scattered manner across various locations within the enclosure, preferably on elevated platforms or feeding structures to avoid contamination from the soil and accommodate the arboreal behaviour of the species; this approach allows that all individuals have access to food, reducing possible aggressions, and prolongs the time spent feeding. Food can also be incorporated in the enrichment program, thus the quantity allocated for this purpose should be considered during diet planning.

To ensure adequate hydration in group-housed Owl monkeys, multiple water sources according to group size, should be always made available and properly shaded to not exceed in temperature. It is mandatory to regularly monitor water quality and perform daily a correct disinfection of bowls or other containers assigned to water administration (Global Federation of Animal Sanctuaries, 2013).

3.4 Captive breeding management

The management of reproduction in captivity is often challenging due to space limitations or inability to replicate the correct social structure and pair-bonding required. Improper husbandry techniques may lead to excessive stress experienced by animals with consequent decreased in reproductive success. Since reproduction is among the natural behaviours that animals shall have the opportunity to perform, whenever possible, is necessary to adopt measures to facilitate its achievement. This, however, implies accurate planning regarding the design of the enclosures to keep constant high welfare standards; if a facility considers unfeasible the birth of new individuals, it must adopt contraceptive strategies suitable for the species following veterinarians' advice. As an example, males' vasectomies, along with the use of MGA (melengestrol acetate) and Suprelorin (deslorelin acetate) in females, were the contraceptive methods employed for owl monkeys' population growth control at DuMond Conservancy centre (Fernandez-Duque, 2023).

In contrast, the establishment of ex situ captive breeding programs allows to support species conservation and research by forming a self-sustaining population which may provide valuable individuals for reintroduction and preserve threatened wild groups. Species Survival Plan Programs (SPP), managed by AZA – Association of Zoos and Aquariums of North America, are developed to help zoos and accredited institutions in the management and maintenance of ex situ captive populations. Among these is the DuMond Conservancy structure, whose colony of Owl monkeys is included in the AZA Studbook, hence it follows and implements their recommendations.

The captive breeding of Owl monkeys at the DuMond Conservancy was analysed between 1987 and 2004, where it was possible to observe a clear seasonal pattern of reproduction,

with birth peaks during warmest period from May to October, and a birth interval of 13.4 months (Wolovich et al., 2005). Furthermore, mate choice results to be a crucial determinant of mating and reproductive success in captivity, underling the importance of maintaining the monogamous social structure that closely resembles the one of wild populations and monitoring the owl monkeys' behaviour during pair formation.

3.5 Safety measures

In any captive setting, it is crucial to prioritize the safety of housed species to minimize stress and prevent injuries that could compromise their health. On the other side facilities must guarantee a safe working place for the personnel operating in direct contact with animals and provide adequate training support to face every kind of emergency. The enforcement of a security protocol, drafted in conformity with national and international laws, is the starting point for the planning of all husbandry measures mentioned in this chapter. The Association of Zoos and Aquariums (AZA) sets out the annual revised welfare standards that accredited facilities must comply with, including security protocols.

Firstly, animal's optimal health must be ensured by specialists through adequate veterinary care for the prevention and treatment of diseases. Special attention should be given to owl monkeys' species, and primates in general, as potential carriers of zoonotic diseases transmissible to humans; therefore, quarantine structures for isolation should be available. Secondly, a strict hygiene schedule must be implemented, which includes proper sanitization of all furnishing within the enclosure (concrete walls, wire mesh, branches, feeders and platforms) performed regularly using non-toxic disinfectants. To prevent any source of infection food must be stored and prepared in an appropriate way to avoid bacterial contaminations, while pests control systems shall be employed to keep rodents outside animals' enclosures. Solidity of enclosure perimeters and doors must be periodically checked to prevent animal escape, while structures present inside or environmental enrichments undergo regular maintenance to avoid unwanted injuries due to equipment failure (AZA Accreditation Standards 2.0, 2.6, 2.7, 2.8, 10.2, 11.1, 2024).

For what concern staff safety, is fundamental to be aware of the potential risks related to diseases transmission from working with neotropical primates; zoos and sanctuaries should invest in training courses to enable the personnel to be prepared for any possible situations, including emergencies such as animal escapes, disease outbreaks and structural defects.

