EXPEDITION REPORT

Icons of the Amazon: jaguars, pumas, parrots and peccaries in Peru

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Abstract

Jaguar and puma presence in the Las Piedras Biodiversity Station, department of Madre de Dios, Peru: Eighteen days of intensive sampling was conducted to examine the occurrence and interactions of jaguar and puma at an ecotourism and Brazil nut concession in the Department of Madre de Dios, Peru. A research station (Las Piedras Biodiversity Station LPBS) was used as lodging and a start point for surveys with volunteers recruited by Biosphere Expeditions. The concession was located at the margins of the Las Piedras River, which drains from the Andean foothills through the Amazon forest. Five camera traps recorded 15 photographs of jaguar. Together, jaguar and puma were recorded 76 times, in 40 locations among track traps and opportunistic records, on seven trails distributed over nine 2 x 2 km cells and covering a polygon of 6,900 ha. The number of sample occasions in each trail varied from one to five times. Signs were found during all track surveys, an indication of good habitat conditions for these cats. Puma and jaguar tracks were recorded in the same track trap on the same day only once, but in six traps the two species were recorded on different days, suggesting a small spatial overlap (different from the previous year), but a temporal separation in trail use. The results are encouraging, showing that the habitat is still in very good condition and ideal to study the biology of species in their natural state, and particularly the effectiveness of current concession models to maintain optimal biodiversity levels.

The impact of feline predator activity on spatial patterns of terrestrial mammal claylick use: Jaguar, puma and ocelot are the three largest felines in the Amazon rainforest; with the jaguar the largest and the ocelot the smallest of these three. They feed on a range of other forest users, ranging from rodents and birds in the case of the ocelot, to the forest's largest herbivore, the tapir, in the case of the jaguar. Most prey items of the cats are herbivores, and herbivores are the main users of mineral licks, known locally in Peru as claylicks or colpas. Clay binds dietary toxins and is also an important source of sodium. While species and individual need for clay is unknown, claylick visitation by claylick-using species occurs on an almost daily basis. Claylicks would thus be a logical place for predators to seek prey. We established two track trap arrays of 300 x 300 m, consisting of 49 track traps in each array for a total of 98 track traps at LPBS during 2009. Eight days of monitoring (four days for each array) showed higher presence of claylick-using species at the array located on a claylick compared to the control. Ocelot presence was fairly even between arrays, but jaguar signs were only recorded once. During a repeat survey of these arrays in 2011, jaguar and puma signs accounted for 44% of all signs recorded. There was a converse reduction in the presence of signs from claylick-using species, most notably white-lipped peccary. While this is indicative of avoidance patterns of predators by the prey species, white-lipped peccaries were also infrequently recorded in track traps covering 15 km of trails and were also not recorded in camera traps, suggesting peccaries were simply less common in the area overall. Further studies are needed in order to draw firm conclusions.

Trends in encounter rate of large birds, monkeys and terrestrial mammals from a long-term study in southeastern Peru: The biggest threats to the integrity of the Amazon rainforest are currently large-scale land conversion to agricultural crops and pasture. Remaining seemingly intact forest can be severely influenced by non-timber forest resource extraction. Specifically, hunting can result in local extinctions, reduction in bird and mammal biomass and consequent changes in forest functional ecology. Hunting associated with mahogany and cedar extraction occurred extensively along the Las Piedras River during the 1990s. In 2002, LPBS, a former timber and Brazil nut concession, was acquired for conservation and tourism purposes, leading to the cessation of hunting. Monitoring of terrestrial and large bird populations at LPBS was conducted using line transect methods from 2003 to 2011, although no monitoring occurred during 2007 and 2010. Small species of monkey, such as saddle-backed tamarin, showed little change in encounter rate between years. However, large species of monkey known to be targeted by hunters – including red howler monkey and spider monkey – increased over the survey period until 2009, as did large bird species (Spix's guan, razor-billed curassow and pale-winged trumpeter). Trends for the ungulates were less clear. Overall, populations of the target species appear to be stable under the current land management practices, although white-lipped peccary and other species that range over areas larger than that protected by the concessions will undoubtedly become impacted by the increasing human activity associated with timber extraction and other land-use practices on neighbouring land.

Sentinel behaviour at a macaw claylick: The Peruvian department of Madre de Dios has the highest concentrations of the most species-rich parrot claylicks in the world. A parrot claylick is an exposed area of clay (normally vertical and often associated with an eroding river bank) frequented on a daily basis by up to 20 species of parrot. The clay that is consumed is high in sodium content. Parrot claylicks vary greatly in the numbers and species that visit them and we conducted observations at a claylick on the Las Piedras River used predominantly by Peru's largest parrot, the red-and-green macaw. Red-and-green macaws are monogamous birds that form social flocks in association with food sources (usually large, seed-bearing trees) and at claylicks. At claylicks the birds can be observed perched in the trees around the claylick for long periods, while normally only a short period is spent feeding on the clay. Over 15 days we monitored individual macaw behaviour using a perch-scan method and a variety of behaviour categories in order to test predictions made from sentinel behaviour theory. Sentinel behaviour can be described as coordinated vigilance. We predicted that at least one bird should be in a visible location when feeding on the claylick occurs (i.e. there should be at least one individual in a sentinel position); that the proportion of behaviour described as 'vigilant' should increase when birds are on the claylick (i.e. that while part of the flock are vulnerable to predation while on the clay, the rest of the flock will compensate with greater vigilance); and that calling should increase when birds are on the claylick (as sentinels announce their activity with calls). Birds were present in the vegetation around the claylick on 97% of occasions when birds were on the clay, and these individuals were significantly more vigilant. Furthermore, there was a significant positive correlation between birds scored as calling and birds scored as eating. Together, this suggests a process of coordinated vigilance among red-and-green macaws in relation to claylick activity.

A comparison of human impacts on large and medium mammal presence: A variety of mammals were observed at LPBS and compared to encounter rates of the Posada Amazonas Lodge on the Tambopata River (PAL). Both are in effect private reserves, with LPBS brought under protection nine and PAL 17 years ago. LPBS, due to its remote location, is surrounded by relatively intact forest and experiences little human and tourism impact. PAL is much closer to the population centre of Puerto Maldonado, surrounded by heavily utilised forest and has more human and much more tourism impact. After assessment of the large and medium mammal species assemblage through line transect methods, it is believed that LPBS has undergone full recovery, displaying full saturation of complete mammal species biodiversity at equilibrium. At PAL, by contrast, where source-sink dynamics cannot take effect, there are very few cat predators and lower diversity of primates, particularly of those species, such as spider monkey, which are heavily targeted by hunters, have low reproductive rates and depend on source-sink systems for recovery. Without the formation of corridors through the surrounding community and agricultural land, perhaps joining other lodges of the lower Tambopata area, it is probable that small ecotourism sites of protected secondary forest, such as PAL, will never be able to recover full species biodiversity, and can only support an increment in numbers of the species that have been left behind. Tourism as a protective activity then depends on real management in the face of opportunist hunting from nearby human populations, and also corridors as a connection to low-impacted forest, in order to promote full biodiversity.

A comparison of primate behaviour reactions towards human presence: In order to aid protected area management, a study of primate flight and other behaviours was conducted at LPBS, PAL and a hunted claylick site (CL) near PAL. CL showed the highest frequency of escape and vigilance behaviours, indicating that all species feel most threatened there, most likely because the site is hunted frequently. Animals appeared to behave most relaxed at PAL. The reason for this is habituation through large tourist groups visiting the forest frequently. There also appears to be a correlation in terms of species size at hunted sites and canopy level of high human traffic sites. At CL, larger-bodied species show highest stress, while at PAL with high tourist traffic, high canopy dwellers show the lowest stress reactions. At LPBS, with the lowest human impact and traffic, there appears to be general wariness of humans and thus medium flight responses and low stress levels. Finally, there appears to be a correlation between stress and flight levels of those species most targeted by hunters, i.e. species most heavily hunted are the most nervous and stressed, and flee most readily.

Resumen

Presencia de jaguar y puma en la Estación de Biodiversidad Las Piedras, en el departamento de Madre de Dios, Perú: por dieciocho días se recolectaron datos intensamente, para examinar la ocurrencia e interacciones del jaguar y del puma en una concesión de nueces brasilera en el departamento de Madre de Dios, Perú. La estación de pesquisas (Las Piedras Estacion de Biodiversidad LPBS por sus siglas en inglés) fue usada como lugar de hospedaje y punto de partida para los estudios con los voluntarios de Biosphere Expeditions. La concesión está localizada a las márgenes del rio Las Piedras, que drena de los pies de los andes a través de la selva Amazónica. Cinco trampas fotográficas registraron 15 fotos de jaguar. En total, jaguares y pumas fueron registrados 76 veces, en 40 locales entre trampas de huellas y registros opportunisticos, en 7 senderos, distribuidos en nueve celulas de 2x2 km, cubriendo un polígono de 6,900 hectareas. El número de ocasiones de muestreo en cada sendero variaba de uno a cinco veces. Durante la busca por huellas se encontraron señales de buenas condiciones de hábitat para estos gatos. Las huellas de los pumas y jaguares fueron registrados en la misma trampa de huellas, en un mismo dia, solamente una unica vez, al paso que fueron compartidas seis trampa de huellas en diferentes días (8% de todas las trampa de huellas), sugiriendo una superposición espacial inexpresiva (diferente del año pasado), pero una separación temporal en el uso de los senderos, todos en una muy fina resolucion en la escala espacial. Los resultados son animadores, mostrando que el hábitat está aún en muy buenas condiciones, e ideal para el estudio de biología de las especies en su estado natural, y particularmente la efectividad de los modelos actuales de concesión para mantener niveles óptimos de biodiversidad.

El impacto de la actividad predadora de felinos en padrones espaciales de uso de colpas por los mamíferos: El jaguar, el puma y el manigordo son los tres felinos más grandes en la selva Amazonica, siendo el jaguar el más grande y el manigordo el más pequeño de los tres. Ellos se alimentan de una variedad de otros usuarios del bosque, desde roedores pequeños y pájaros (en el caso del manigordo), hasta lo mas grande de los herbívoros, el tapir, en el caso del jaguar. La mayoría de las presas de los gatos son herbívoros, y los herbívoros son los mayores usuarios de tierras saladas, conocidos localmente en Peru como lambedor de arcilla o colpas. La arcilla se liga a las toxinas de la dieta y también es una fuente importante de sodio. Mientras la necesidad del consumo de arcilla en las especies y en los individuos es desconocida, las visitas a las colpas por usuarios de colpas son realizadas todos los días. Por lo tanto los lugares donde hay colpas sería lógicamente un lugar que los predadores buscarían sus presas. Establecimos dos matrizes de armadillas de huellas de 300mx300m, consistiendo de 49 armadillas de huellas en cada matriz, dando un total de 98 armadillas de huellas en LPBS durante 2009. El monitoreo por ocho días (cuatro días por matriz) mostro una presencia mayor de usuarios de colpa en la matriz ubicada en una colpa que en el control. La precencia del manigordo fue bastante similar entre las matrizes, pero los rastros del jaguar sólo fue registrada una vez. Durante una repeticion de la investigacion de estas matrizes en el 2011, los rastros de jaguares y pumas sumaron 44% de todos los signos registrados. Hubo una reducción contradictoria en la presencia de rastros de especies usuarias de colpa, con mayor notoriedad el pecarí de labios blancos o huangana. Mientras esto es un indicativo de padrones de evitación de los predadores de las especies de presa, los huanganas fueron también infrecuentemente registrados en trampas de huellas que cubrían 15 km de caminos, y tampoco no fueron registrados en trampas fotograficas, sugiriendo que los huangana simplemente fueron menos comunes en toda áreas en 2011. Mas estudios serían necesarios para conclusiones sin ambigüedades.

Tendencias en la tasa de encuentro de grandes aves, monos, y mamiferos terrestres desde un studio a largo plazo en el sudeste de Peru: Los mayores peligros a la integridad de la selva amazónica son en la actualidad, el cambio a gran escala de plantaciones agrícolas y pastizales. Los remanentes de bosque aparentemente intactos pueden ser influenciados severamente por la extraccion de recursos forestales no maderables. Especificamente la caza puede resultar en extinciones locales, la reduccion de la biomasa de los pájaros y mamíferos; en consecuencia trayendo cambios en en la funcionalidad de la ecología de la selva. La caza, asociada con la extracción de caoba y del cedro ocurrió extensivamente a lo largo del rio Las Piedras durante los noventas. En el 2002, LPBS, la otrora concesión de madera y nueces del Brasil fue comprada para propósitos de conservación y turismo, llevando esto al cese de la caza. El monitoramiento de poblaciones de aves terrestres y de grande porte en LPBS fue conducido usando métodos de transección en lina desde el 2003 al 2011, aunque no hubo monitoramiento durante el 2007 y 2010. Las pequeñas especies de monos, como pichicho común mostraron pocos cambios en las proporciones de encuentro entre los años de estudio. Sin embargo especies de mayor porte conoscidamente blancos de los cazadores – incluyendo el mono aullador rojo y mono aranã o marimonda – incrementaron su presencia durante el periodo de estudio, hasta 2009, igual que lo hicieron las aves de gran porte (pava amazónica, paují tuberoso y tente alipálido). La tendencia para los ungulados fueron menos claras. En general las poblaciones de las especies blanco aparentan estar estables durante el actual manejo de tierras. Aunque las huanganas y otras especies que están sobre áreas mayores as la concesionadas, seguramente serán impactadas por la creciente actividad humana asociada a la extracción de madera y otras prácticas de uso de tierra en las redondezas.

