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Impact of diet and environmental enrichment management in stereotyped behaviours: a case study in tayra *Eira barbara*

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Abstract
Holistic approaches have been implemented to minimise stress expressed as stereotypies associated with low welfare conditions, which can arise from a range of factors such as frustration, adaptation attempts and neurological problems. Such behaviour was identified in a tayra housed in the facilities of the Santacruz Zoo (San Antonio de Tequendama, Colombia), for which a five domains model of animal welfare evaluation was carried out. This allowed the creation of a corrective plan that included the provision of a hiding place, nutritional management and environmental enrichment. Prior to the corrective plan, the tayra displayed the following behaviours within a 12-hour period: 28.8% stereotypies, 28.8% inactivity, 25.3% aggressive behaviours, 8.2% feeding-related behaviours and 7.7% locomotion activities. After implementing the corrective measures, the behaviours shifted to 16.2% stereotypies, 15.2% inactivity, 28.0% feeding-related behaviours and 8.0% locomotion activities. In conclusion, evaluating and managing the five domains is an essential practice for zoos and can lead to significant improvement in an animal's welfare status.

Background

In the context of animal welfare, focus is directed towards the animals' quality of life and their way of perceiving it (Mellor et al. 2020). This includes guaranteeing an environment adapted to meet the physical, psychological and social needs of each species, even considering the animal's ability to feel both positive and negative emotions (Ward and Hosey 2020). A critical aspect to ensure optimal levels of wellbeing is to periodically improve evaluation techniques, avoiding biases due to anthropomorphic perceptions (Maple and Perdue 2013). The evaluation of animal welfare has become common practice in zoological institutions, for which reason associations such as the European Association of Zoos and Aquaria (EAZA) have established basic guidelines for the assessment of animal welfare (EAZA 2019). This evaluation can be carried out based on variables that are divided into two categories: indicators based on resources and indicators based on the animal (Mellor and Beausoleil 2015). These variables are included within the model of five domains (Mellor 2015, 2017), made up of four functional components: nutrition, health, environment and behaviour—all related to the biological functions of the animal—and a mental component considered as the affective state (McGreevy et al. 2018; Mellor et al. 2020; Poirier and Bateson 2017; Vaz et al. 2017).When any of the domains are deficient, it is common to encounter behavioural problems such as stereotypies (Mawdsley and Rampton 2005). One strategy to combat stereotypies and their negative effects is the use of environmental enrichment (Wegman and DeLong 2023). Enrichment is defined as the addition of stimuli to the environment to increase behavioural opportunities for the benefit of the psychological and physiological wellbeing of individuals (Maple and Perdue 2013; Salas et al. 2018).

Each of the enrichments and strategies to be used must be defined based on two key points: the identification of deficiencies under the five domains model, and knowledge

Table 1. Tools and evaluation criteria of the 5 domains for a case study in *Eira barbara.*

Domain	Criteria	Aspects to evaluate	Tools/ Methods
Nutrition	Absence of prolonged hunger	Diet amount Feeding frequency	Santacruz Zoo database Observation
	Absence of thirst	Number of available drinkers Water availability Water quality	Observation API® Freshwater master test kit Diet sheets used
	Diet variety	Amount of ingredients	Body condition score[1]
	Proper nutrition	Body condition Weight Nutritional value of diets	Software Zootrition 2.6 Nutritional requirements[1]
Environment	Thermal comfort	Shelter areas Ventilation	Observation
	Space for free movement	Habitat size Available area for locomotion	Measuring tape
	Habitat complexity	Substrate variety Availability of visual barriers Availability of furniture to simulate climbing activity	Observation
Health	Absence of injuries	Locomotion Signs of pain Physical integrity	Observation Clinical examination
	Absence of diseases	Fecal consistency Absence of symptoms associated with pathologies	Fecal score[2] Clinical examination
	Veterinary attention	Examination frequency Timely application of treatments	Santacruz Zoo medical record sheets
Behaviour	Opportunity for developing natural behaviours	Foraging opportunities Variety of behaviours Frequency of certain behaviours	Ethogram[3]