The eleven species of owl monkeys, belonging to the genus *Aotus*, are not dangerous and classified as non-threatening animals; however, if not necessary, staff should limit the contact in the enclosure with these New World monkeys, even though they are expected to be inactive during the day (Global Federation of Animal Sanctuaries, 2013).

4. CASE STUDY: a practical example of Husbandry for Owl Monkeys at Alturas Wildlife Sanctuary

During my academic traineeship carried out at Alturas Wildlife Sanctuary (Costa Rica), I had the opportunity to be engaged in husbandry tasks addressed to one specimen of Owl monkey housed at the facility. I was able to learn the peculiar behaviour of the species and how this influence their treatment in captivity.

In this chapter I report the main features about the management protocol applied for this species at Alturas, together with captive behavioural observations performed while I was an intern there.

4.1 Alturas Wildlife Sanctuary Introduction

Alturas Wildlife Sanctuary is a non-profit organization located in Dominical (Puntarenas, Costa Rica), dedicated to rescue, rehabilitation and release of injured Costa Rican wildlife. The centre is divided in two main units, each including multiple working sectors, focused on different animal care actions. The first unit includes the veterinary clinic where injured animals are received and treated with the purpose of release them back to the wild if feasible according to individual cases. The other department is the Sanctuary that currently houses permanently 33 animals of various species in 15 enclosures surrounded by the local forest. These animals have arrived at the Sanctuary from illegal trade, possession as pets, improper management or because they have suffered physical or either neurological

problem incompatible with a life in the wild. The Sanctuary offers to animals a safe place where staff, interns and volunteers work to provide them with the best care possible in relation to species- specific and individual needs. A proper husbandry approach is therefore essential to ensure animal welfare in this captive scenario.

4.2 Owl monkey Frida’s history and husbandry protocol at Alturas

Among the animals housed at the Sanctuary there is a specimen of Owl monkey named Frida (picture on the right), an adult female belonging to the *Aotus zonalis* species native of Panama. This species is normally distributed from South regions of Panama to Northern Colombian forests, thus is not endemic to Costa Rica at all. Panamanian Owl monkeys (*Aotus zonalis*)



are classified as near threatened in the IUCN Red List (2021), consequently to significant wild populations decline attributable mainly to habitat loss and illegal trade. Moreover, non-regulated hunting of the species for pet trade and biomedical research has contributed to further reduce its distribution across native habitat range. The protection of this species is therefore of fundamental importance to prevent wild populations to become vulnerable or even endangered. Conservation efforts are in place, primarily aimed to educate local communities on the ecological role of Owl monkeys within their habitat and dispel negative beliefs correlated to them; an example of organization devoted to this educational campaign is the Fundación Pro-Conservación de los Primates Panameños (FCPP) (Méndez-Carvajal and Link, 2021).

Frida actually arrived at the Sanctuary on 3rd December 2016 after being confiscated from illegal pet possession and trade close to the Costa Rican-Panamanian border. Attempts to bring her back to her country of origin have failed, due to legislative and government transfer inconveniences; Panama has in fact refused the repatriation of this owl monkey’s specimen. The possibility of releasing Frida in the wild has not been considered, as owl monkeys are not present in the Costa Rican ecosystems, hence she may pose a threat to them. The final decision was to keep her at Alturas Wildlife Sanctuary where high welfare standards are

applied to preserve her well-being under the best circumstances possible and following a dedicated husbandry protocol constantly improved, as described in the next paragraphs.

4.2.1 Housing measures

Frida is housed in one of the Sanctuary's enclosures completely dedicated to her. This is outlined by a cuboidal shape (4.90 m x 3.88 m x 4.95 m) and delimited, on each side included the top, by a wire mesh fence anchored to a concrete basement which runs along the ground border of the enclosure; while the natural substrate is composed of soil and gravel ensuring a proper water drainage. Furthermore, one section of the roof is covered with panels to offer shade and protect against adverse weather conditions. The staff access point consists of a double door (1.17 m x 1.07 m x 2.00 m) positioned on one lateral side, and securely locked externally to prevent any escapes. (Fig. 7,8)

The large enclosure size allows the correct development of natural behaviours intrinsic to the species and promote explorative attitude. For the same purpose, permanent furniture placed within the enclosure was designed according to the biological needs of the individual.

