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A comparative study of activity budgets in captive and semi-free ranging Hatinh and Delacour's langurs (*Trachypithecus hatinhensis* and *T. delacouri*)

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Summary

Captive reintroductions have become a popular tool for increasing viable populations of endangered primates. Comparisons of primate behavior in captive and wild settings provide critical insight to improve the success of reintroduction efforts. To better understand how captive vs. wild settings influence time budgets of Delacour's langurs and Hatinh langurs (*Trachypithecus delacouri* and *T. hatinhensis*), a study was conducted at the Endangered Primate Rescue Center in Cuc Phuong National Park, Vietnam. Study objectives included exploring differences in time budgets between the two study species and understanding influences of housing conditions on time budgets of caged vs. semi-wild groups. During the observation period (July 3rd-August 31st, 2011), each group was observed on rotating days using scan sampling at three-minute intervals. Results indicate that dominant behaviours include resting and feeding in all species-enclosure combinations. Yet significant changes in time budgets were observed for each species between the enclosure types, with particularly marked differences among age/sex classes. Juveniles and infants of both sexes typically engaged in play behaviour more than did adults in all settings.

So sánh quỹ thời gian hoạt động của loài vọoc Hà Tĩnh và vọoc mông trắng (*Trachypithecus hatinhensis* và *T. delacouri*) trong điều kiện nuôi nhốt và bán hoang dã

Tóm tắt

Giải pháp tái hòa nhập các cá thể được sinh sản trong điều kiện nuôi nhốt về môi trường tự nhiên nhằm tăng viện số lượng quần thể trở nên phổ biến đối với các loài linh trưởng nguy cấp. Những nghiên cứu nhằm so sánh tập tính giữa các cá thể nuôi nhốt và ngoài tự nhiên rất cần thiết để hoạt động tái hòa nhập thành công. Nghiên cứu về sự ảnh hưởng của điều kiện sống lên quỹ thời gian hoạt động của hai loài vọoc Hà Tĩnh và vọoc mông trắng được tiến hành tại Trung tâm Cứu hộ Linh trưởng Nguy cấp, Vườn Quốc gia Cúc Phương, Việt Nam. Những mục tiêu của nghiên cứu bao gồm việc tìm hiểu sự khác nhau về quỹ thời gian hoạt động của hai loài linh trưởng này cũng như sự ảnh hưởng của điều kiện chuồng trại lên quỹ thời gian hoạt động của mỗi loài. Thời gian nghiên cứu tiến hành từ ngày 3 tháng 7 năm 2011 đến ngày 31 tháng 8 năm 2011. Phương pháp quan sát scan-

sampling với khoảng cách đều là 3 phút. Kết quả cho thấy tập tính nghỉ ngơi và ăn chiếm phần lớn quỹ thời gian hoạt động ở cả hai loài và điều kiện sống khác nhau. Có sự thay đổi đáng kể về quỹ thời gian hoạt động giữa hai loài và điều kiện sống. Đặc biệt có sự sai khác về quỹ thời gian hoạt động của các cá thể có độ tuổi và giới tính khác nhau. Cá thể bán trưởng thành và con non ở cả hai giới tính đều có nhiều thời gian dành cho tập tính chơi đùa hơn những cá thể trưởng thành.

Introduction

Captive reintroductions reflect a strategy to increase viable populations of endangered species in the wild (e.g. Baker, 2002). Captive propagation of primates is one way of increasing the number of individuals in species suffering low population numbers due to hunting pressures and/or habitat fragmentation generated by anthropogenic activities and environmental change. But reintroduction efforts require more than pools of captive-bred individuals ready for release into the wild. Success in these endeavours requires understanding of how reintroduced species utilize natural environments, affording thoughtful consideration of the habitat characteristics required for their survival (Stoinski et al., 2002; Keith-Lucas et al., 1999; Baker, 2002). In this way, conservation of flagship species can be leveraged to conserve complex natural environments that are important for biodiversity conservation more generally.

The “limestone langurs” (several species of the genus *Trachypithecus*) (Groves, 2007) are examples of flagship primates that promise to play a pivotal role in preserving the future of biodiversity hotspots within Vietnam. They naturally inhabit dense forests situated on steep limestone karst formations (Vogt et al., 2008). These biodiversity-rich habitats contain thousands of species of flora and fauna that are greatly threatened by rapid human-induced environmental change (Nadler, 2008). Although interest has grown in the diet and locomotor behaviour of limestone langurs in recent years (e.g., Workman & Covert, 2005; Stevens et al., 2008; Workman, 2010), relatively little information has been published to date on activity budgets for many *Trachypithecus* species in the wild. This paucity of data limits our understanding of how such primates adapt to their surroundings in and out of captivity, hampering reintroduction efforts. In particular the Delacour’s langur is both critically endangered and endemic to Vietnam, so conservation efforts aimed at elevating this species as a symbol of national pride may be particularly fruitful in the long term survival of karst forest ecosystems throughout the region.