Comportamiento de sentinela en una colpa de guacamayos: El departamento de Madre de Dios en Peru tiene la mayor concentracion de especies de loros asociadas a las colpas en el mundo. Una colpa de loros es una area de arcilla expuesta (normalmente vertical y frequentemente asociada a un lado erosionado de un rio) frecuentada diariamente por hasta 20 especies de loros. La arcilla consumida tiene alta concentración de sodio. Colpas de loros varian mucho en numero de especies que las visitan. Nosotros conducimos observaciones en una colpa en el Rio Las Piedras usado predominantemente por el loro mas grande de Peru, el guacamayo rojo y verde. Guacamayos rojo y verde son pájaros monógamos que formam grupos sociales en asociación com fuentes alimenticias (geralmente con arboles grandes con semillas) y en colpas. En colpas los pájaros pueden ser observados posados en arboles alrededor de las colpas por largos periodos, mientras normalmente poco tiempo es usado en palimentarse de arcilla. El comportamento individual del guacamayos rojo y verde foi monitoreado por mas de 15 dias usando un metodo de escanear posaderos y una variedade de categorias de comportamientos, para probar predicciones hechas por la teoria de comportamiento sentinela. Hemos previsto que por lo menos un pájaro deberia estar en posición visible durante la alimentación en una colpa (i.e. debe haber por lo menos un individuo en posición de sentinela); que la proporción de comportamiento descrita como 'vigilante' deba aumentar cuando los pájaros esten en la colpa (i.e. que mietras una parte del grupo este vulnerable a ser predado mientras en la arcilla, el resto del grupo compensaria con una vigilancia mayor); y que los llamados deban aumentar cuando los pájaros esten en la colpa (los sentinelas anuncian sus actividades con llamados). Pájaros estaban presentes en la vegetacion alrededor de las colpas en 97% de las occasiones en las cuales los pájaros estaban también en la arcilla, y estos individuos se encuentraban mas vigilantes. Además, hubo una correlación significativa entre pájaros llamando y pájaros alimentándose. Juntos, sugeren un proceso de coordinación vigilante entre los guacamayos rojos y verdes en relación a la actividad en colpas.

Comparación del impacto humano en la presencia de mamíferos grandes y medianos: Se observaron una variedad de mamíferos en LPBS, y sus tasas de encuentro fueron comparadas con las de la Posada Amazonas Lodge en el Rio Tambopata (PAL). Las duas son efectivamente reservas privadas, siendo que LPBS fue protegida desde hace 9 años atrás y PAL 17 años atrás. LPBS, debido a su locación remota está rodeada de un bosque relativamente intacta, y experimenta un impacto muy pequeño de presencia humana y de turistas. PAL está mucho más cerca al centro poblado de Puerto Maldonado, y rodeado de una floresta más utilizada y tiene más impacto humano y turístico. Después de una evaluación de mamíferos grandes y medianos a través de métodos de transecciones in linha, se cree que LPBS ha experimentado una recuperación completa, mostrando una completa saturación de biodiversidad de especies mamíferas al equilibrio. En la PAL, en contraste, donde dinamicas de fuente y dreno no pueden llevarse a efecto, hay muy pocos predadores felinos y muy baja diversidad de primatas, particularmente de las especies tales como mono araña o marimonda, los que son altamente buscados por los cazadores, tienen muy bajos niveles de reproducción y dependen de sistemas fuente y dreno para recuperarse. Sin la formación de corredores a través de las comunidades vecinas y tierras de agricultura, quien sabe uniendo otras posadas de la área del bajo Tambopata, es probable que pequeñas áreas de ecoturismos de protección de bosque secundário, tal como la PAL, nunca serán capaces de recobrar la biodiversidad de especies en su totalidad, y podrán solamente soportar el incremento, en números, de las especies que han sido dejadas. El turismo como una actividad de protección dependerá de un manejo real frente a una caza oportunista a partir de las poblaciones humanas cercanas, y también corredores como una conexión a los bosques con bajo impacto, de tal manera a promover una biodiversidad completa.

Comparación de las reacciones del comportamiento de primatas a la precencia humana: Con el fin de ayudar a el manejo de áreas protegidas, un estudio de escape de primatas y otros comportamientos fue conducido en LPBS, PAL y el sitio de colpa CL, cerca del PAL. CL mostró la mayor frecuencia de comportamientos de vigilancia y escape, indicando que todas las especies se sienten más amenazadas en ese local, probablemente porque el lugar es frecuentemente lugar de caza. Los animales aparentemente se mostraban más relajados en PAL. La razón de esto sería que estaban acostumbradas a grandes grupos de turistas que visitaban la floresta frecuentemente. También parece que hay una relación con referencia al tamaño de la especie en lugares de caza y altura del dosel en lugares de alto tráfico de humanos. En el CL, las especies más grandes mostraron mayor estrés, mientras que en el PAL con alto tráfico de turistas, y un grande número de habitantes del alto dosel muestran las menores reacciones de estrés. En LPBS, con menos impacto y tráfico humano, parece que hay desconfianza general de los humanos y por lo tanto reacciones de escape medianas y bajos niveles de estrés. Finalmente aparentemente hay una relación entre el estrés y niveles de escape en las especies más buscadas por los cazadores, es decir las especies más cazadas son las más nerviosas y estresadas y escapan más rápidamente.

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1. Expedition Review

M. Hammer (editor)
Biosphere Expeditions

1.1. Background

Biosphere Expeditions runs wildlife conservation research expeditions to all corners of the Earth. Projects are not tours, photographic safaris or excursions, but genuine research expeditions placing ordinary people with no research experience alongside scientists who are at the forefront of conservation work. Expeditions are open to all and there are no special skills (biological or otherwise) required to join. Expedition team members are people from all walks of life and of all ages, looking for an adventure with a conscience and a sense of purpose. More information about Biosphere Expeditions and its research expeditions can be found at www.biosphere-expeditions.org.

This expedition report deals with a survey of iconic wildlife species in one of the best conserved remaining regions of the Amazon basin with vast areas of unbroken canopy, which ran from 5 June to 1 July 2011. The aim of the survey was to gain a better understanding of the ecological importance of natural claylicks as this information will assist in the development of an environmentally sensitive and sustainable management strategy. The project built on one of Biosphere Expeditions' longest running studies, with the focus changing to better understand the importance of mineral licks in the lives of macaws and peccaries, as well as the top-end predators puma and jaguar. Once we understand how the claylick ecology works, strategies for their sustainable use in eco- and nature tourism can be developed that will benefit local people and wildlife and provide strong incentives to protect more natural habitat that is currently threatened by unsustainable and short-term gain logging, gold mining and oil and gas exploration.

1.2. Research area

Figure 1.2a. Flag and location of Peru and study site.

An overview of Biosphere Expeditions' research sites, assembly points, base camp and office locations is at Google Maps.

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Peru is located on the Pacific coast of South America and is the third largest country on the continent. Two-thirds of Peruvian territory is located within the Amazon basin. The expedition base camp is within the department of Madre de Dios, internationally known as 'the Biodiversity Capital of the World'. The department already contains two large national parks covering over half of its 78,000 km² area – Manu and the vast Bahuaja-Sonene (Tambopata) area. The Rio Piedras is located between the two.
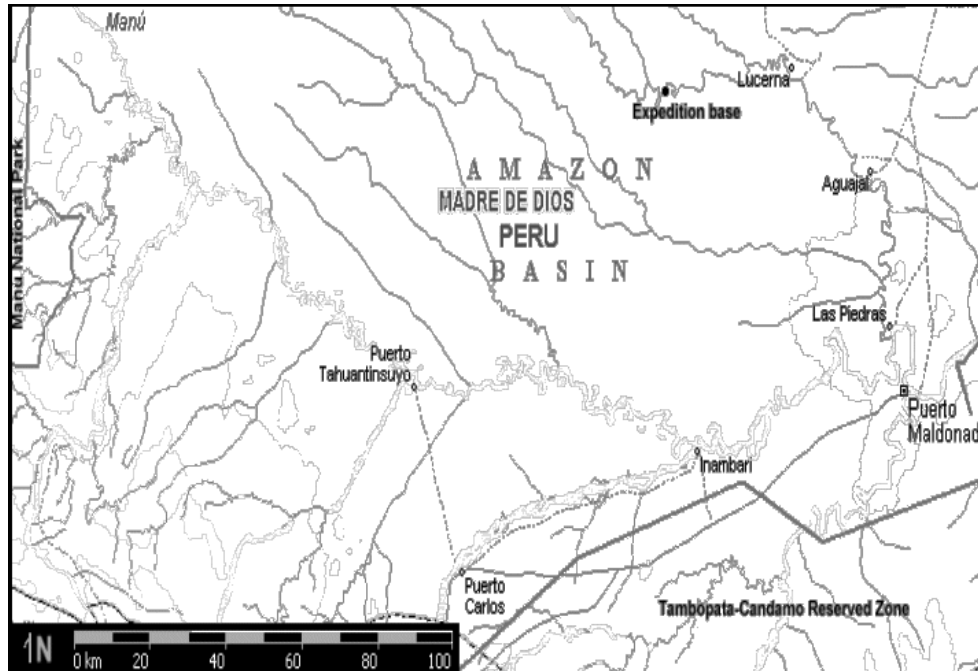
Figure 1.2b. Map of the area showing Puerto Maldonado (assembly point), Manu (NW corner), Tambopata-Candamo (SE corner) and base camp location (N edge).

In terms of biological diversity, the research area is amongst the richest in the world. The area's ecosystems hold several world records in flora and fauna species numbers and are recognised as one of the planet's biodiversity hotspots. Research conducted over the last 20 years in the Bahuaja-Sonene National Park has shown that it harbours more species of birds (587), butterflies (1,230) and many other animal taxa than any other location of comparable size. It has recently also been identified as the largest uninhabited and untouched rainforest wilderness on Earth, covering about 1 million hectares (2.5 million acres) of undisturbed and unhunted habitat (the nearest rival, the island of New Guinea, has about 100,000 hectares of uninhabited tropical forest habitat). The area is also home to a number of landmark animals listed in the IUCN's Red Data Book. Amongst them are the giant river otter, giant armadillo, giant anteater, ocelot, jaguarundi, jaguar, harpy eagle, crested eagle, spectacled caiman, and black caiman. Over 150 different species of tree can be found within 100 m^2 alone, and the WWF and IUCN have identified the area as a 'Centre of Plant Diversity'.

1.3. Dates

The expeditions ran over a period of four weeks divided into two two-week slots, each composed of a team of international research assistants, scientists and an expedition leader. Slot dates were:

5 – 17 June | 19 June – 1 July 2011

1.4. Local conditions & support

Expedition base

The expedition was based in a remote region along the Las Piedras River. Base camp was a large, comfortable jungle lodge / research station made from local materials with twin rooms, showers and toilets. By and large team members paired up to share rooms. All meals were prepared for the team and vegetarians and special diets were catered for.

Field communications

Mobile phones did not work in the remote research area. Base camp had a radio for emergency communication with Puerto Maldonado. The expedition leader sent an expedition diary to the Biosphere Expeditions HQ every few days and this diary was then distributed to team members and appeared on the Biosphere Expeditions website at www.biosphere-expeditions.org/diaries for friends and family to access.

Transport & vehicles

Team members made their own way to the Puerto Maldonado assembly point. From there they travelled six to seven hours by boat to base camp. Once at base, most studies were conducted on foot. Boats were also used for transport where necessary. All transport, boats and vehicles were provided from the expedition team assembly point onwards and back.

Medical support & insurance

The expedition leader was a trained first aider, and the expedition carried a comprehensive medical kit. Further medical support was provided through a medical post in the Colpayo community, about three hours away by boat. The nearest hospital was in Puerto Maldonado, about six hours by boat. Safety and emergency procedures were in place, but did not have to be invoked as there were no serious medical incidences.

1.5. Expedition scientist

Alan Lee is a graduate of Manchester Metropolitan University. His undergraduate studies in biology were conducted in South Africa, where he grew up. After working as a game ranger for one of South Africa's most exclusive lodges, Mala Mala, he moved to England for a change in career direction and for travel opportunities, which to date have taken him to every continent except Antarctica. He first came to Peru in 2002 when he worked as a guide at Explorer's Inn, and then joined the Tambopata Macaw Project. From 2003 to 2004 he supervised teams of volunteers on a project looking at the impacts of tourism on large mammal wildlife. In 2005 he was scientific adviser for the Biosphere Expedition to Las Piedras. During 2006 as part of his ongoing research into the impact of claylicks on parrot abundance, he was project manager for the Tambopata Macaw Project at Posada Amazonas and Refugio Amazonas.

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Sara Rehman is a graduate of the University of Manchester and has taken part in biological surveys in the UK, Spain and Indonesia. Sara came to Peru to volunteer on Alan's Macaw Project and soon found herself back again managing Fauna Forever, a project that assesses the impact of tourism on wildlife. More recently Sara has designed her own project to monitor mammal distribution in relation to claylicks, making her the lead researcher of The Mammal Project with Rainforest Expeditions' lodges.