Among the various equipment provided to Frida there are: a nesting wooden box to rest, a concrete pool for water administration, elevating feeding platforms and several climbing structures. All these structures are surrounded by a variety of plant species growing inside the enclosure offering a natural layout together with functional support to enable furniture configurations. Climbing frameworks supplied, essential for arboreal locomotion, include branches, bamboo ladders and waterproof fabric drapes arranged on different height levels and occupying the entire enclosure's volume, as visible on the pictures below (Fig. 9,10,11).

Due to the singular circumstance that brought Frida to become a resident animal at the Sanctuary, it has not been possible until now to accommodate the social nature of owl monkeys by introducing conspecifics with her as there are no other specimens present in Costa Rican territory. Even though Alturas Wildlife Sanctuary efforts to find a solution to this critical issue are constantly pursued, collaboration with other sanctuaries did not lead to successful results. Is currently in process an accurate search for compatible species, received at the Sanctuary or coming from other institutions, that can be a source of companionship and social stimulation for Frida. Compatibility studies on selected species must be carried

out to seek for the right candidate animal. Additionally, the introduction of a new animals inside Frida’s enclosure should be carefully planned before and monitored to avoid aggression and injuries which may affect their well-being instead of improving it; however the monitoring of the introduction of a new species is complicate due to the nocturnal lifestyle of this, making difficult immediate interventions if necessary.

Lack of sociability can cause stress and abnormal behaviours development, for this reason this gap needs to be compensated by the use of appropriate enrichments and multiple differentiated stimuli.



Fig.7



Fig.8

Fig. 7,8,9,10,11 Pictures of the external and internal appearance, including permanent furniture, of Frida’s enclosure at Alturas Wildlife Sanctuary.



Fig.9



Fig.10



Fig.11

4.2.2 Daily care and Enrichments

The routine care provided to the Owl Monkey Frida at Alturas includes enclosure cleaning, food administration and enrichment delivery. To avoid disturbing situations during Frida's rest period (day light timeframe), access to the enclosure by personnel to carry out basic husbandry activities is limited to one time per day. The collection of waste materials, such as organic elements, faeces or leaves, and the rinsing of platforms and equipment is performed once a day during the afternoon; this to prepare the environment for the active interval of the monkey after sunset. In addition, once per week a deep cleaning of all surfaces within the enclosure, using bleach and disinfectant, is conducted to eliminate food residues and potential pathogens.

Frida is fed on a daily basis with a single meal provided before dusk, and it consists of a mixture of fruits (mango, apple, papaya, banana) and vegetables (broccoli, cucumber), supplemented with a protein source either of vegetal (avocado) or animal (chicken) origin. The diet composition depends on food availability at the Sanctuary and is alternated between beginning and end of each week together with fresh browse provision. Food is presented together with enrichments (examples described below) or scattered around the enclosure and on elevating platforms to reach also higher parts.

The enrichment calendar implemented at Alturas is tailored for Frida's species needs and her current individual situation; it constitutes, along with proper enclosure design, an essential tool to make this specimen's life worth and enhance animal's naturalness in captivity. The schedule is constantly changed by the staff, suggesting the use of different types of enrichments every day in order to ensure variability and promote engagement. The enrichments range from nutritional and structural devices to toys and sensorial activities, mainly olfactory ones. A descriptive list of key enrichments adopted at Alturas Wildlife Sanctuary is provided below, considering that is continuously expanding thanks to research conducted by volunteers and interns.

Examples of enrichments applied for Owl monkeys at Alturas:

- Cardboard tubes with food inside, sprayed with basil scent;
- Hang balls with peanut butter;
- Egg carton “sandwich” with food (Fig.13);
- Puzzle feeders (Fig.12);
- Basil scent on soft toys;
- Corn husks parcels with some food;
- Food inside kongs (soft plastic toys);
- Blanket sprayed with basil scent;
- Rub coffee grounds on branches;
- Lime scent on soft toys;
- Wobble feeder with peanuts;
- Fresh branches;
- Hammocks;
- Box with leaves and food inside;
- Bells;
- Bamboo twister block with food inside;
- Wooden box with food inside;
- Coconut scent on soft toy (on hanging platform);
- Pouch hangers with food inside;
- PVC feeders (large holes) with food inside (Fig.15);
- Pineapple crowns with food inside;
- Wooden pouch feeder;
- Vanilla scent on fabric sheet placed on hanging platform;
- Bamboo feeders with holes;
- Milk carton with holes for food (Fig.14);