Material and Methods

Study setting and subjects

Established in 1993, the Endangered Primate Rescue Center (EPRC) is located within Cuc Phuong National Park, Vietnam, and strives to augment dwindling numbers of Vietnamese primate species in the wild through its internationally recognized captive breeding program (Nadler, 2008). The EPRC works vigorously to care for the influx of primates confiscated from markets and from the illegal pet trade throughout the country. Moreover, the EPRC has become a model for captive breeding of some of the world’s most endangered primates including Delacour’s and Hatinh langurs (Nadler, 2007). The EPRC’s success in breeding these rare primates in captivity makes it a leader in primate reintroduction projects.

In particular, Delacour’s and Hatinh langurs are ideal priorities for addressing how captive-bred animals respond to reintroduction into natural habitats. Both langurs are represented at the EPRC and have bred successfully in captivity. Moreover, both are currently housed in both semi-natural

and caged enclosures, and individuals residing in the semi-natural setting are soon slated for reintroduction into the wild. Importantly, these congeners inhabit similar conditions in the wild, making them interesting candidates for exploring time budget patterns among closely related animals. Finally, both species are endemic or near endemic to Vietnam and have been listed as either endangered (Hatinh langur) or critically endangered (Delacour's langur), hence information about their biology is a priority for informing the conservation effort. This study is the first to compare activity budgets of these two species in captive and semi-wild enclosures at the EPRC.

Specific aims

Our first goal is to explore whether and how the time budgets of two limestone langur species differ, using comparisons made between Hatinh and Delacour's langurs in both the caged and semi-wild settings at the EPRC. No extensive time budget studies have to date been published on Delacour's langurs in their natural habitat, and little is known about activity budgets in the Hatinh langur. The species are similar in body size and proportions, are closely related, and live in limestone karst forested habitat, relying heavily on leaves as their main food source (Nadler et al., 2003; Nadler et al., 2007; Workman, 2010). Hence appreciable differences would not be expected in the time budgets of the two study species housed in similar enclosure types. Both study species are highly folivorous, so as for other folivores, activity budgets are expected to emphasize resting in order to digest the cellulose and toxins present in the leaves (Nadler et al., 2003; Zhaoyuan Li & Rogers, 2004; Chengming Huang et al., 2003; Matsuda et al., 2009;).

The second study goal is to examine how time budgets differ for each study species in the caged vs. semi-wild housing conditions. Greater variety of locomotor substrates and higher habitat heterogeneity has both been shown to alter primate time budgets (Zhaoyuan Li & Rogers, 2004; Jaman & Huffman, 2008). In the present study, langurs occupying the semi-wild enclosures have access to a larger habitat area, providing a richer environment than do smaller and more uniform cages. Accordingly animals occupying semi-wild enclosures are expected to allocate more time foraging/feeding, more time traveling, and less time engaging in social activities (Jaman & Huffman, 2008).

Study site

This study was conducted in the Endangered Primate Rescue Center. The two caged enclosures used for this study share the same dimensions (10.1m x 5.1m x 3.2m) and are labelled 6B and 10B. Cage 6B housed 4 Delacour's langurs (1 adult male, 1 adult female, 1 juvenile female and an infant male). Cage 10B housed 6 Hatinh langurs (1 adult male, 2 adult females, 2 juvenile males and 1 infant male). The two semi-wild enclosures (Hill 1 and Hill 2) comprise 2 ha and 5 ha respectively. The hills consist of fairly undisturbed karst limestone forest and are each enclosed by a solar powered electric fence. During the study period, Hill 1 housed two muntjacs (*Muntiacus muntjak*), five Delacour's langurs (1 adult male, 2 adult females, 1 juvenile male and an infant female) and 1 female northern white-cheeked gibbon (*Nomascus leucogenys*). Hill 2 housed 8 Hatinh langurs (2 adult males, 2 adult females, 2 juvenile males, 1 infant male and 1 infant female).

Data collection and analyses

Between July 3rd and August 31st, 2011 behavioural observations were conducted on study subjects housed in semi-wild and caged conditions (Table 1). Caged groups were selected to match group compositions available in the semi-wild enclosures. Observations of the animals

Table. 1. Behavioural category definitions.