1.6. Expedition leader

Jiri Haureljuk was born in the Czech Republic and now lives in Australia. In this home country, Jiri studied forestry and after compulsory military service he worked for the regional forestry department as a forester and part-time ranger. His first long-haul trip aroad, to India and Nepal, turned out to be life-changing as Jiri was bitten by the travel bug. After a serious spell of globetrotting, he started leading groups in Kenya and the Middle East, before he eventually moved to Africa. There he spent five years, on and off, traversing almost the entire continent on an overland truck and safari guiding before finally moving to Melbourne. When not travelling around the world chasing elusive animals for Biosphere Expeditions and his ever-growing photo library, Jiri is running Melbourne-based wildlife tours, showing visitors the beauty of Victoria state. Jiri is also a published photographer and a keen sportsman.

1.7. Expedition team

The expedition team was recruited by Biosphere Expeditions and consisted of a mixture of ages, nationalities and backgrounds. They were (with countries of residence in parentheses):

5 – 17 June 2011

Martha Anderson (USA), Ege Arguden (Turkey), Karlene Bain (Australia), Deepika Benawra (Switzerland), Rita Gobet (Switzerland), Nick Hughes (UK), Cornelius Kugler (Germany), André Moum (Norway), Christine Pienaar (Australia), Sara Salih (Canada), Flavio Spaini (Switzerland).

19 June – 1 July 2014

Sam Atkins (Australia), Tamara Caddy (journalist, Australia), Ken Dawson (UK), Conny Kirstein (Germany), Tristan Lehnert (USA), Savannah Lehnert (USA), Thomas Mayer (Germany), Anne Noack (Germany), Uwe Noack (Germany), Marina Schmidt (Switzerland), Mark Smith (USA), Lisa Weinstock (USA).

1.8. Expedition budget

Each team member paid towards expedition costs a contribution of £1,220 per person per two-week slot. The contribution covered accommodation and meals, supervision and induction, a permit to access and work in the area, all maps and special non-personal equipment, and all transport from and to the team assembly point. It did not cover excess luggage charges, travel insurance, personal expenses like telephone bills, souvenirs etc., or visa and other travel expenses to and from the assembly point (e.g. international flights). Details on how this contribution was spent are given below.

Income	£
Expedition contributions	25,480

Expenditure

Base camp and food includes all meals, lodging, base camp equipment, boat transport	4,488
Equipment and hardware includes research materials & gear, etc. purchased in UK & Peru	604
Staff includes salaries and travel expenses for all local and international staff	6,611
Administration includes permits, registration fees, sundries, etc.	462
Team recruitment Peru as estimated % of PR costs for Biosphere Expeditions	4,887
Income – Expenditure	8,428

Total percentage spent directly on project	**67%**

1.9. Acknowledgements

1.10. Further information & enquiries

More background information on Biosphere Expeditions in general and on this expedition in particular including pictures, diary excerpts and a copy of this report can be found on the Biosphere Expeditions website www.biosphere-expeditions.org.

Copies of this and other expedition reports can be accessed via at www.biosphere-expeditions.org/reports. Enquires should be addressed to Biosphere Expeditions via www.biosphere-expeditions.org/offices.

2. Jaguar and puma presence at the Las Piedras Biodiversity Station, department of Madre de Dios, Peru

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2.1. Introduction

The Madre de Dios Department in Peru, 8.5 million hectares in size, harbours 7.8 million hectares of natural forest in the western Amazon (Grupo La Republica 2004), within the most diverse terrestrial ecoregions in the world (Olson and Dinerstein 2002). Many of the forests in Madre de Dios may be considered pristine habitat and are believed to be amongst the forest blocks that will survive the forecast 50% decline of Amazon forest surface predicted to take place within 20 years (Nepstad et al. 2008).

This is relevant for jaguar populations, as very few habitats will be able to maintain viable populations of jaguars in the future (Sanderson et al. 2002) without requiring management aimed to minimise inbreeding depression. However, illegal logging and mining have spread widely and with them an environmental impact that poses a threat to the future of the area. In an attempt to promote a monitored occupation of land and a more sustainable use of the forest resources, the government has published forest law number 27308 (in June 2000) modifying rules for forest concessions.

The study area, located by the Las Piedras River, has begun to operate under these new concession rules, but in the past and up to the year 2000 it was used for timber extraction under the old regulation. In 2002 logging ceased and the area was converted into an ecotourism and Brazil nut concession.

It is under these conditions that a preliminary survey on the occurrence of jaguars and pumas was conducted to estimate the viability of a long-term study of these large cats under the Biosphere Expeditions volunteer scheme.

2.2. Material and methods

Study area

The study area is located in the department of Madre de Dios, in southeastern Peru, bordering with Brazil and Bolivia to the east. It is in the southwest Amazon moist forests (Ecoregion NT0166 – WWF 2010). Major forest types are seasonally flooded and non-flooded lowland rainforest. The climate is classified as Afa (Kottek et al. 2006).

Sampling

A basic grid of cells each measuring 2 x 2 km was overlaid on the study area's trail system (see Figure 2.2a) in order to provide organised spatial units to analyse presence of jaguars and pumas at a representative scale – the cat species have large home ranges (over 10,000 ha), thus the scale of analysis should be at least larger than this for adequate sample size. By drawing a line around the sampled trail systems, we end up with a polygon 6,900 ha in size. This size of sampled area highlights the experimental nature of the current study, as larger areas should be sampled to obtain meaningful results representative of a large cat population.
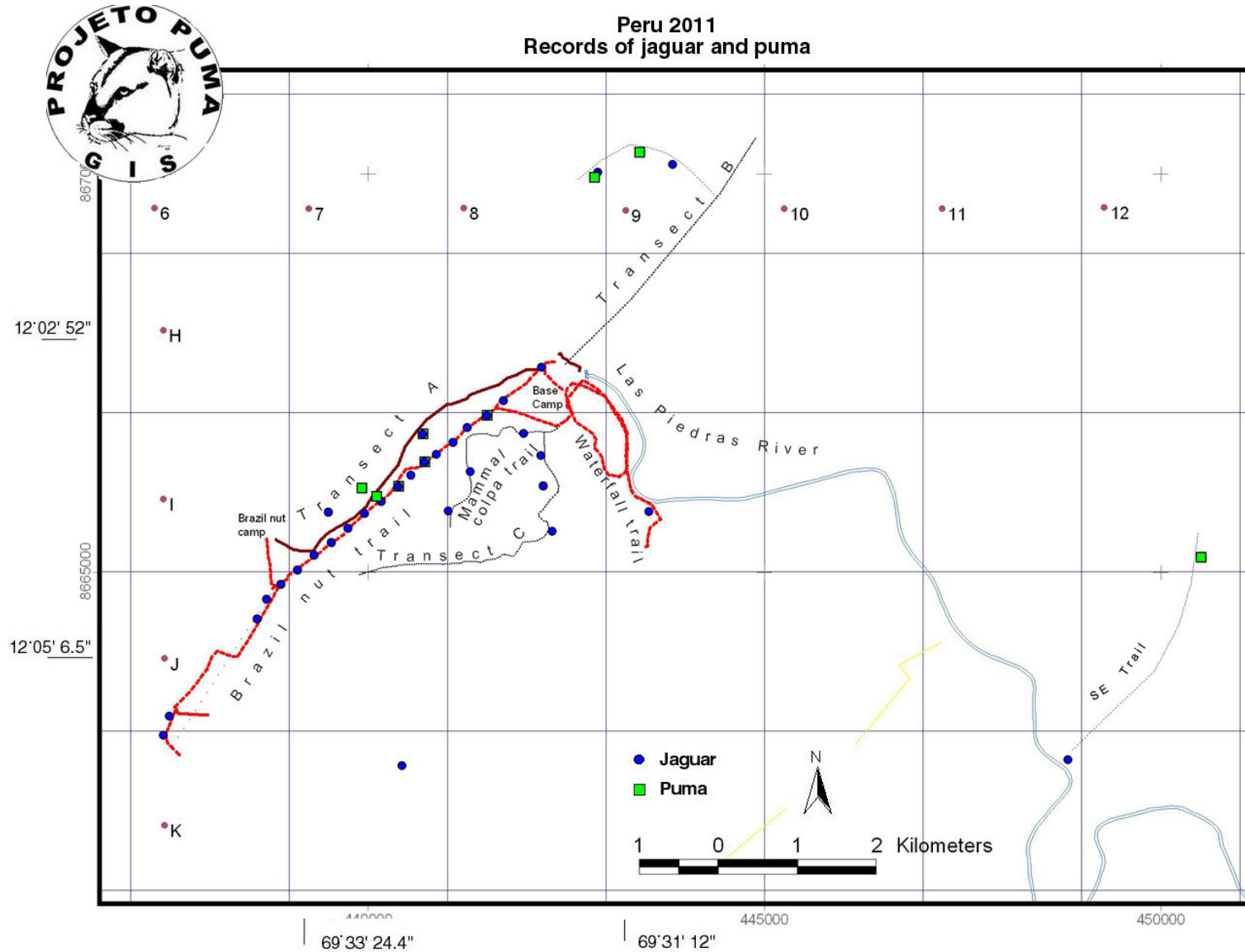
Figure 2.2a. Map of the study area, with details of the trail system, including location of camps, trail system, records of jaguar and puma, and 2 x 2 km cells coded with letter and number. Rectangular UTM system data was zone 19L and Datum SAD69. Coordinates in degrees and minutes are also shown.

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Seven trails were used to diagnose the presence of large cats, with only the 'SE trail' and 'Waterfall trail' being sampled only once and the remaining trails being sampled from two to five times. The longest trail was the 'Brazil Nut trail' ('BNT'), six kilometres in length. In combination, trails covered completely or partially nine 2 x 2 km cells. Each cell was coded by a number and a letter. BNT covered non-flooded lowland forest, whereas locations near the 'Las Piedras River' and 'Transect B' ('Trail B') were subject to seasonal flooding (but not under flood during the period of sampling).

Sampling lasted 18 days, from 10 to 28 June 2011. Thirty-nine locations, mostly track traps (see Appendix 1 on their construction), were sampled and resampled, all containing records in at least one of the surveys, of either pumas or jaguars. Four camera traps were installed on BNT with locations referring to grid locations in Figure 2.2: primary branch (I7, two cameras), leading to Brazil nut concession (J6); and the southern section (K7).

2.3. Results

Track traps

Jaguar and puma together were recorded 76 times, in 40 locations through track traps and opportunistic records, on seven trails distributed over nine cells and covering a polygon of 6,900 ha. The number of sample occasions in each trail varied from one to five times. Signs were found during all track surveys.

Puma and jaguar tracks were recorded in the same track trap on the same day only once and shared six track traps on different days (8%). Puma tracks were recorded 11 times, at nine different locations occupying five cells, whereas jaguar were recorded 69 times distributed over eight cells (Table 2.3).

Table 2.3. History of track trap records of puma (P) and jaguar (J) prints. Data are cell code, track trap or record name and associated trail system (TA = Trail A, TB = Trail B, TC = Trail C, MC = Mammal colpa trail, BNT = Brazil nut trail, SE = Southeast trail, Wat = Waterfall trail); X = no tracks, — = not sampled on the occasion.

Nº of record	Cell code	Track trap code	Occasions – Days in June 2011									
			10	11	13	14	15	16	20	24	27	28
1	I8	TC 550	—	X	X	X	—	—	—	X	J	—
2	I8	TC 850	—	X	J	X	—	—	—	X	X	—
3	I8	TC 1000	—	J	X	J	—	—	—	X	X	—
4	I8	TC 1100	—	J	X	X	—	—	—	X	X	—
5	I8	TC 1500	—	X	X	J	—	—	—	X	X	—
6	I7	TC 2500	—	J	X	X	—	—	—	J	P	—
7	I7	TC 2650	—	X	X	X	—	—	—	X	J	—
8	I7	TC 2725	—	J	X	X	—	—	—	X	X	—
9	I7	TA 1500	—	—	X	X	—	—	—	J	P	—

…continued

			1	2	3	4	5	6	7	8	9	10
10	I7	TA 2000	—	—	X	P	—	—	—	J	P	—
11	I7	TA 2750	—	—	J	X	—	—	—	X	X	—
12	I7	TA 3000	—	—	X	X	—	—	—	J	J	—
13	H8	BN1	—	X	J	—	—	X	—	X	—	X
14	H8	BN3	—	X	J	—	—	X	—	X	—	J
15	I8	BN4	—	P	X	—	—	X	—	J	—	J
16	I8	BN5	—	X	X	—	—	X	—	J	—	J
17	I8	BN6	—	X	X	—	—	X	—	J	—	J
18	I7	BN7	—	X	X	—	—	X	—	X	—	J
19	I7	BN8	—	P	J&P	—	—	X	—	J	—	J
20	I7	BN9	—	X	X	—	—	X	—	J	—	J
21	I7	BN10	—	X	P	—	—	X	—	X	—	J
22	I7	BN11	—	X	J	—	—	J	—	J	—	J
23	I7	BN12	—	X	J	—	—	J	—	X	—	J
24	I7	BN13	—	X	J	—	—	J	—	X	—	J
25	I7	BN14	—	X	J	—	—	J	—	J	—	J
26	I7	BN15	—	X	X	—	—	J	—	J	—	J
27	I7	BN16	—	X	J	—	—	J	—	J	—	J
28	J6	BN17	—	X	J	—	—	J	—	X	—	J
29	J6	BN18	—	X	J	—	—	X	—	X	—	J
30	J6	BN19	—	X	X	—	—	J	—	X	—	J
31	G9	TB1 (Bend)	—	—	—	—	P	—	—	—	X	X
32	G8	TB2 (J1)	—	—	—	—	X	—	—	—	J	X
33	G8	TB3 (P1)	—	—	—	—	X	—	—	—	P	X
34	G9	TB4 (J2)	—	—	—	—	X	—	—	—	J	J
35	I8	MC3	—	X	—	J	—	—	—	—	—	—
36	I8	MC7	—	X	—	J	—	—	—	—	—	—
37	I8	MC9	—	J	—	X	—	—	—	—	—	—
38	K11	SE1	J	—	—	—	—	—	—	—	—	—
39	I12	SE2	P	—	—	—	—	—	—	—	—	—
40	I9	Wat	—	—	—	—	—	—	J	—	—	—

Camera traps

Cameras at cell locations I7, J6 and K7, and at the mammal claylick at I8, yielded jaguar photos. Two different male jaguars (as revealed by the different fur pattern) were photographed, as well as a female jaguar (see chapter 3 below for details and Appendix 2 for photographs).