Fig.12



Fig.13



Fig.14



Fig.15

4.3 Use of camera traps for behavioural observations: results and welfare improvements

Due to the nocturnal lifestyle of Owl monkeys, it is rare to see Frida active during the day. Therefore, employing camera traps, positioned inside the enclosure and capable of recording videos during the night, is required to observe her behaviour and interaction with enrichment activities. In the course of my traineeship at Alturas I was given the opportunity to carry out a project that allowed me to learn how to set up camera traps and collect useful videos for monitoring Frida's activity.

I started by placing three camera traps (Wosoda trail camera) in different locations within the enclosure, in order to have alternative perspectives of recording, both in terms of angles and height. The scheme (Fig. 16) shows the camera traps placement aimed to maximize the capture of Frida's movements in multiple parts and levels of the enclosure; while the recording period was approximately around one month, from 2nd of May 2024 to 26th May 2024.

Despite the advantages of this method to perform observations, camera traps present some limitations which are attributable to: camera traps battery life and functionality, adverse weather conditions that may interfere with videos' sharpness and the influence that camera traps may have on Frida's behaviour. Of course, the limited time available for recording has reduced the completeness of the observations, even though I was able to collect important information concerning her welfare.

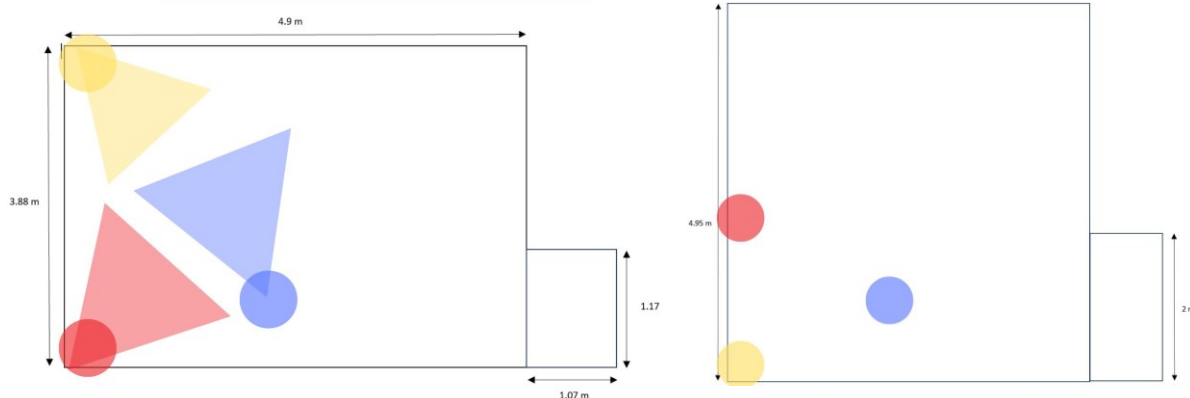


Fig. 16 Camera traps locations within Frida's enclosure. On the right the top view and angles, while on the left the lateral view displaying the heights.

The first outcome of this research was the observation of the activity level pattern performed by Frida, through the analysis of more than 400 videos (with a recording time of 15 seconds each) recorded by the three camera traps, reporting the specific time of the day when she was detected active. The results were compiled and presented in a graph (Fig. 17) describing the activity pattern of this individual during the night, which resembles the one of *Aotus* spp. as found in the literature. Frida exhibits peaks of activity at dawn and dusk, from sunset around 5:30 pm in Costa Rica until before the sunrise (5:30 am). Only few videos recorded Frida active during the day at 2:00 pm, mainly related to external disturbance.