Behaviour	Description
Feeding	Handling, processing or consuming plant material or insects.
Foraging	Manipulating plant material in search of favored food items, moving to another branch or bundle of leaves to feed or looking intently around for a certain leaf species before moving to gather it.
Moving	Changing position or location on bamboo poles, on the cage wires, on the ground or in the trees.
Resting	Inactivity, where the animal is sitting or lying down that is not associated with eating, foraging or social activity.
Social	Activity Interacting with another group member or species whether aggressively, allo-grooming or play. Mothers with infants riding ventrally were not considered to be in the realm of social activity, but the activity in which the mother was otherwise involved was the other activity. The infant was then categorized as “resting” or “feeding” appropriately.
Anti-Predator Behavior	Looking vigilant into the sky at large birds, on the ground for snakes and/or making alarm calls.
Playing	Acting in a playful manner with inanimate objects. Jumping, swinging, or bounding playfully from substrates or other group members without them being engaged.

alternated daily between caged and semi-wild enclosures, with each enclosure type observed for a total period of 12 days throughout the study period at the EPRC (Table 2). Animals of different age/sex classes can easily be discerned using perigenital coloration, body size, pelage colour and other features specific to the individual (specific characteristics/features provided by E. Schwierz). Adults were defined by having reached reproductive maturity: >age five in males and >age four in females (Nadler et al., 2003). Juveniles were defined as animals under the age of sexual maturity but not still dependent on their mothers for feeding. Infants were defined as animals still dependent on mothers for all or part of their dietary intake.

Observations began between 05:30 and 07:00 (depending on weather conditions) and ended at 18:00 each day. Scan sampling was conducted every 3 minutes (Altmann, 1974; Di Fore & Rodman, 2001). Animals housed in the semi-wild enclosures were not seen in every scan and therefore the total amount of data collected varied for those individuals. Total number of observations for cages 6B, 10B, Hill 2, and Hill 1 were 10021, 13984, 3362 and 2585 respectively. The following behaviours were recorded for each scan; feeding, foraging, moving, resting, social behaviour, play and anti-predator behaviours.

All observations were recorded in a water-resistant notebook. Each evening, data were transcribed into a spreadsheet (Microsoft Excel for Mac, version 12.3.2). A total of 29,952 individual activity observations were made. Each individual observation is treated as a separate data point when used in succeeding analyses in order to reduce the potential biases introduced by the scan sampling technique (Clutton-Brock, 1977). Time budgets were calculated as the percentage of all observations occupied by each of the seven behavioural categories (Ha Thang Long et. al, 2010). Pearson’s chi-squared test was used to assess interspecific patterns within a given habitat type, and intraspecific patterns for different habitat types.

Table. 2. Vital statistics of individual observed in the study. Animals born outside the center do not have exact birthdates, but age was approximated to the best of the center's ability. Names are given to the animals at the center as a way of record keeping and distinguishing them apart.

Name	Species	Cage number	Sex	Age class	Birth date
Tilo	*T. hatinhensis*	10B	Male	Adult	06.02.96
Heinrich	*T. hatinhensis*	10B	Male	Adult	20.10.06
2-74	*T. hatinhensis*	10B	Male	Infant	06.04.11
2-60	*T. hatinhensis*	10B	Male	Juvenile	01.04.09
Cuc	*T. hatinhensis*	10B	Female	Adult	07.01.01
Hanh	*T. hatinhensis*	10B	Female	Adult	04.04.02
Kurt	*T. hatinhensis*	Hill 2	Male	Adult	1995
2-75	*T. hatinhensis*	Hill 2	Male	Infant	??.05.11
2-59	*T. hatinhensis*	Hill 2	Male	Juvenile	29.12.08
2-56	*T. hatinhensis*	Hill 2	Male	Juvenile	??.09.07
2-62	*T. hatinhensis*	Hill 2	Male	Juvenile	??.05.09
Erna	*T. hatinhensis*	Hill 2	Female	Adult	1993
Minni	*T. hatinhensis*	Hill 2	Female	Adult	1994
2-76	*T. hatinhensis*	Hill 2	Female	Infant	??.05.11
Jonathan	*T. delacouri*	6B	Male	Adult	21.02.98
1-25	*T. delacouri*	6B	Male	Infant	20.03.11
Johanna	*T. delacouri*	6B	Female	Adult	09.07.03
Jojo	*T. delacouri*	6B	Female	Juvenile	29.07.08
Longtail	*T. delacouri*	Hill 1	Male	Adult	1990
Gil	*T. delacouri*	Hill 1	Male	Juvenile	08.01.08
Manu	*T. delacouri*	Hill 1	Female	Adult	28.07.96
Buschi	*T. delacouri*	Hill 1	Female	Adult	27.10.05
1-23	*T. delacouri*	Hill 1	Female	Infant	20.05.10

Results

Time budgets of all species-housing combinations are summarized (Table 3).