Additional records of mammals

While surveying, the following species were also recorded, either by sighting (monkeys) or recorded by camera traps or signs. A variety of monkeys including red howler monkey *Alouatta seniculus*, spider monkey *Ateles chamek*, saddle-backed tamarin *Saguinus fuscicollis*; several ungulates including: peccary *Tayassu* spp., tapir *Tapirus terrestris*, brocket deer *Mazama* spp.; several rodents including: brown agouti *Dasyprocta variegata*, paca *Agouti paca*; and armadillos including: *Dasypus* spp. and *Priodontes maximus*.

Logistics and trail system

The trails used covered half of a single jaguar or puma territory, more than was covered during the 2009 survey (Lee at al. 2010). Nevertheless, territory overlap allowed us to sample more than a single individual in the same area, as demonstrated by the photos with different individual jaguars recorded. This is nonetheless not enough to draw conclusions that will be meaningful to communicate to a broader scientific audience. To address this problem, it is recommended that the trail system be further expanded and that trails further away from camp be sampled during more occasions to balance sample effort across the whole study area.

2.4. Discussion

Logistics and trail system

The main purpose of this work was to follow up a previous pilot study (Lee at al. 2010) to address the feasibility of a long-term study of jaguars and pumas in the concession area where the Las Piedras Biodiversity Station is located.

The high encounter rates of jaguars and pumas and that of other species demonstrate that the study area maintains most of its original characteristics, allowing these cats to exist in numbers that closely, if not completely, resemble their natural density and distribution.

The current trail system was an improvement from the pilot study, but it has to be expanded for a more extended study on large cats and on species with large home ranges, such as the white-lipped peccaries.

Biological outcome

Jaguars and pumas seem to be widespread in the study area, as are their prey. There was no reason to go further and use a more rigorous protocol for data analysis on occupancy – the information acquired is quite straightforward and the extent of spatial sampling and limitation of time did not allow for speculation on any additional factor that may be affecting the distribution of the cats.

This year the range overlap at the finest scale between jaguar and pumas differed from the previous year, when there was an overlap of 40% in use of the same track traps, now reduced to 8% overlap. This may reflect an increase in jaguar density and/or a change in puma behaviour (avoidance of trails), but more data in coming years must be acquired before such statements can be made with any certainty. Spatial segregation of jaguars and pumas has been widely reported as a standard interaction pattern between the two species, either indirectly from the interference between prey species (e.g. Mendes Pontes & Chivers 2007), or directly as an interference by jaguars while occupying the best habitats (e.g. Schaller & Crawshaw 1980).

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3. The impact of feline predator activity on spatial patterns of terrestrial mammal claylick use

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3.1. Introduction

Geophagy, the intentional consumption of soil, has been reported for many vertebrate taxa (Mahaney and Krishnamani 2003), especially mammals (Krishnamani and Mahaney 2000, Mills and Milewski 2007, Kikouama et al. 2009). Exposed areas of soil where mammals come to eat dirt on a regular basis have been reported from South America (de Oliveira et al. 2006), Africa (Klaus et al. 1998) and Asia (Clayton and MacDonald 1999). These are known variously as licks, salt licks, mineral licks, claylicks or, in Peru, as colpas. Many reasons have been put forward to explain geophagy (Klaus and Schmid 1998, Mills and Milewski 2007), the most common of which appear to be dietary mineral supplementation, especially sodium (Ayotte et al. 2006), and the fact that soil serves as a buffer against dietary toxins (Brightsmith et al. 2008, Klein et al. 2008).

The western Amazon, and southeastern Peru in particular, has the highest concentration of claylicks in South America (Brightsmith et al. 2009, Lee et al. 2009). The Las Piedras River drainage basin may have one of the highest concentrations of mammal claylicks in Peru's department of Madre de Dios (Brightsmith et al. 2009). Analysis of soil consumed by parrots shows that the consumed soil is high in sodium relative to a parrot's regular diet (Powell et al. 2009). Montenegro (2004) analysed tapir diet in northern Peru and showed that sodium requirements cannot be met through the browse and fruits tapirs eat. She suggests that tapirs in that region therefore depend on sodium from mineral licks. In addition, fruits have a much lower concentration of sodium than browse. These deficits probably also extend to the largely frugivorous peccaries and deer. In general, claylicks are used by herbivores and there are no records for regular geophagy from carnivores.

The jaguar *Panthera onca* is the largest felid in the Americas and is categorised on the IUCN Red List as 'Near Threatened'. The jaguar's distribution has been reduced by more than 50% within the past century (Sanderson et al. 2002), but it still ranges from New Mexico and Arizona in the USA to the north of Argentina, occurring in a variety of environments. Top predators such as the jaguar play an important role in the ecosystems in which they occur by limiting the number of herbivores, thereby reducing the pressure on plants (Terborgh 1988). This top-down regulation by predators maintains diversity. However, due to its habitat preference and generally unobtrusive nature, it is hard to study and was until recently the least studied of the large cats. Little information is available on the jaguar considering its large distribution. This lack of knowledge arises from the difficulty associated with studying the species in its natural environment, its generally low population density and its cryptic habits (Furtado et al. 2008).

The puma *Puma concolor* has a wider distribution and overlaps the range of the jaguar extensively. However, where they overlap, spatial, temporal and dietary partitioning is usually observed (Novack et al. 2005).

In Brazil, white-lipped peccary *Tayassu pecari* closely followed by jaguar preferred Buritizal forests, whereas collared peccary *Tayassu tajacu* followed by puma exploited the other available high-ground forest types (Pontes and Chivers 2007). Fluctuations in food supply regulated the dynamics of the two species of peccaries, which ultimately determined the whereabouts of the large cat predators (Pontes and Chivers 2007). The presence of a claylick can influence spatial patterns of distribution of its users (Holdo et al. 2002, Bravo et al. 2008). As a consequence, human hunters in Peru are known to visit claylicks on their hunting excursions (Montenegro 2004). Whether the same is true of large cats has not been shown to date, although radio-tracking fixes of female jaguars in Brazil suggest a pattern of spatial avoidance among females during the wet season (Cavalcanti and Gese 2009). With predation risk, prey species greatly restrict their use of available habitats and consumption of available food resources, so effects of top predators consequently cascade down to the trophic levels below them (Ale and Whelan 2008).

Objective

Use track traps to compare terrestrial mammal species richness and claylick use during a survey with little cat presence, compared to a survey with high cat presence.

3.2. Methods

The study site was the concession area associated with the Las Piedras Biodiversity Station (Figure 3.2a). The concession area has two large mammal claylicks, one of which is 2.7 km from the study base. Previous observations here have confirmed the presence of the four large ungulate species – tapir, white-lipped peccary, collared peccary and red brocket deer – and various rodents including paca, brown agouti and green acouchy (described in Hammer and Tatum-Hume 2003). The first survey was conducted from 6 November 2009 to 4 December 2009. The second survey was conducted from 13 to 28 June 2011.

In order to record track presence, two arrays of seven parallel access lines of 300 m length and spaced 50 m apart were created (Figure 3.2a). The first array created (COLPA) was located so that the centre of the array was on a known mammal claylick. The second array (CONTROL) was located less than 1 km east on the same stream that runs through the claylick array. Before the location of the second array was chosen, extensive surveys were conducted to ensure no large mammal claylick existed in the array.

Access lines were cut in a grid system and avoided the use of existing trails wherever possible, as cats and other species are known to use these. Track traps were arranged in each trail, spaced 50 m apart. Each array took one day to cut access lines, with the help of six people, plus additional manpower to mark and measure. A second day was generally needed to create the track traps (49 per array). To remake track traps in 2011 a day was needed for each array. Each track trap in each array was then checked every second day, weather allowing (arrays were checked after at least 24 hours with no rain). Tracks were identified to species level when possible.
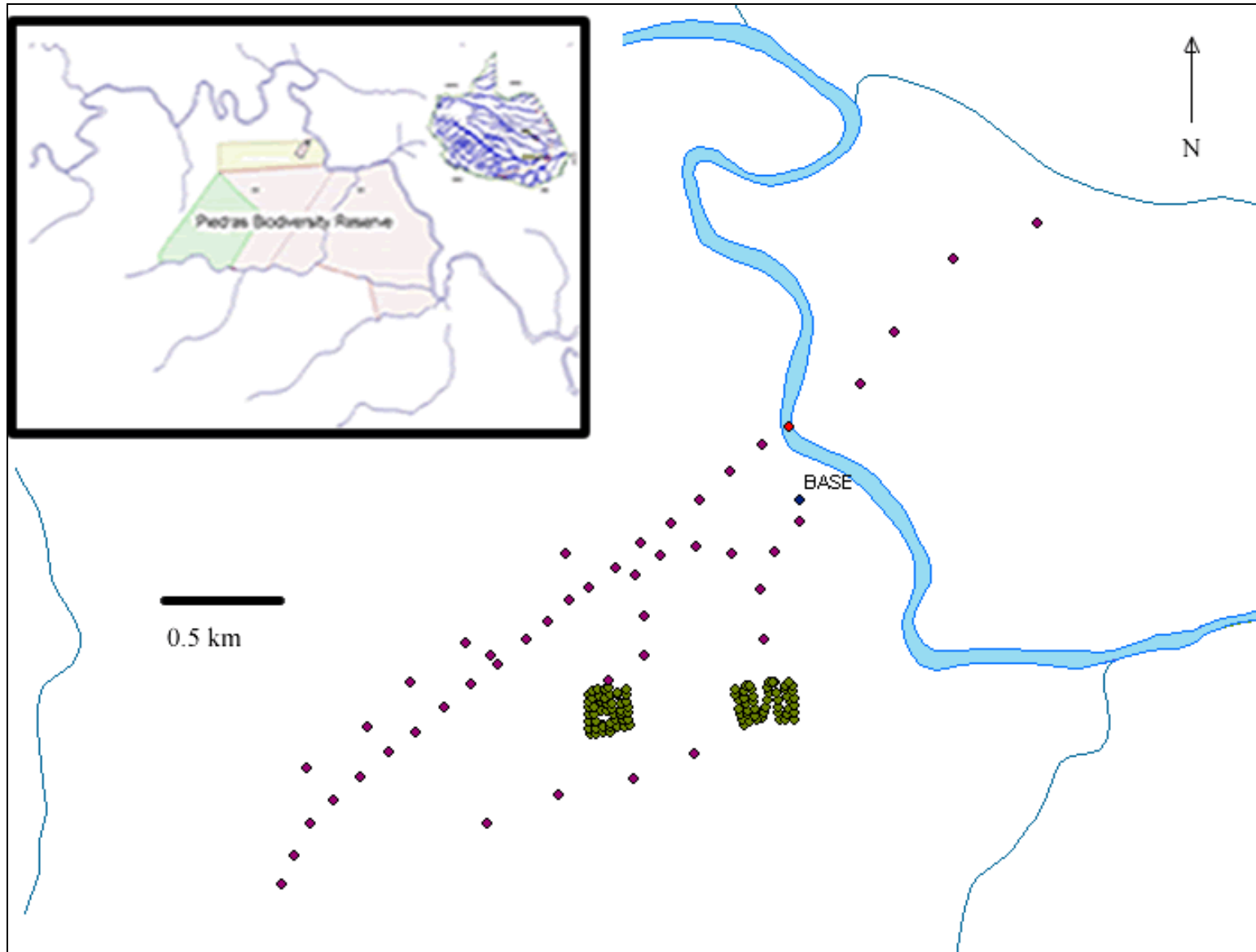
Figure 3.2a. Map of the concession area on the Las Piedras River, indicating the location of the track traps (purple diamonds) and track trap arrays (clusters of green dots). COLPA on the left, CONTROL on the right.