[1]AZA (2010), [2]following De Cuyper et al. (2021), [3]Designed by the author.

of the biology of the species. This study evaluated a specimen of *Eira barbara* (Linnaeus 1758), commonly known as tayra. Due to its carnivorous nature and its constant hunting, foraging and displacement behaviours, this species has shown a high susceptibility to the development of locomotor stereotypies, especially related to anticipatory behaviours, when kept in captivity (Pereira and Oliveira 2010). This matches the high incidence of locomotor stereotypies in carnivores in general (Clubb and Vickery 2006; Dallaire et al. 2012; Malmkvist et al. 2013; Panizzon and Azevedo 2019; Polanco et al. 2018).

Considering the importance of evaluating and improving animal welfare conditions within zoological institutions, it was decided to work with an individual *Eira barbara* located within the facilities of the Santacruz Zoo. This specific animal exhibited frequent and extensive episodes of abnormal behaviours classified as stereotypies. Emphasis was placed on applying an evaluation of all the domains and correcting the deficiencies detected in the nutrition and behaviour domains.

Actions

Study subject

The focus of this study was a female individual *Eira barbara* of approximately 9 years of age located within the facilities of the Santacruz Zoo. The female was housed in an individual 16.82 m^2 outdoor exhibit, without access to congeners or other animals. The exhibit was equipped with a 3 × 2 m indoor area, which the animal only had access to during the nighttime or on rainy days. The exhibit featured a small pool used for drinking, an area with soil as substrate and several branches placed throughout the space to simulate the presence of trees. At the time of the assessment, there was no shelter area, hiding spot or nest box available for use during the day. No clinical signs of disease or pain were reported, so the individual was not under any medical treatment.

Ethical approval

Ethical approval was not required for this study because the zoo institution considered that the activities carried out were within usual management practices.

Evaluation tools

Evaluation of the five domains was carried out using a scheme adapted from Sherwen et al. (2018). This scheme incorporated different criteria and tools to identify deficiencies in the management of each domain (Table 1). The assessment was based on comparison with the recommendations issued by AZA (2010) in their manual of care for mustelids. The assessment was carried out twice: once before and once four weeks after implementation of the corrective actions.

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Table 2. Behavioural catalogue in *Eira barbara*

Group	Behaviour	Description
Feeding	Drinking	Drink water or other liquid
	Feeding	Eat food/edible items
	Searching for food	Sniff and scratch near feeding area
Locomotion	Walking	Forward locomotion with slow walk
	Running	Forward locomotion in quadrupedal position, faster than walking
	Climbing	Use limbs to climb vertical or steep surfaces and reach high points
	Playing	Interact with objects/people in an active, non-aggressive way
Exploration	Investigating	Walk through various points of the enclosure sniffing air or objects
	Sniffing	Inhaling air through the nose near to objects or surfaces
	Biting	Open and close the jaw by exerting pressure on an object
Rest	Lying down	Rest weight on the ventral part of the body on the floor or a horizontal surface
	Sleeping	Lie down with eyes closed, making minimal movements
	Sitting	Weight supported on the hind legs, bent and resting on the ground, while the front legs are extended and straight
Aggression	Attacking	Attempt to physically harm people through the enclosure's mesh using claws or teeth
	Alert status	Keep ears up, tail up and look carefully toward sources of noise or movement
	Vocalizing	Emit sounds from the throat
Self-care	Scratching	Rub claws or teeth against localised areas of the body
	Preening	Bite and lick different areas of the body with quick, non-aversive movements
	Rubbing	Rub parts of the body repetitively on surfaces
Stereotypies	Pacing	Walk/run back and forth repetitively and with no apparent functionality
	Route tracing	Move along the same route repetitively on specific branches with all four legs
Human-animal interactions	Participation in goal-oriented behaviours	Execution of specific behaviours guided by operant conditioning

Ethogram

An ethogram was developed based on a catalogue of behaviours recorded for the species by various authors (Ercoli and Youlatos 2016; Panizzon and Azevedo 2019), along with some of the behaviours seen in the individual under study (Table 2).