Table. 3. Summary of activity budgets for Hatinh and Delacour's langurs occupying caged and semi-wild enclosures.

	Cage 10B Hatinh langurs	Hill 2 Hatinh langurs	Cage 6B Delacour's langurs	Hill 1 Delacour's langurs
Resting	53.51%	56.96%	51.10%	44.80%
Feeding	31.94%	16.83%	34.54%	28.02%
Moving	5.63%	8.88%	7.21%	11.36%
Social	4.85%	6.85%	3.02%	13.49%
Playing	3.43%	10.04%	3.88%	1.70%
Foraging	0.54%	0.03%	0.56%	0.58%
Anti-predator	0.10%	0.42%	0.20%	0.04%

The interspecific time budgets of the langurs are compared for caged settings (Fig. 1) and semi-wild settings (Fig. 2). The intraspecific differences for langurs occupying different enclosure types are compared (Fig. 4).

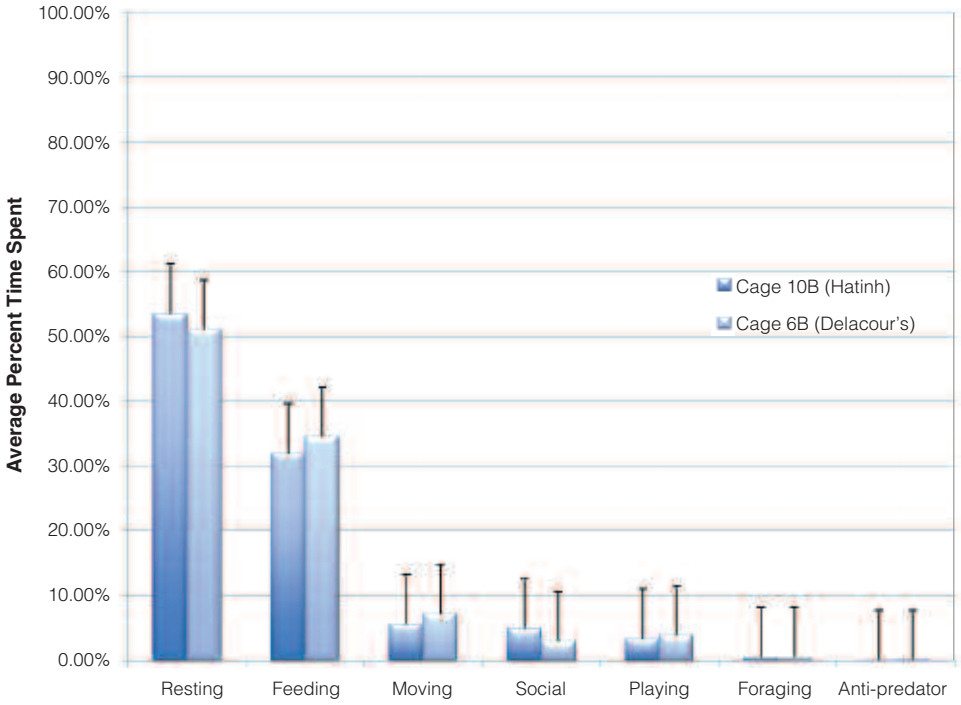

Fig.1. Bar graph depicting interspecific comparisons of time budgets of Hatinh and Delacour's langurs in caged environments.