0.5 km

BASE

N

3.3 Results

The 2009 results were based on four days at each array, being the period from 19 November to 3 December, and to compare between surveys four random days were selected for each array for the 2011 survey.

During 2009, 90 tracks of target species that could be identified were recorded, compared to 136 during 2011. A large number of pale-winged trumpeter, tinamou species, tortoise and small rodent tracks were also registered, but will not be considered further here. The mean number of tracks registered per day per array (excluding non-target species) was 19 for the colpa, and 12 for the control during 2009, while it was higher at 29 for the control during 2011, with 21 for the colpa. Species that use the claylick were encountered more than three times as often in the colpa array (Table 3.3a) during 2009, with the most commonly recorded species being white-lipped peccary, which was registered exclusively in the colpa array. Paca, the second highest registration, was also recorded 2.5 times more often in the colpa array. The only claylick user to be recorded in the control array that was not recorded in the colpa array was tapir. Anecdotally, tapir use the mammal claylick very rarely. Ocelot was the most common non-claylick user recorded, and was the species with the highest number of registrations in the control array. Jaguar was recorded on only one occasion, in the colpa array. During 2011, more species were recorded in the control matrix and this included both species that use claylicks and those that do not. The number of cat tracks was substantially higher during 2011, including jaguar, accounting for 44% of all tracks. White-lipped peccary was recorded less frequently between surveys, although red brocket deer was recorded more often.

Table 3.3a. Total number of registrations of tracks in two track trap arrays, for four trap days each. Species are subdivided into those that have been recorded eating soil at claylicks during previous observations (Hammer and Tatum-Hume 2003) and those that have not.

Species	2009			2011		
	Colpa	Control	Total	Colpa	Control	Total
Claylick users						
Brown agouti	2	2	4	4	6	10
Green acouchy	2	1	3	3	7	10
Paca	10	4	14	15	10	25
Tapir	0	1	1	0	1	1
Red brocket deer	1	1	2	3	7	10
Collared peccary	4	4	8	2	9	11
White-lipped peccary	17	0	17	6	3	9
Claylick user subtotal:	36	13	49	33	43	76
Non-claylick users						
Armadillo	3	4	7	3	3	6
Grey brocket deer	6	3	9	0	0	0
Giant anteater	1	1	2	2	0	2
Giant armadillo	0	2	2	1	0	0
Jaguar	1	0	1	4	23	27
Puma	0	0	0	3	4	7
Ocelot	8	5	13	11	15	26
Non-claylick subtotal:	19	15	34	24	45	68
Total:	55	28	83	57	88	144

Table 3.3b. Records of jaguars (called Female, Jerry, Matthias) from camera traps and other auspicious jaguar encounters during the course of the June 2011 survey.

Date	Female	Jerry	Matthias	Unknown
14/06/11			1	1
17/06/11		1		
19/06/11		1	1	
20/06/11				1
21/06/11			2	
22/06/11			1	
23/06/11			1	
24/06/11	1			
Jiri encounters and photos the female and Jerry at the mammal colpa (see photos in Appendix 2 and diary in Appendix 5)				
27/06/11		1	1	
Alan, Thomas and Connie encounter all three jaguars on the mammal colpa trail. The battle of the males is overheard (see diary, Appendix 5)				
29/06/11		2		

During 2009, the highest number of registrations of species that are known to feed at claylicks were recorded at the track traps located in close proximity to the mammal claylick (Figure 3.3). On no occasion was more than one set of tracks of claylick-using species found in the control, despite habitat and trail variables being similar. However, in 2011 there is no clear pattern between records of animals in track traps between matrix locations. Although a higher number of cat signs were recorded in the control matrix, the ranges of the large cats would typically encompass the colpa as well as the control matrix given these locations were less than one kilometre apart.

The very high number of jaguar encounters can be explained by the presence of a female in heat. The jaguar known as Matthias had been recorded previously using the main trail (Brazil Nut trail) through the concession area, and a second male jaguar was also present (Mazzolli 2010). It is presumed that this is not a coalition as observed with lions, but rather an indication that the ecotourism concession is likely to be the boundary between two resident jaguars. The presence of the female jaguar in heat undoubtedly resulted in greater activity of the resident jaguars.
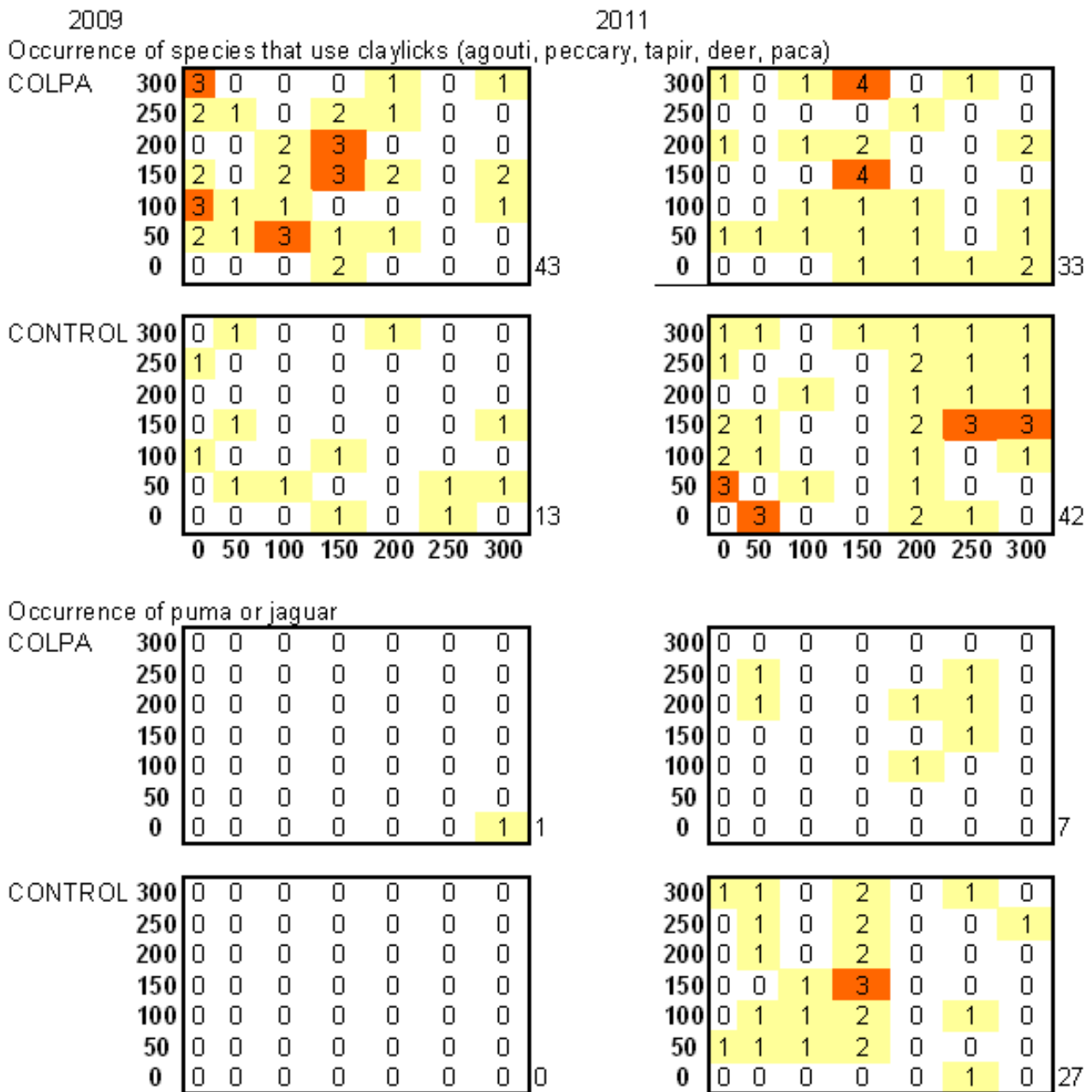
2009 / 2011

Occurrence of species that use claylicks (agouti, peccary, tapir, deer, paca)

COLPA — 2009

	0	50	100	150	200	250	300	
300	3	0	0	0	1	0	1	
250	2	1	0	2	1	0	0	
200	0	0	2	3	0	0	0	
150	2	0	2	3	2	0	2	
100	3	1	1	0	0	0	1	
50	2	1	3	1	1	0	0	
0	0	0	0	2	0	0	0	43

COLPA — 2011

	0	50	100	150	200	250	300	
300	1	0	1	4	0	1	0	
250	0	0	0	0	1	0	0	
200	1	0	1	2	0	0	2	
150	0	0	0	4	0	0	0	
100	0	0	1	1	1	0	1	
50	1	1	1	1	1	0	1	
0	0	0	0	1	1	1	2	33

CONTROL — 2009

	0	50	100	150	200	250	300	
300	0	1	0	0	1	0	0	
250	1	0	0	0	0	0	0	
200	0	0	0	0	0	0	0	
150	0	1	0	0	0	0	1	
100	1	0	0	1	0	0	0	
50	0	1	1	0	0	1	1	
0	0	0	0	1	0	1	0	13
	0	50	100	150	200	250	300	

CONTROL — 2011

	0	50	100	150	200	250	300	
300	1	1	0	1	1	1	1	
250	1	0	0	0	2	1	1	
200	0	0	1	0	1	1	1	
150	2	1	0	0	2	3	3	
100	2	1	0	0	1	0	1	
50	3	0	1	0	1	0	0	
0	0	3	0	0	2	1	0	42
	0	50	100	150	200	250	300	

Occurrence of puma or jaguar

COLPA — 2009

	0	50	100	150	200	250	300	
300	0	0	0	0	0	0	0	
250	0	0	0	0	0	0	0	
200	0	0	0	0	0	0	0	
150	0	0	0	0	0	0	0	
100	0	0	0	0	0	0	0	
50	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	1	1

COLPA — 2011

	0	50	100	150	200	250	300	
300	0	0	0	0	0	0	0	
250	0	1	0	0	0	1	0	
200	0	1	0	0	1	1	0	
150	0	0	0	0	0	1	0	
100	0	0	0	0	1	0	0	
50	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	7

CONTROL — 2009

	0	50	100	150	200	250	300	
300	0	0	0	0	0	0	0	
250	0	0	0	0	0	0	0	
200	0	0	0	0	0	0	0	
150	0	0	0	0	0	0	0	
100	0	0	0	0	0	0	0	
50	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0

CONTROL — 2011

	0	50	100	150	200	250	300	
300	1	1	0	2	0	1	0	
250	0	1	0	2	0	0	1	
200	0	1	0	2	0	0	0	
150	0	0	1	3	0	0	0	
100	0	1	1	2	0	1	0	
50	1	1	1	2	0	0	0	
0	0	0	0	0	0	1	0	27

Figure 3.3. The number of encounters at two track trap arrays, COLPA and CONTROL, for two sampling periods: 2009 and 2011. The top section shows cumulative scores for any species known to use a claylick, while the lower section shows track traps where jaguar or puma presence was recorded. Grid reference, where 150 represents the location of the mammal claylick in the colpa array. Results represent cumulative results from four survey days at each array.

25

3.4. Discussion

Species assemblage

From the 2009 survey the indication was that the presence of a claylick influenced the spatial movements and presence of terrestrial mammal species that use geophagy sites. White-lipped peccary tracks were recorded in the colpa array on almost all days, and were usually present in multiple track traps as herd sizes in the area were large (ca. 50+) and usually spread over a large area. However, during the 2011 survey, peccaries were encountered infrequently along the transects (see chapter 6 below) and were never recorded on any camera traps, either on the mammal claylick or along the trail system. This indicates that the presence of this principal food source of the jaguar was lower in the overall survey area in 2011.

Encounter rates of prints in 2011 were higher due to increased encounter rates of deer and a suite of terrestrial rodents including acouchy, agouti and paca. Although all these species use the claylick, the presence of these species was instead recorded in the control matrix. There was no evidence for a new claylick in the control matrix or anywhere in the vicinity. The overall higher encounter rate may be due to a lower disturbance threshold during the 2011 survey – as the existing trail infrastructure was created in 2009. It may also be that some of the opened lines were then made use of by the local mammal population. Furthermore, the 2009 survey was undertaken during the start of the wet season, while the 2011 survey was undertaken in the middle of the dry season. Both arrays contained a stream, and the presence of water may have been a local driving factor behind the high encounter rate with some terrestrial mammals.

Visual observations of mammal claylicks show that visitors rarely spend much time in the vicinity after eating and disperse quickly into the surrounding forest. In addition, visitation rates with people present in the observation blind appear to be lower than would be expected from the track record from days when no people are present (unpublished data), suggesting that claylick visitors are very wary of predators or unusual conditions around the claylick.

The influence of jaguar activity on claylick use

More jaguar tracks were recorded in the control matrix – with one track trap containing 23 jaguar prints. It may have been that this track was in the location where the paired jaguars were interacting. All three cat species were recorded in the colpa matrix on the camera trap. Cat presence by all counts was substantially higher during 2011 compared to 2009. Conversely, white-lipped peccaries were recorded far less frequently. One would expect the presence of jaguar to be correlated with the presence of their principal prey item. Instead, the reverse was found, most likely as jaguar presence could be explained by a female in heat. It is possible that the increased presence of jaguars and the other cats resulted in displacement of white-lipped peccary, but this remains a matter of speculation without further study, as peccaries are known to move large distances and much of this movement is most likely related to the presence of food.