For the behavioural evaluation an observation period of 16 days was established, with 8 days in weeks with high visitor numbers and 8 days in weeks with low visitor numbers. This totaled 16 non-consecutive days, taking 2–3 days from each week until the total observation time was covered.

Activity records were taken every 10 minutes during randomly distributed 2-hour slots (Figure 1). This scheme was applied to behavioural evaluation both before and after the implementation of corrective actions, resulting in a total of 468 observations representing three 12-hour periods in each evaluation period.

Nutritional actions

The authors decided to carry out a gradual reduction in calories (as metabolisable energy). This reduction took place over a total period of 12 days, with approximate decreases of 150 kcal metabolisable energy every 4 days. The calculation was based on the daily requirement calculated using the energy formula proposed by Iversen (1972) for the basal metabolic rate of mustelids. This result was multiplied by two as a maintenance constant:

$$BMR = 84.6 \times W^{0.78}$$

$$ME = BMR \times 2$$

Where BMR is basal metabolic rate in kcal metabolisable energy per day, W is body weight in kg and ME is metabolisable energy required per day.

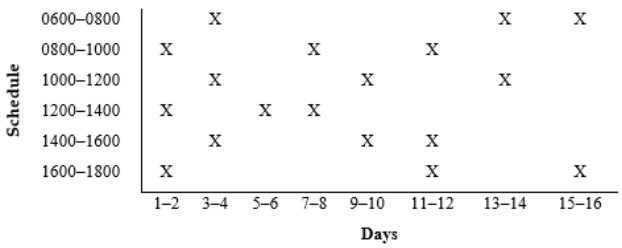

Figure 1. Hourly distribution of observation periods

Table 3. Comparison between nutritional requirements and estimated nutritional composition of the original (A) and proposed (B) diets

Nutrients	Requirements	Diet A	Diet B
MER (Kcal)[1]	657.2	1639.51	1188.80
Protein (%)	17.5–26	22.60	28.96
Fat (%)	5–8.5	9.18	7.72
Ca (%)	0.5–1.2	0.30	0.620
P (%)	0.5–1	0.50	0.61
Vitamin A (UI/Kg)	500–5900	3530.00	4072.55
Vitamin E (mg/Kg)	27–50	18.17	20.554
Thiamine (mg/Kg)	1–2.5	1.00	5.73
Riboflavin (mg/Kg)	1.6–10.5	1.10	6.728
Niacin (mg/Kg)	11.4–20	26.10	53.492
Vitamin B12 (mg/Kg)	0.022–0.035	0.01	0.02
Vitamin C	-	692.00	148.047
Na (%)	0.04–0.3	0.08	0.072
Mg (%)	0.04–0.06	0.03	0.04
K (%)	0.4–0.6	0.30	0.4

[1]MER= Metabolic Energy Requirement, calculated with the formula proposed by Iversen (1972).

The diet was reduced from 1639.5 to 1188.8 kcal metabolisable energy per day, and nutritional imbalances were corrected based on species requirements versus the estimated nutritional composition (obtained with Zootrition 2.6 software). This correction balanced the levels of Na, Mg, K, B-complex vitamins and the Ca:P ratio (Tables 3 and 4).

In the original diet (Diet A), the ingredients were chopped into pieces of approximately 2 × 2 cm and offered twice a day at 0900 and 1400, using a single feeding point. In the proposed diet (Diet B), food was delivered in large pieces or whole fruits according to the weight of the formulated diet. The food was offered at different randomly selected points located under the branches within the enclosure, with a new schedule of 0800, 1200 and 1500.

Environmental actions

After evaluating the environmental domain, a deficiency was identified concerning the enclosure's size, as it did not meet the minimum space requirements outlined by AZA (2010). Recommendations were provided to the institution to consider renovating the enclosure to a minimum area of 47 m^2. However, renovations were not carried out during the evaluation period of the present study.