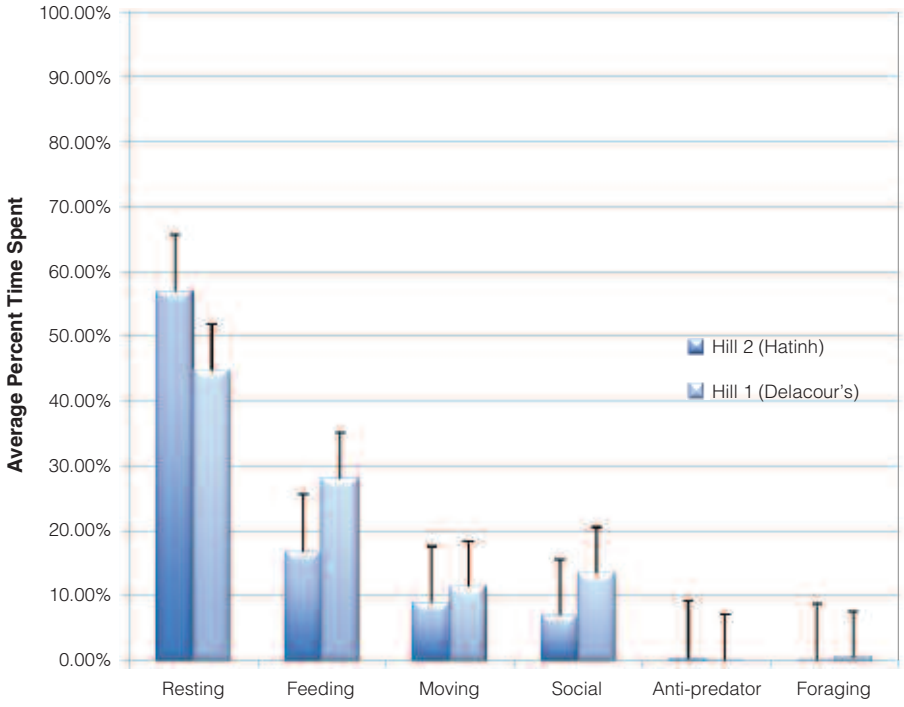

Fig.2. Bar graph showing interspecific comparisons of time budgets of Hatinh and Delacour's langurs in semi-wild environments.

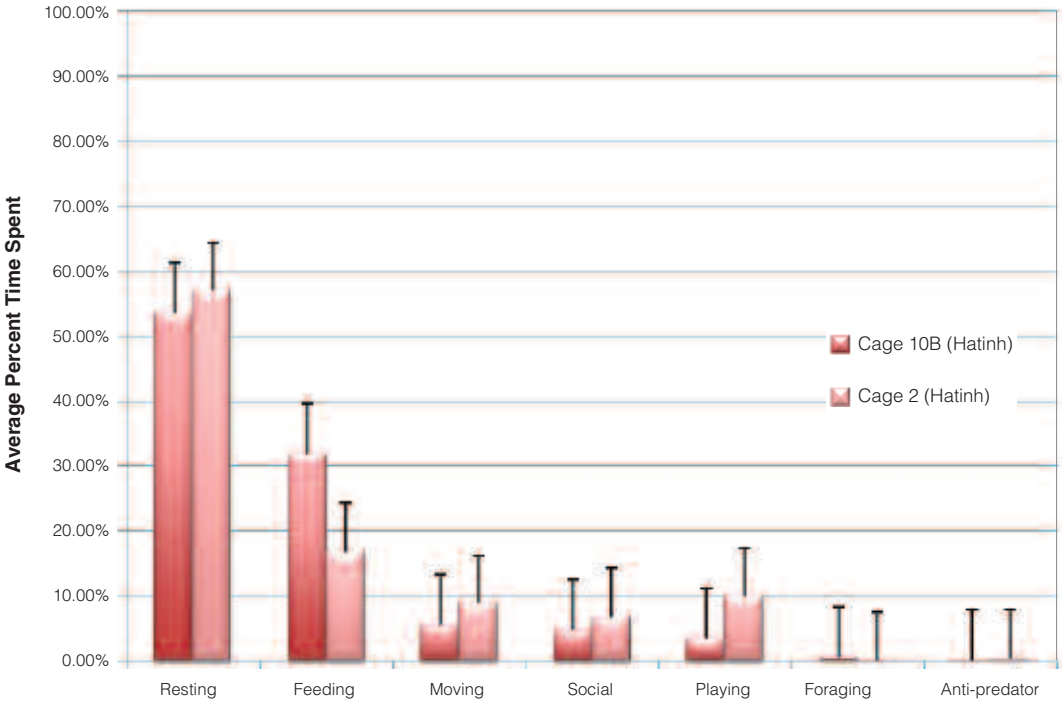

Fig.3. Bar graph depicting intraspecific comparisons of time budgets of Hatinh langurs occupying caged and semi-wild environments.