Ocelot tracks were encountered frequently in both arrays and during both surveys. Ocelots may perhaps be visiting the area due to the large number of rodent species (brown agouti, green acouchy and paca) that visit the claylick. For instance, paca was one of the most common visitors of the region's claylicks (Brightsmith et al. 2009).

While initial speculation was that the mammal claylick was no longer in use by terrestrial mammals, this seeming abandonment of the site was most likely not due to a change in the current soil profiles whereby desirable soils were no longer present as photos from the camera traps showed Spix's guans, squirrels and agoutis eating soil.

Recommendations for future research

This study found several contrasting differences in encounter rate between arrays and surveys. While the decrease in peccary activity in 2011 could tentatively be explained by greater predator presence, there are several confounding variables. Some of these can be easily eliminated from future surveys by conducting surveys during one selected season (the dry season is recommended so that tracks are less likely to be washed out by rain). The original study design was to place track trap arrays at two known claylicks, to find a third claylick for a third claylick array, and then create three control claylicks. The aim was to determine if there were spatial patterns in jaguar hunting patterns, as this flexible predator has been shown to vary activity and hunting patterns temporally based on prey availability. The original design was to have arrays based on a 1 km grid, with track traps 100 m apart. However, it became clear soon after initiating the creation of the first array that this was not feasible. In order to implement such a study design, a dedicated team of experienced machete wielders would need to be sent to the study site at least a week in advance. Expedition members would need a day to check the entire array, possibly broken into an afternoon and morning shift. Team members could identify tracks using a guide (see Appendix 3) together with the track trap guides available at the study site. If in doubt, broad grouping could be used, e.g. the two peccary species could be grouped, as could deer. Such a study would be very useful for elucidating the extent of spatial influence of claylicks not only on ungulates and other claylick users, but also on their predator species.

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4. Trends in encounter rate of large birds, monkeys and terrestrial mammals from a long-term study in southeastern Peru

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4.1. Introduction

Primates and other large-bodied mammals are good indicators of low-level disturbance and hunting, as they play an important role in the livelihood of native peoples as a source of dietary protein (Peres 2000). In Amazonian forests, hunting is one of the most important causes of large vertebrate population decline in areas that otherwise remain undisturbed, whether or not they are formally protected (Peres 2000). Hunting is often the most important threat to wildlife even in forests affected by selective logging (Thiollay 1989), fragmentation (Peres 2001) and understory fires (Barlow and Peres 2006). The largest indirect effect of selective logging along the Las Piedras River is bush meat hunting, which occurs around all logging camps (Schulte-Herbruggen and Rossiter 2003).

The Las Piedras drainage basin contained some of the last commercially viable stands of big-leafed mahogany *Swietenia macrophylla* and cedar *Cedrela odorata* in Peru which were highly sought after on the international markets (Blundell and Gullison 2003). As trees were cleared from the area and local authorities clamped down on illegal activities in around 2005, the impact of loggers diminished and in some cases logging concessions were abandoned (Tatum-Hume 2006). At the time of the study, with increased demand for hardwoods for construction in developing countries, logging of different species is now observed once again.

The survey site was part of a large logging concession between 1994 and 1999, during which time wood was selectively extracted using chainsaws, circular saws and tractors. For three months a year between 1993 and 2000 a Brazil nut collector also worked in the study area. Each logging camp on the Las Piedras River had an average of nine workers, each of whom consumed 313.2 g of bush meat per day (Schulte-Herbruggen and Rossiter 2003). It is estimated that almost 6 t of bush meat was consumed over the extraction period, the equivalent of 799 spider monkeys *Ateles belzebuth* or 198 white-lipped peccaries *Tayassu pecari*, two of the preferred bush meat species (Tatum-Hume 2006).

Since 2002 the study site has been protected from logging and hunting activities as part of an ecotourism concession and here the results of a long-term transect study to determine trends in population recovery in the local mammal and large terrestrial bird community are provided.

Objectives

1. Determine changes in yearly encounter rates from line transects for the diurnal mammal assemblage and indicator bird species at a study site on the Las Piedras River.

2. Determine presence and relative encounter rate changes for inconspicuous mammals through track trap and camera trap monitoring.

4.2 Methods

Surveys were conducted within a conservation concession, ecotourism concession and Brazil nut concession currently administered by Fundacion Corazon del Curandero (The Heart of the Healer Foundation) and previously administered by Tambopata Expeditions (Figure 4.2a below). The study base was the Las Piedras Biodiversity Station (LPBS) located at GPS position S 12º05.663' W 69º52.852'. The concession lies north of the 1.09 million ha Bahuaja-Sonene National Park, east of Manu National Park, and south of Alto-Purus community reserve. Major forest types are floodplain and terra firme (Salmón et al. 2003). The concession is located on the Las Piedras River, a low-gradient white-water river that meanders through a 2 km wide floodplain and is flanked by terraces up to 30 m high. Vegetation is humid subtropical rainforest. Rainfall for the region ranges between 1,600 and 2,400 mm and temperature between 10ºC and 38ºC (Räsänen 1993).
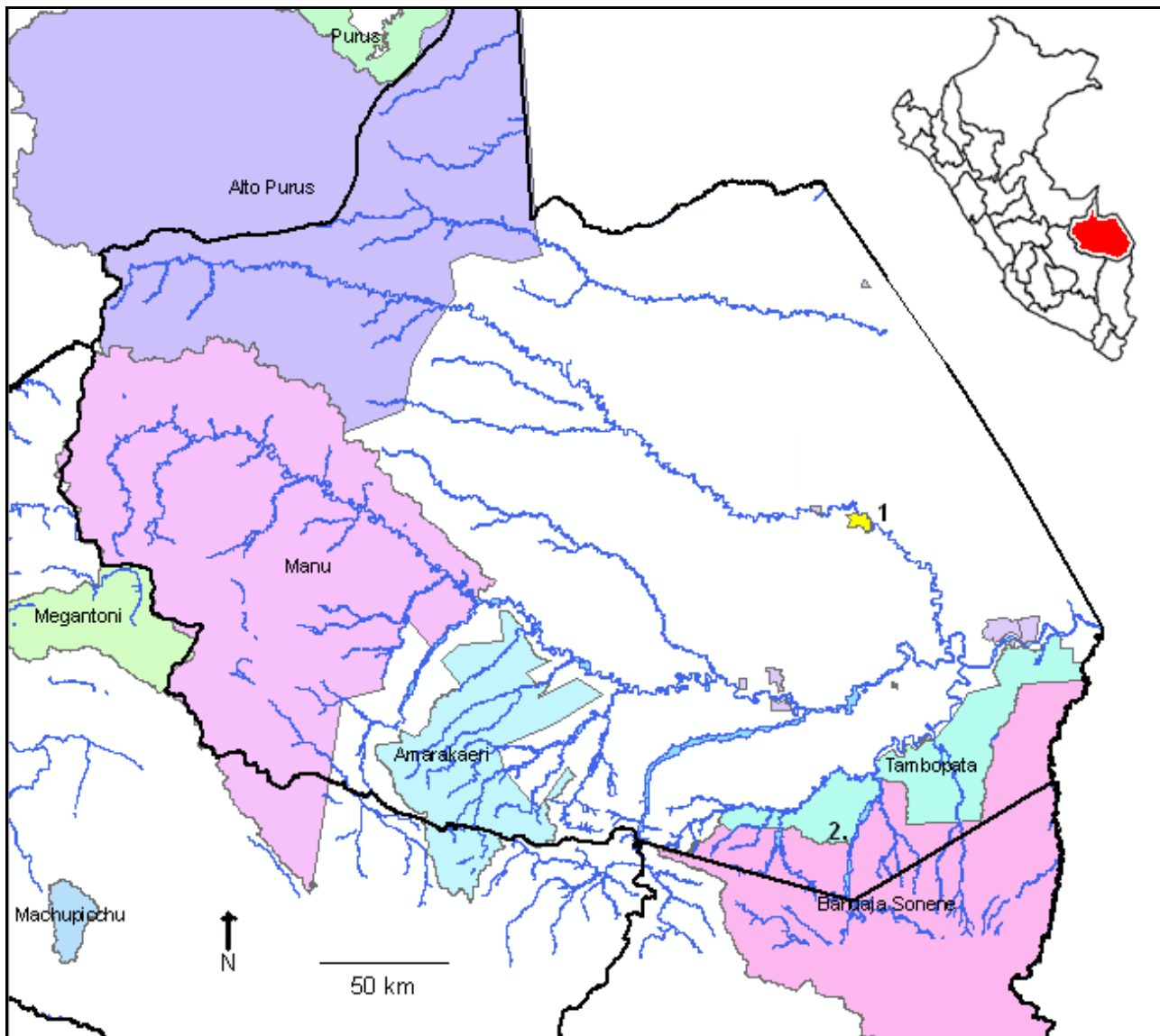
Figure 4.2a. Map of the protected areas of the Madre-de-Dios department, southeastern Peru, showing the location of the Las Piedras tourism concession (yellow area, 1).

Transect survey

Floodplain transects were located in mature forest and terra firme and included no-longer flooded terraces of the Holocene floodplain of these rivers and ancient Pleistocene alluvial terraces (Räsänen 1993). Variable-width line transect surveys were used to estimate the densities of the focal species following the methods of Peres (1999) and Bibby et al. (1998). Morning surveys were conducted from half an hour after daybreak, which varied from 05:30 in December to 06:15 in July, finishing at 11:00 at the latest.

Three transects of 2 km in length were located in floodplain forest types, and three transects of up to 4 km in length were located in terra firme forest. Floodplain forest transects were of shorter length due to the extent of this forest, which generally extended no more than this distance from the Las Piedras River, while areas of terra firme were far more extensive. Total length of transects was 16 km. For each detection event the observers recorded the time, distance along the transect, species, number of individuals, the perpendicular distance from the trail to the individual or centre of the group, group width, cue (how first detected), demography, and weather conditions every 15 minutes. Where possible the perpendicular distance was measured using a Bushnell rangefinder to achieve the greatest accuracy.

Track trap and camera trap survey

Every 500 m along each transect a track trap was placed by clearing an area of vegetation approximately 1 x 1 m, or the width of the track, and softening the soil sufficiently so that it was able to retain the prints of passing terrestrial animals. This was especially important for determining terrestrial mammal presence during this survey, which took place in the dry season, when the ground is hard, usually covered with leaves, and there is little chance of encountering tracks outside of prepared areas. Four Cuddeback and two Bushnell camera traps were placed along trail systems and on mammal claylicks in order to check track identification, species presence, and identification marks of individual species. Time setting was set to one photo each minute in the case of the Cuddeback cameras, and in the case of the rapid-fire Bushnell (which was set to take three photos, one each second, when activated) only one record was chosen of a sighting per minute, with the rest of the photos presumed to be repeats.

4.3. Results

Transect survey

From 2003 to 2011, 829 km of transects were walked at the LPBS. The results of this report concentrate on the 27 transects (103 km of survey) that were conducted during 2011 where 92 groups of eight species of diurnal monkey were encountered. The average encounter rate of 0.89 groups per km is in line with the cumulative average for the previous years of 0.87, although patterns differed among species. Night monkey was also encountered, but is not considered further here as night transects were not conducted during 2011. Four species showed a relative increase in group and individual encounter rate for 2011 compared to the cumulative average for the previous period (Table 4.3a). Of the species which were encountered more frequently, spider monkeys were the only group to be encountered in smaller group sizes. The most commonly encountered troops were saddle-backed tamarins, followed by brown capuchin monkeys. Squirrel monkeys were encountered in the largest mean group sizes.

Table 4.3a. Results of encounter rates with troops of monkeys for 2011 (average groups per km and individuals per km) compared to the cumulative average for 2003 to 2009 ('pre 2011'). Percent change of 2011 compared to previous period are presented. Average group sizes are also presented.

	Groups per km			Individuals per km			Average group size		
	2011	pre 2011	% change	2011	pre 2011	% change	2011	pre 2011	% change
Spider monkey	0.19	0.12	37%	0.50	0.49	2%	2.6	4.2	-62%
Red howler monkey	0.05	0.10	-100%	0.19	0.28	-47%	4.0	3.0	25%
Brown capuchin	0.14	0.21	-50%	0.56	0.94	-68%	4.1	4.7	-15%
White-fronted capuchin	0.11	0.06	45%	0.53	0.44	17%	5.0	8.5	-70%
Saki monkey	0.05	0.04	20%	0.16	0.13	19%	3.2	3.1	3%
Dusky titi monkey	0.06	0.07	-17%	0.12	0.18	-50%	2.0	2.6	-30%
Squirrel monkey	0.02	0.06	-200%	0.46	1.25	-172%	23.5	20.3	14%
Saddle-backed tamarin	0.28	0.23	18%	1.67	1.28	23%	5.9	5.9	0%

Long-term trends in encounter rates of individuals over time at this stage are not straightforward to interpret (Figure 4.3a). Of all the monkey species, only saddle-backed tamarin was recorded at higher numbers in 2011 compared to 2009.