Attention was given to habitat complexity, as there was no hiding place in which the animal could seek refuge. It was decided to provide a hiding spot or nest box in the outdoor area of the enclosure. The provided hiding area was constructed in concrete resembling a cave with a height of 50 cm and a depth of 1 m. Inside, dry leaves and straw were placed as bedding material.

Health actions

After conducting a physical examination under anaesthesia and reviewing the medical history, no significant abnormalities were observed, and as such, it was deemed unnecessary to take any actions related to this domain.

The weight obtained in the pre-corrective assessment was taken during the physical examination, while the final weight reported after corrective actions was achieved through operant conditioning of the individual.

Behavioural actions

After the first assessment, some corrective actions were established including implementation of a calendar of cognitive, nutritional, sensory and physical environmental enrichments on an inter-daily frequency (Table 5). A list of enrichment elements and strategies was considered, constructed from a literature review on scents, foods and objects previously used in other

Table 4. Diet composition in the previous (Diet A) and proposed diet (Diet B).

	Inclusion (% as fed)	
Ingredient	Diet A	Diet B
Fruits	47.4	45.6
Dry adult dog food	11.3	7.9
Chicken/Beef	9.2	22.7
Egg	12.9	6.9
Calcium supplement	0	0.3
Homemade wheat biscuit	19.3	16.5

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Table 5. Enrichment calendar for tayra

Week	Monday	Tuesday	Wednesday	Thurday	Friday	Saturday	Sunday
1	S		P			F	C
2		C		S		F	P
3	F		P			S	C
4		S				C	F

S: Sensory enrichment; P: Physical enrichment; F: Feeding enrichment; C: Cognitive enrichment".

institutions. Additionally, a daily routine for initiation into the institution's operant conditioning programme was implemented. For this programme, the objective is to encourage the individual's voluntary participation in behaviours that allow routine and clinical management (e.g. getting on the scale for weighing, allowing palpation and permitting medicine administration). The daily routine successfully elicited the behaviour of getting on and remaining on the scale for weighing.

Results

Among the four functional domains evaluated, shortcomings were identified in the nutrition and behaviour domains. The following sections discuss the findings, corrective actions and their impacts on the individual's wellbeing.

Feeding and nutrition

The initial weight of the individual before the corrective actions was 5.7 kg, with a slightly elevated body condition score of 3.5 on a five-point scale according to the AZA (2010) guidelines for mustelids.

When evaluating the estimated nutritional composition of the diet and the requirements suggested by AZA (2010) for *Eira barbara*, excesses of energy and fat were evident to which the slight increase in body condition score was attributed. With a gradual reduction in calories, the individual reached a weight of 5.1 kg and a body condition of 3.0. Additionally, the imbalance of the Ca:P ratio was corrected by adding calcium carbonate, going from an initial ratio of 0.6:1 to 1:1.

Regarding the feeding schedule, location and presentation, it was evident that after the changes, there was a noticeable impact on the total time required for consumption of the diet. Differences were found between the average time invested before and after the corrective plan (4.6±2.4 minutes and 15.2±4.5 minutes, respectively).

Another change observed after the dietary modification was in the consistency of the individual's faeces, which transitioned from a state 6 on the fecal score scale (De Cuyper et al. 2021) to a variable state between 4 and 5 (Figure 2). This change was associated with the general decrease in carbohydrates and the increase in highly digestible protein.

Behaviour

Before the intervention, there was a high incidence of stereotyped behaviours of pacing (20.6%) and route tracing (8.2%), which together represented 28.8% of the total time evaluated. The same value was obtained for periods of inactivity categorised as 'rest' behaviours (28.8%), followed by an incidence of 25.3% of aggressive behaviours, 8.2% for activities associated with feeding, 7.7% for other locomotion activities and 1.2% for exploratory activities.

The absence of some behaviours associated with positive animal welfare is highlighted, such as play, positive human-animal interactions, the option to choose between remaining visible to visitors or being hidden and participation in goal-oriented behaviours. However, the caregivers mentioned that the tayra under study has demonstrated over the years a high capacity for a positive response to occasional environmental enhancements that were provided.