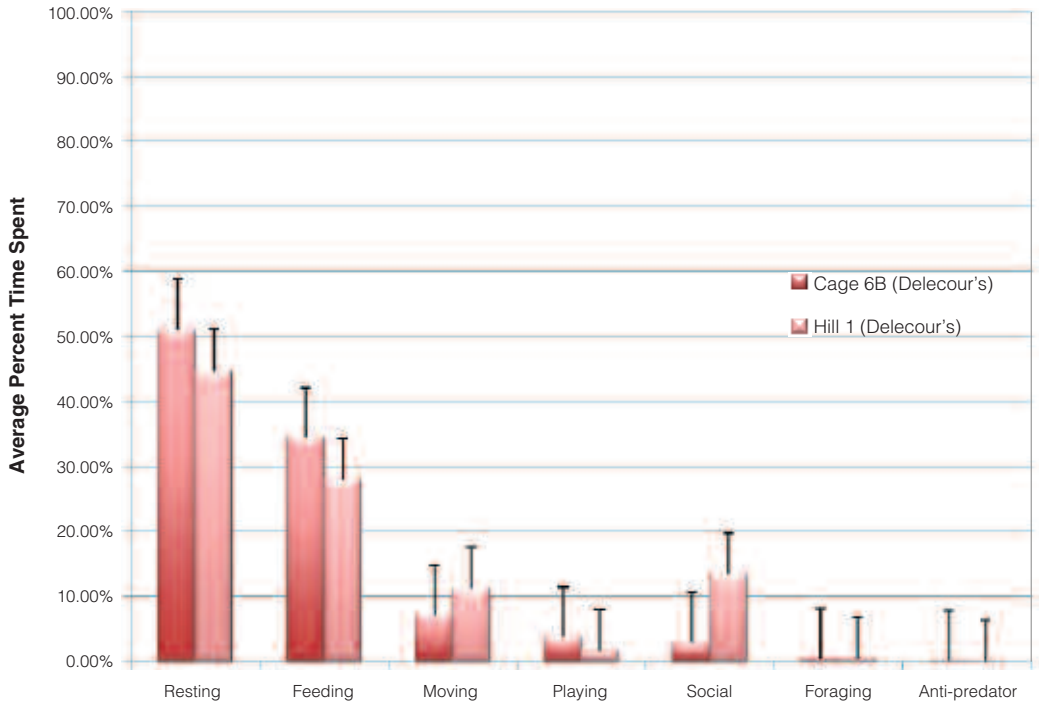

Fig.4. Bar graph depicting intraspecific comparisons of time budgets of Delacour's langurs occupying caged and semi-wild environments.

Interspecific comparisons in similar enclosure types

Chi-squared analyses of Delacour's and Hatinh langurs housed in caged settings were found to differ significantly in time spent feeding, moving, resting and engaging in social behavior ($p<0.05$ for each comparison). Study species in caged setting exhibited no significant differences in foraging, anti-predator and playing behaviors (Fig. 1).

Delacour's langurs and Hatinh langurs housed in semi-wild enclosures on Hill 1 and 2 exhibited significant differences in the following behaviours; feeding, foraging, resting, social, anti-predator and playing behaviours ($p<0.05$ for each comparison). Species did not differ in their time spent travelling (moving) in the semi-wild setting. Specific chi-squared and p-values for the comparisons between the two species in each enclosure type are summarized (Table 4).

Table. 4. Statistical results for interspecific comparisons in cages and semi-wild enclosures, and intraspecific comparisons for Hatinh and Delacour's langurs in both enclosure types.

Chi-squared values for time budget comparisons: Interspecific in the same enclosure types and itraspecific in different enclosure types

	Feeding		**Foraging**		**Moving**		**Resting**		**Social**		**Anti-Predator**		**Playing**	
Comparisons between	X^2	p-value	X^2	p-value	X^2	p-value	X^2	p-value	X^2	p-value	X^2	p-value	X^2	p-value
Interspecific														
Cage 10B and Cage 6B	40.22	<0.001	0.67	0.41	3.90	<0.05	48.28	<0.001	120.95	<0.001	1.48	0.22	0.02	0.88
Hill 1 and Hill 2	20.11	<0.001	10.29	<0.001	0.04	0.84	185.06	<0.001	23.12	<0.001	11.27	<0.001	226.27	<0.001
Intraspecific														
Cage 10B and Hill 2	2580.22	<0.001	62.06	<0.001	127.42	<0.001	1975.47	<0.001	188.32	<0.001	0.04	0.85	23.71	<0.001
Cage 6B and Hill 1	1775.08	<0.001	26.80	<0.001	178.31	<0.001	2478.01	<0.001	3.54	<0.001	17.19	<0.001	267.22	<0.001

Intraspecific comparisons in different enclosure types

Chi square analyses of Hatinh langur time budgets in different enclosure types (Cage 10B and Hill2) revealed significant differences in the amount of time spent feeding, foraging, moving, resting, and engaging in social and playing behaviours ($p<0.05$ for each comparison). No significant differences were observed in anti-predator behaviour (Fig. 3).