Spider monkey

Red howler monkey

Brown capuchin monkey

White-fronted capuchin monkey

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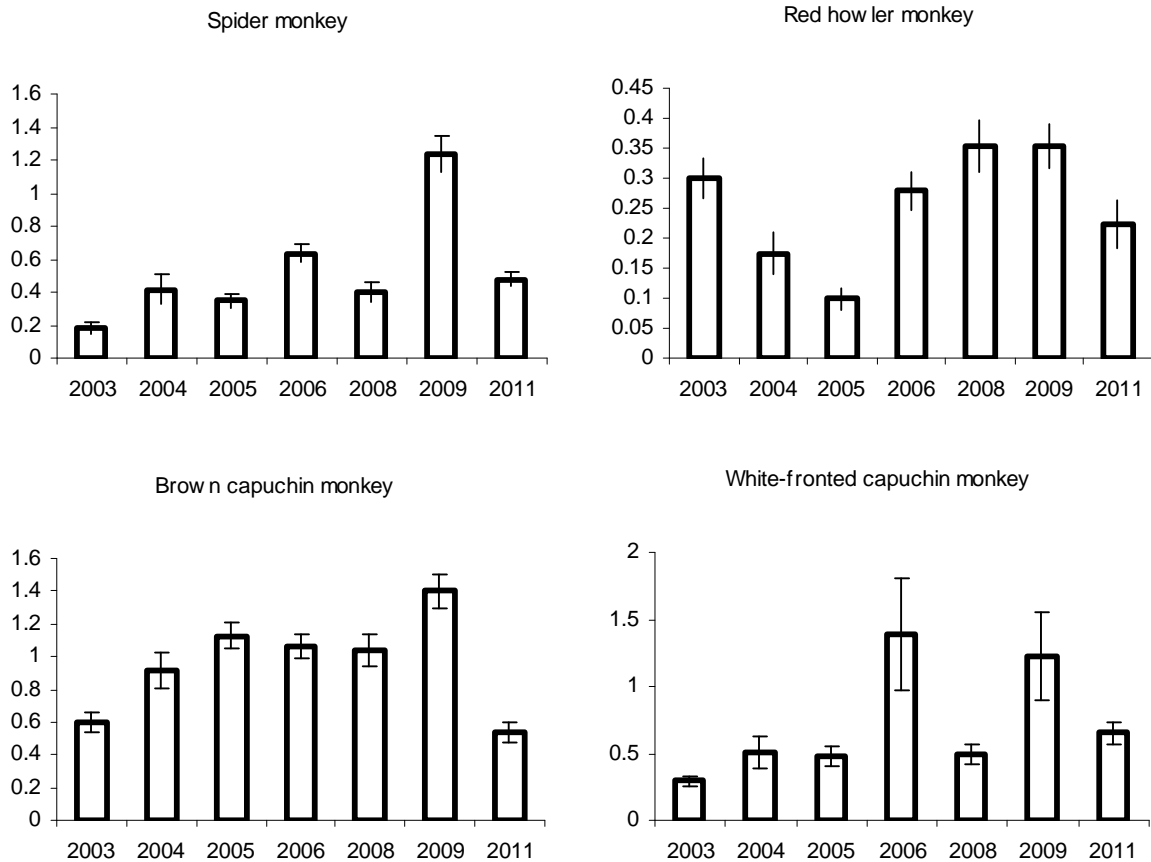
Figure 4.3a (part 1 of 3). Annual mean encounter rate (individuals per kilometre) for the eight species of diurnal monkey, plus terrestrial mammals and large birds encountered at LPBS. Error bars represent standard error.

Saki monkey

Dusky titi monkey

Squirrel monkey

Saddle-backed tamarin

Southern Amazonian red squirrel

Brown agouti
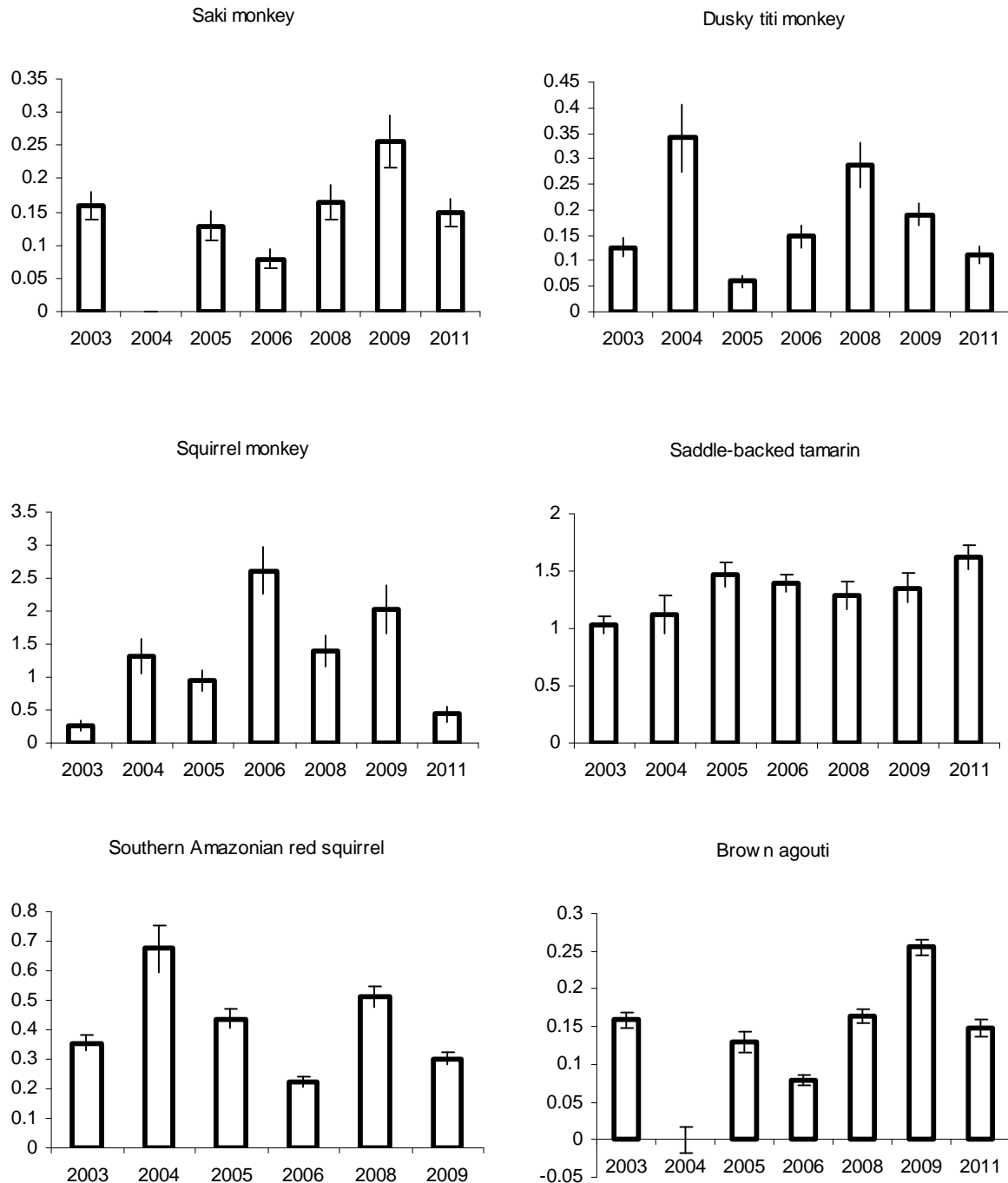
Figure 4.3a (part 2 of 3). Annual mean encounter rate (individuals per kilometre) for the eight species of diurnal monkey, plus terrestrial mammals and large birds encountered at LPBS. Error bars represent standard error.

34
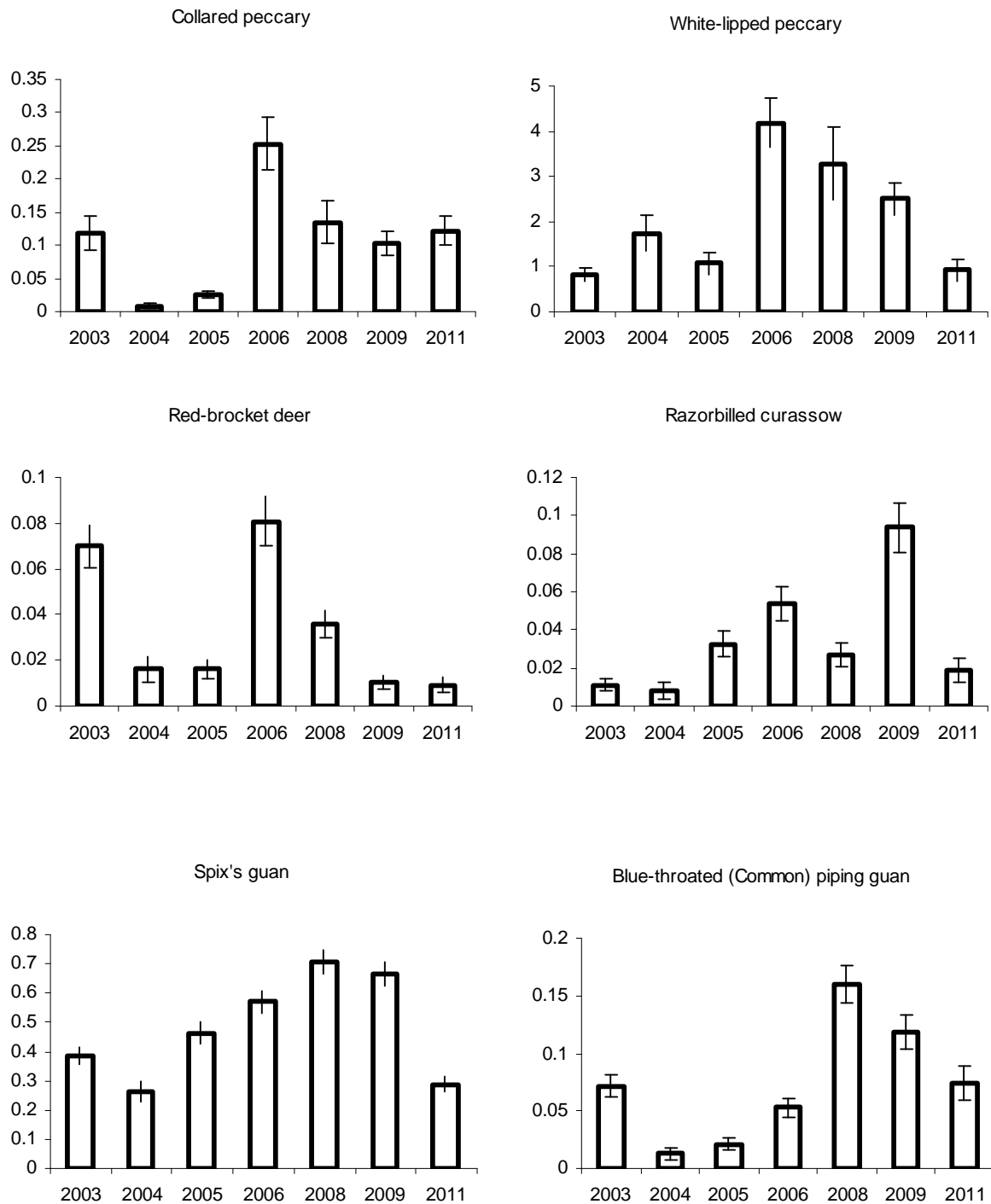
Figure 4.3a (part 3 of 3). Annual mean encounter rate (individuals per kilometre) for the eight species of diurnal monkey, plus terrestrial mammals and large birds encountered at LPBS. Error bars represent standard error.

The impact of weather on target species encounter rates

During the first three weeks of the expedition, the weather could be considered fairly mild, with the occasional thunderstorm. The last week was cold due to the arrival of a friaje (local cold front). Most transects reported some degree of cloud (mean cloud percentage: 56 ± 39%), although three transects conducted in the mild period recorded no cloud. All transects associated with the friaje recorded close to overcast conditions for the entire survey period. Wind was mixed (mean wind strength with 2 being high: 0.15 ± 0.29), with the strongest winds associated with the first days of the friaje.

Eleven surveyed species had more than five encounters during transects, allowing correlation analysis with the mean daily cloud and wind scores. They were brown agouti, green acouchy, brown capuchin monkey, spider monkey, dusky titi monkey, monk saki monkey, red howler monkey, white-fronted capuchin monkey, saddle-backed tamarin, red squirrel and Spix's guan. No species showed a correlation between mean encounter rate (individuals per km) and cloud; and the same applied for the presence of fog in the early morning. Southern Amazonian red squirrel was positively correlated with mean daily wind (r_s = 0.4, p = 0.04, n = 27), while no other species were. Squirrels may seek shelter from windy conditions by coming to the ground, where they are more detectable. However, no other species (e.g. the monkeys) come to the ground, and thus wind is unlikely to influence detectability in the same way across species.