The stereotyped behaviours, specifically route tracing, were more evident at times of public presence near to the habitat and were accompanied by aggressive behaviours such as vocalisations, always directed at the public.

The second behavioural evaluation showed a decrease in the occurrence of stereotypies, with a total of 16.2% of the observations registered: pacing 10% and route tracing 6.2%. Visible 'resting' behaviour accounted for 15.2%, to which time spent hiding in the lair of 12.5% must be added, which results in a similar amount of inactivity (27.7%) to before the changes. The most prevalent behaviours were those associated with feeding, obtaining an incidence of 28%. Likewise, the behaviours grouped in the exploration and locomotion categories were increased at 8 and 14%, respectively.

Lastly, new behaviours were observed that had not been registered before the changes. Playing and nest building or bedding comprised 5 and 2.2% of behaviours respectively. Notably, the animal continued to use the new hiding spot to a large extent even four weeks after its introduction.

Discussion

Revised dietary and environmental management significantly influenced the subject's overall behaviour. Comparing the observed decrease in stereotypies, along with an increase in welfare-related behaviours like locomotion, exploration and new activities such as play, to the existing literature reveals a promising advance toward enhancing the tayra's quality of life.

In practice, the change was distinct, especially during those days in which there was a high number of visitors. As mentioned, this tayra presented its highest peaks of stress and aggression

Figure 2. Fecal consistency of Eira barbara stools (A) before and (B) after the change of diet

when it was surrounded by stimuli from visitors. However, by providing environmental enrichment and a hiding lair, the records of vocalisations, aggressions and stereotyped behaviours directed to or associated with the outside stimuli of visitors decreased. These behaviours prevailed during the times of day when there was no enrichment, which coincided with regular feeding times. When recording activity, the specific distinction between the occurrence of anticipatory and non-anticipatory stereotypies was not made; however, given the reduction in route tracing (not seen as an anticipatory behaviour), it is hypothesised that most of the recorded pacing might be linked to the anticipation of food delivery, and the impact seen as pacing reduction could be linked to nutritional management.

Another key factor regarding food provision is the location at which the diet is presented. Tayras by nature show a preference for arboreal foraging (Cuarón et al. 2016; Huck et al. 2017; Lima et al. 2020). According to Presley (2000), they usually dedicate a large part of their time to foraging activities. Supplying food at a fixed location may provide little stimulation and could potentially be a stressor, as it restricts the animal's ability to sufficiently express this natural behaviour.

The low occurrence of exploring and food acquisition behaviours before implementing the corrective plan aligns with the authors' recommendations, supporting the proposal of replacing the fixed feeding point with a series of random feeding locations within the enclosure. This provides a certain degree of unpredictability which avoids the negative aspects of boredom (Wolfensohn et al. 2018). This is corroborated by the increase in food-related activities, extended feeding times and the apparent reduction in stress seen as a lower frequency of aggressions and stereotypies after the modifications.

The findings regarding stereotypies in the absence of a corrective plan were similar to those reported by Panizzon and Azevedo (2019). Their study on captive *Eira barbara* individuals showed a frequency of expression of stereotypies of 37% and a low frequency of activity of 16% during three days of observation for a period of seven hours per day. This suggests that under those conditions, wellbeing is poor. The same conclusion is reached by Pereira and Oliveira (2010) who demonstrate the difficulty of managing this species in captivity, primarily due to its requirements for living space and movement; these authors consider the tayra highly susceptible to the development of stereotypies.

Based on the findings of the current study, evaluating and managing the factors encompassed in the five domains model is an effective approach to increase the wellbeing of zoo animals. Most

Figure 3. Percentage of occurrence of the behaviours recorded for the individual under study before and four weeks after the application of the corrective plan.

particularly, modifying the method of diet provision in terms of predictability and distribution across space and time is a powerful tool to influence carnivore behaviour. It is important to continue implementing new measures that cater to each case and species in a specific way. Additionally, regular monitoring of measurable variables is necessary to ascertain whether the implemented changes are indeed producing the anticipated results. Efforts should be made to gather information that establishes the baseline for minimum welfare standards expected for each species.

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