Similar comparisons among Delacour's langurs housed in different enclosure types (Cage 6B and Hill 1) revealed significant differences in the amount of time spent feeding, foraging, moving, resting, and engaging in anti-predator and playing behaviours ($p<0.05$ for each comparison). Differences in time spent engaging in social behaviors did not reach significance (Fig. 4).

Discussion

Time budget comparisons to other langur species

Delacour's and Hatinh langurs in this study spent most of their time resting (44.80% - 56.96%) and feeding (16.83% - 34.54%) in both caged and semi-wild environments. A similarly large

percentage of time spent resting has also been observed in many other species of langurs (grey-shanked douc langur *Pygathrix cinerea*: Ha Thang Long et. al, 2010; Francois' langur *Trachypithecus francoisi*: Qihai Zhou et. al, 2007; white-headed langur *Trachypithecus leucocephalus*: Chengminh Huang et. al, 2003; Zhaoyuan Li & Rogers, 2004; Cat Ba langur *Trachypithecus poliocephalus*: Schneider et. al, 2010). This emphasis on time allocated to resting is likely related to their folivorous diets. Longer resting periods allow for microbial digestion to break down the cellulose in plant cell walls (Oates & Davies, 1994; Nadler et. al, 2003). The process by which these monkeys digest leafy material is somewhat similar to that of a ruminant animal (Oates & Davies, 1994). Many of the microbes found in the rumen of artiodactyls are also found in the saccus gastricus of langurs in the genus *Trachypithecus* (Oates & Davies, 1994).

Importantly, in addition to the large amount of time spent resting and digesting, a high proportion of time was also allocated to feeding. Likely more initial processing of plant matter is conducted orally because *Trachypithecus* species do not possess a presaccus like that of colobines in the genera *Procolobus*, *Rhinopithecus*, *Pygathrix* and *Nasalis* (Oates & Davies, 1994). Indeed, they have been observed to masticate longer than those species possessing a presaccus and they may depend even more heavily upon enzymes produced by their large salivary glands to facilitate the breakdown of cell walls in their food (Wright et. al, 2008). *Trachypithecus* also exhibit deeper mandibular corpora than *Pygathrix*, perhaps related to longer chewing durations exhibited by *Trachypithecus* (Wright et. al, 2008). Since the behavioural category 'feeding' included mastication of foodstuffs, a large amount of time (16.83% - 34.54% of total time budget) was allocated to feeding in both species regardless of enclosure type. The necessary time required to both orally process and digest the leafy material reduces the remaining activity budget for participation in other behaviours (e.g., playing, social interactions, moving). A more complex digestive system, deeper mandibular corpora, high cusped bilophodont dentition and enlarged salivary glands likely serve as specializations for feeding on hard-to-digest plant materials, underscoring limestone langur uniqueness relative to feeding generalists in the Order Primates.

Interspecific comparisons in similar enclosure types

Since the *Trachypithecus* species examined herein are close in body size, and they inhabit similar habitats in the wild, it was hypothesized that they would not exhibit significantly different time budgets in a given enclosure type. Interestingly Hatinh and Delacour's langurs exhibited significant differences in time spent feeding, moving, resting and engaging in social interactions within the caged setting ($p < 0.05$ for each). The null hypothesis was also rejected for the two species inhabiting semi-wild enclosures in amount of time spent feeding, foraging, resting and engaging in social interactions and anti-predator behaviours ($p < 0.05$ for each). Hatinh langurs generally rested more of the time, and fed less than did Delacour's langurs (Fig. 1 and 2).

Differences documented between caged Hatinh and Delacour's langurs in this study may reflect true differences in the activity patterns of these species. Alternatively, the pattern might be attributed to differences in sampling intensity in different weather conditions during the study period. Observations of both species in semi-wild enclosures were also complicated by visibility and navigating high-relief karst terrain made slippery by rain, providing considerable challenges for obtaining the full 10-hour observation period each day. Animals were more easily visible was when they were feeding; hence observational data may reflect such practical limitations. Presumably such limitations might influence similar studies of limestone langurs. Nonetheless, the present study

is valuable in the context of how little is known of the activity budgets of these closely related species, and these observed differences can serve as a baseline and contribute to hypotheses to be tested in future studies.

Intraspecific comparisons in different enclosure types

Cages at the EPRC differ in food placement and substrate availability from the nearby semi-wild living environments, hence it was hypothesized that there would be a significant difference in the behaviour of each langur species between the two housing environments. Because of increased opportunities to seek out preferred food items, langurs in semi-wild areas were expected to allocate more time to foraging, feeding and moving. Hatinh langurs in this study exhibited significant differences in six of the seven behaviours recorded (feeding, foraging, moving, resting, social and playing) when housed in different enclosures.