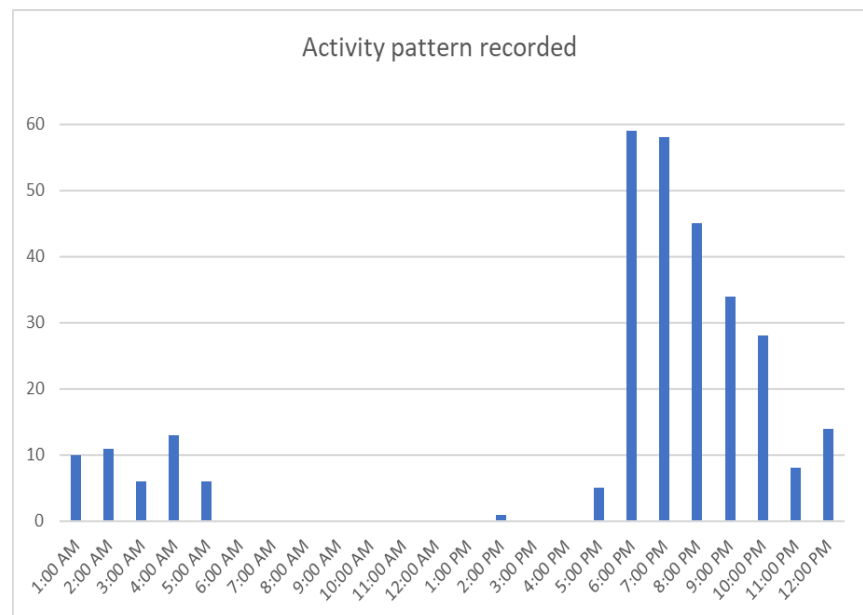


Fig. 17 Frida’s activity pattern graph, sum of videos when Frida was detected active in the different timeframe of the day.

Through the review of the documented videos, it was also possible to track the behaviour displayed by Frida during active periods, including interactions with enrichments provided. Observations, in fact, revealed engagement with several types of enrichments, such as puzzle feeders and other food related activities (PVC feeders, boxes), as well as with hammocks and soft toys. She was also observed participating in other activities, including drinking and eating, climbing the fence and jumping from branch to branch.

On the other hand, a significant finding was the detection of presumed stereotypic behaviours expressed by Frida. In the videos were captured episodes of pacing, defined as recurrent locomotion along a fixed path, frequently repeated multiple times throughout the night within a few minutes of each other. The emergence of this pacing behaviour may be correlated to a lack of social stimulation due to Frida’s unusual housing conditions of being

kept alone in the enclosure that compromise her welfare. Considerations have been made regarding this circumstance, but further analysis are needed to investigate the exact frequency and duration of episodes and assessing the precise causes, with the purpose of defining the appropriate measures to implement.

Concrete actions have been taken to respond to this alarming signal, mainly focused on the modification of the internal environment of the enclosure by adding new structural supplies, including ropes and other bamboo ladders, in order to create alternative configurations and provide diverse exploration pathways throughout the enclosure.

Videos from camera traps were recorded also after the addition of these new enriching elements, and the observable results demonstrated the active interaction of Frida with them (Fig. 18,19). Moreover, the novel equipment was added with the intention of periodically change its position to improve enclosure dynamicity and complexity, while decreasing boredom and distress. However, further observations over time would be necessary to assess whether the modifications made have partially reduced the exhibited pacing pattern. All these adjustments have been done to enhance as much as possible Frida's well-being in captivity, with the hope that further progress can be made to find a compatible companion.



Fig.18



Fig.19

CONCLUSIONS

In this thesis, I aimed to collect and describe all the best husbandry practices to be applied in captive settings housing specimens of *Aotus* spp., supporting the goal of ensuring high welfare standards in compliance with those set up by international organizations devoted to the care of wild animals in zoos, sanctuaries and related facilities.

From the analysis of the species biology and behaviour, it emerged the demand for an integration of research methods involving both field and captive studies, this to expand our understanding and, consequently, the techniques we should enforce in these settings. The nocturnality and arboreal features, that characterize the behaviour shared among the genus, pose a significant obstacle for observations of wild populations, which can be countered by research conducted in controlled environments simulating the natural ones. It is precisely in this context that animal welfare must be emphasized to obtain valid and comparable results, together with assisting species-specific needs.

The establishment of an appropriate housing, feeding, enrichment and care management is the baseline approach to satisfy animals' physical and mental state, as well to promote naturalness.

Owl monkeys, although they are still relatively unknown, are excellent examples of evolutionary adaptations and strategies developed to cope with their native environment; therefore, they deserve protection and conservation efforts within their habitat, which is facing several threats, including anthropogenic activities. Facilities that house these specimens play a fundamental role in encouraging education and preservation about these unique species.

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