Surprisingly, observed differences were often in the opposite direction from expectations, with the Hatinh langurs in semi-wild conditions spending significantly less time foraging and feeding, but rather spending significantly more time resting, and engaging in play and other social behaviours ($p < 0.05$ for each). Hatinh langurs did, however, spend more time moving when housed in semi-wild conditions on Hill 2, following expectations that animals would travel more outside of the cages given opportunities to utilize the higher level of habitat heterogeneity.

Delacour's langurs housed in caged and semi-wild conditions also exhibited appreciable differences in their time budgets. Six of the seven recorded behaviours significantly differed by enclosure type. As for Hatinh langurs, and contra our predictions, significantly more time was spent feeding in the caged setting. Resting, and playing behaviours followed expectations and were significantly higher in the caged setting, whereas foraging, moving and anti-predator behaviours were higher in the semi-wild setting ($p < 0.05$ for all).

In general, animals in this study spent more of their time moving about semi-wild enclosures and more time feeding in the cages. Increased habitat size and heterogeneity in the semi-wild setting likely accounts for movement differences, with higher distances among food sources requiring greater time spent in travel. A greater amount of time spent socializing in semi-wild enclosures is most likely attributable to a greater number of juveniles and infants playing with one another in the semi-wild enclosures. For example, Hatinh langurs on Hill 2 and Delacour's langurs on Hill 1 showed a significant increase in play behaviour from those Hatinh langurs housed in Cage 10B and Delacour's langurs housed in Cage 6B ($p<0.05$). This group had more juvenile/infants than did the Hatinh group housed in Cage 10B. Moreover, animals chasing one another around the forest were considered to be engaging in "social behaviour" and animals took advantage of the different substrates available to them during their games of "chase". The larger areas for movement also allowed for longer periods of chasing from one tree to the next or from karst to karst, and indeed habitat heterogeneity has been observed to significantly alter time budgets in primates (Zhaoyuan Li & Rogers, 2004; Jaman & Huffman, 2008).

Conservation implications

Future propagation of the limestone langur group in Vietnam, and indeed throughout South-east Asia, may increasingly rely upon small rescue/conservation centres like the Endangered Primate Rescue Center (EPRC). Small remaining population size for many species in the wild renders each individual critical for the population's variability, such that further losses could be detrimental to the

survival of the species as a whole. The EPRC has assumed a vital role in protecting Vietnam's biodiversity by providing a venue for expanding scientific understanding of primate biology and life history traits, and through efforts to protect wild populations and intercede in the illegal animal trade. Importantly, the EPRC has excelled not only in rescuing individuals of critically endangered species; it has also showed unparalleled success in captive breeding of these delicate animals. The next step for the conservation effort is to capitalize on this success via reintroductions of captive-bred animals back into suitable natural environments.

This observational study was conducted to help increase understanding of how time budgets vary in limestone langurs as a function of living conditions, and to develop baseline data that can inform soft-release techniques for captive reintroduction efforts. The IUCN recommends that animals housed in captivity first be transitioned into a semi-wild enclosure before release into a natural habitat. Significant activity budget differences in Hatinh and Delacour's langurs occupying caged and semi-wild settings suggests behavioural plasticity among the limestone langurs and supports the IUCN recommendation of soft-release to allow the animals time to adapt to larger ranges and different foraging requirements/opportunities. Practical considerations that also influence reintroduction efforts include budget, personnel time and space constraints.

Situation of the EPRC within the Cuc Phuong National Park offers advantages for future release endeavours. Coordination of efforts between the two entities may provide valuable opportunities to engage in and monitor captive releases with intensified protection efforts in place. A strong reintroduction project that increases primate density within the park is likely to bring an influx of revenue from visitors interested in flagship langur species. Managed well, an increase in park profits can further enhance protection efforts and contribute to the additional captive release efforts for these and other species.

Conclusions

This study, designed in collaboration with the EPRC's ongoing conservation, captive breeding and reintroduction efforts, provides important baseline behavioural data used to help understand habitat requirements for preserving biodiversity important to Vietnam's future. The nation's high number of critically endangered primates, as noted the IUCN's 25 Most Endangered List (Mittermeier et al., 2012), has focused international attention on limestone langur species on the brink of extinction. Future conservation initiatives will be augmented by intensified environmental education and recommendations for development of additional parks and protected areas.

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