Track trap and camera trap survey

Approximately 20 track traps spread across the four transects were checked at varying intervals ranging from every two to seven days. Data from 2008, 2009 and 2011 are considered here, where the track trap protocol was employed as part of the transect monitoring – i.e. distances surveyed are as outlined above (we do not consider the track trap array or track traps made for the cat sign survey as neither protocol covered multiple years). Relative track encounter rates are shown in Figure 4.3b below. Peccary species were encountered most often in track traps overall across the range of the study, but far less frequently in 2011. Both jaguar and agouti or paca showed increasing trends in detection over the survey period, while puma and ocelot were relatively constant. No armadillo tracks were recorded in 2011 along the transects (although *Dasypus* sp. and the giant armadillo were encountered in the track trap array – see chapter 3). As expected, cats featured prominently in the track traps as cats are known to use trails as part of their territorial route patrols.

Cameras were operational for 60 trap nights during the 2011 survey. It soon became apparent that the sensor of at least one Cuddeback camera was compromised, while the flash of another camera did not fire. Despite this, photographs of 11 target species were acquired, the majority being from the mammal claylick and consisting of Southern Amazonian red squirrels and Spix's guans (see Table 4.3b below, and photos of selected animals in Appendix 2). An unusual series of photos consisted of a troop of red howler monkeys comprising a male, females and juveniles, which fed on the mammal claylick for 32 minutes. Also unusual by their absence, neither peccary species was recorded on the camera traps, nor was the nocturnal rodent paca.
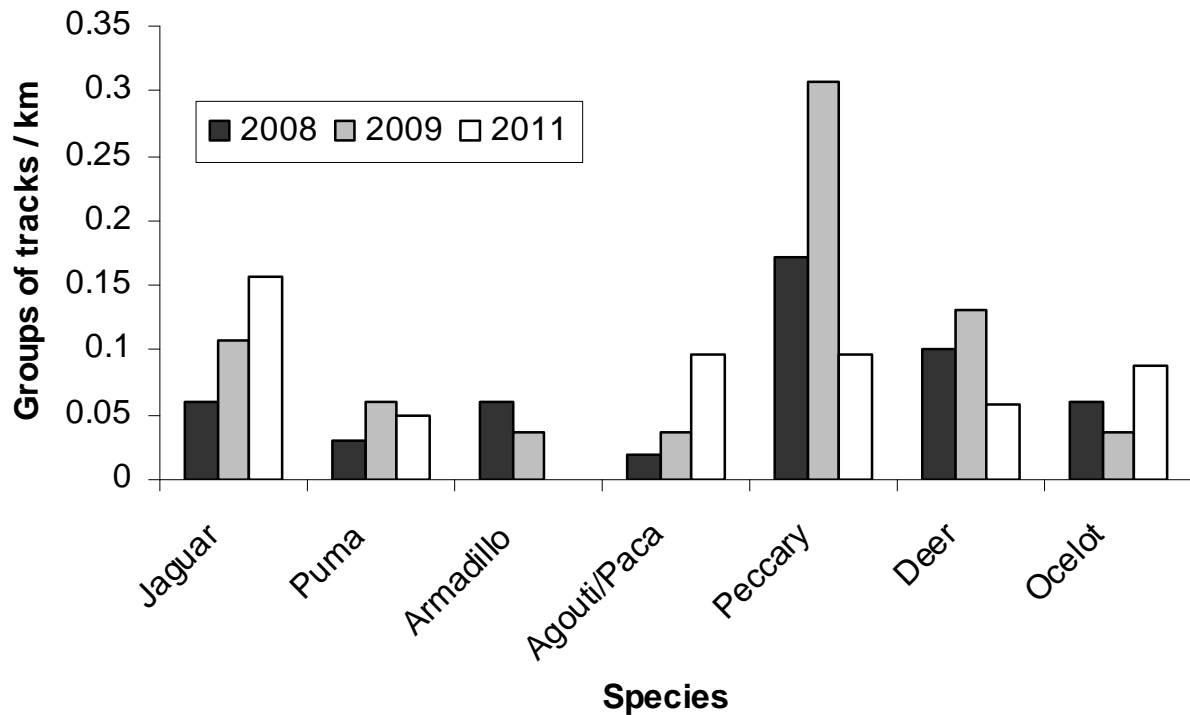
Figure 4.3b. Trends in mammal track encounter rate in track traps along transects from 2008 to 2011. Deer represents red brocket and grey brocket deer. Peccary represents collared and white-lipped peccary.

Table 4.3b. The number of photographs of target mammal and bird species from LPBS from a maximum of six camera traps placed along trails and at a mammal claylick.

Species	Brazil nut trail	Brazil nut concession	Mammal claylick	Trail C	Total
Brown agouti	2	2	8	2	14
Common opossum	1				1
Jaguar	13	1	2		16
Ocelot	5		1	1	7
Pale-winged trumpeter	4				4
Razor-billed curassow			2		2
Red brocket deer		1			1
Red howler monkey			1		1
Red squirrel			18		18
Puma			1		1
Spix's guan			30		30
Tapir	3				3

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More than 10 photos were obtained of four species, which allowed us to construct a basic chart of daily temporal activity (Figure 4.3c). Spix's guans and squirrels were most active on the claylick at 9:00 until 12:00, but otherwise absent. Brown agoutis were active during the day, and their activity pattern shows little overlap with jaguar activity. Jaguar photos were obtained from 17:00 until 10:00 and while there is no clear peak in activity, several 'blank' photos from cameras where the flash did not fire may account for this. Ocelots were only active at night, while the one puma photo obtained was during the day.
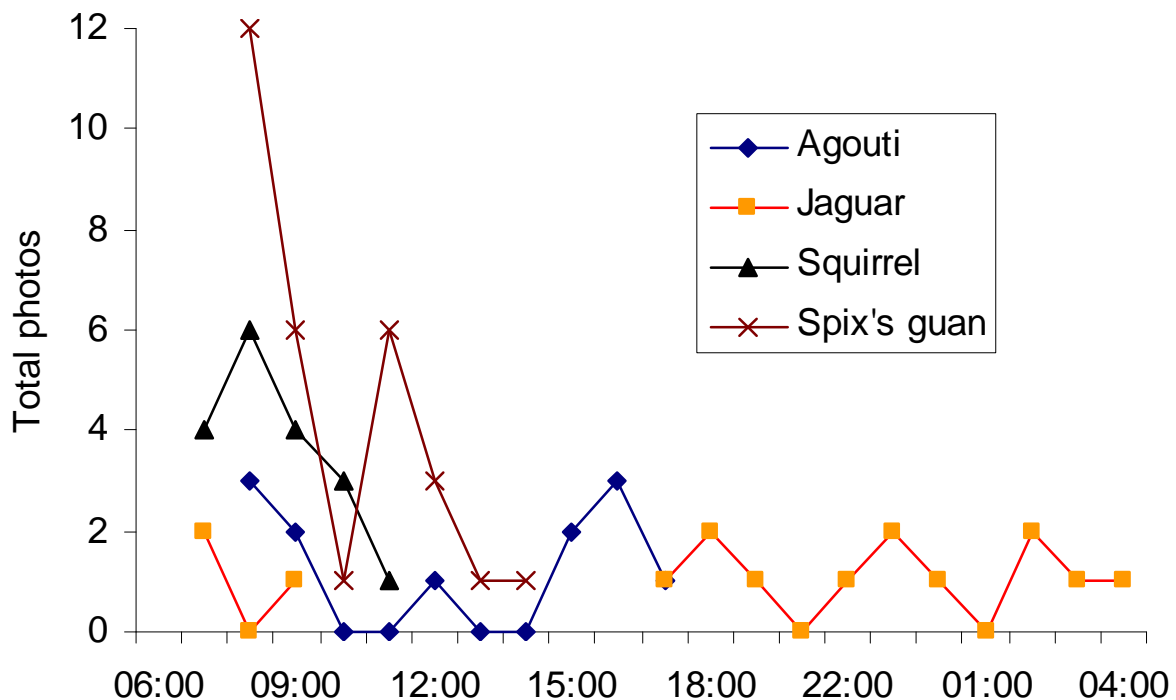
Figure 4.3c. Daily trends in activity represented by total numbers of photos taken at hourly intervals for the four most commonly photographed species: brown agouti (agouti), jaguar, Southern Amazonian red squirrel (squirrel) and Spix's guan.

4.4. Discussion

The primate assemblage

In terms of species number and composition, the primate assemblage at LPBS is similar to those documented at other western Amazonian forest sites, where as many as 14 sympatric primate species can be found. Previous studies carried out in conjunction with Biosphere Expeditions have shown that hunting has not depleted species richness in the area, but may have affected abundance (Hammer and Tatum-Hume 2003). In this discussion, I comment on the trends displayed in 2011 and speculate on their reasons.

Since 2003 there has been a significant increase in spider monkeys. At the end of the last Biosphere Expeditions 2010 report we predicted that spider monkeys had reached saturation levels after several years of recovery, based on our density estimates and those found in areas without hunting. Spider monkeys are very vulnerable to hunting activities. Although we will never know original population levels, the very significant population

increase would suggest that the population was reduced dramatically by hunting activities. Spider monkeys are locally extinct on the lower Tambopata River in areas located closer to the region's largest population centre, Puerto Maldonado, as these areas are more accessible to hunters. Sites where monkeys previously occurred have still not been recolonised since the designation of the area's protected status in 2000. During this survey we found that numbers of individuals were down from 2009 levels, that group encounter rate had increased, but that overall group size was down. This probably represents a change in foraging strategy between dry and wet seasons. The 2009 surveys were undertaken in November, the start of the rainy season when fruit is generally considered abundant. This survey took place in the dry season, when overall fruit availability is low. Some large troops were encountered at individual fruiting trees, but a better foraging strategy would lead to the break-up of the larger social groups into smaller foraging parties to reduce competition on more widely distributed and lower density fruit abundance.

Red howler monkeys, brown capuchins and white-fronted capuchins have all shown a small but not statistically significant increase in abundance since 2003. Many studies have demonstrated that hunting has a negative impact on mammal populations (Peres 1999, Naughton-Treves 2002) and in some cases can cause local or global extinction (Bodmer et al. 1997). Local extinctions did not occur at the study site and populations appear to be recovering for a number of possible reasons. The site is surrounded by relatively undisturbed forest, which may have acted as a source for the dispersal of mammals into the study site. Such source-sink dispersal has been widely accredited for rebuilding mammal populations in areas of hunting. Secondly, hunting only occurred over a relatively short period of time on a non-commercial basis.

Red howler monkeys are the only species of howler monkey in Peru, occupying the middle and upper levels of mature and disturbed rainforest (Emmons 1997). As they are quiet and slow-moving, their inactivity makes them inconspicuous and it is possible that in the case of this species the density sampling assumption of $g(0) = 1$, i.e. all animals on the line of the transect are detected, is not true. In 2009 we expected howler monkey numbers to remain stable or increase slightly in future surveys, subject to natural fluctuations, and this appears to be the case. Howler monkeys are predated on by harpy eagles (Piana 2007). Harpy eagles were regularly seen at the survey site during previous years of the study, and in 2004 a harpy eagle was observed feeding on a howler monkey. However, no harpy eagles were seen in 2011 and harpy eagle populations may have decreased as they nest in large trees which are currently being targeted by woodcutters in the region, and as settlers moving in from the recently constructed Interoceanic Highway to the east shoot the birds to protect livestock (Fernandini pers comm.).

The omnivorous brown capuchin monkeys forage for fruit, eggs, nestlings and small mammals in the middle to lower canopy and take fruit from the upper canopy (Emmons 1997). Density estimates of 12–17 ind./km^2 from 2009 were reasonably high and suggest territory sizes of 25–100 ha. We predicted that the brown capuchin monkey populations were stable and would remain relatively unchanged in future surveys. Brown capuchin monkeys were encountered less frequently during the 2011 survey, but so were squirrel monkeys with which they are frequently associated. As opposed to a population decline, this suggests that both species have changed foraging strategies and were probably foraging more in lowland or floodplain forest, away from the majority of transects located in terra firme forest.

White-fronted capuchin monkeys appear to share a niche in terms of canopy use and diet with brown capuchin monkeys. They are reportedly found in larger groups (7–30 individuals), and with a mean group size of 10, this species was found in the second largest groups after squirrel monkeys in this study. The species is apparently naturally absent from much of its expected range in southeastern Peru. Group encounter rate was generally low, and troop sizes fluctuated greatly. This species may have faced direct persecution from Brazil nut collectors as they are one of the only species capable of cracking open the hard outer nut casing to get to the nuts. This activity was observed and filmed by expedition leader Jiri Haureljuk during this survey. We speculate that range sizes are large, and that there may be some complicated group structure, with troops splitting and joining at various intervals. Although we do not expect density to increase, a lack of any clear trend means more information on this species is needed to understand population trends.

Saki monkeys reportedly favour terra firme forests (Emmons 1997) and were absent from transects through floodplain forest in our study. Saki monkeys are not found south of the Madre de Dios River. Our mean group size (3) is within the given range of 2–8. Saki monkeys are stealthy and quiet and will sit motionless in dense leafy vegetation. Although not registered on transects during 2004, the species has been encountered more frequently from 2005 onwards. There is only one breeding female per troop and she gives birth every two to three years. This may explain why population increase was the lowest of the hunted monkey species after brown capuchin. We expected saki monkeys to become more frequently encountered in future surveys, but no increase was observed in the current survey, suggesting instead that the population has reached a saturation point.

Dusky titi monkeys live in family groups of up to five individuals, usually in the middle or lower levels of dense forest (Emmons 1997). In areas where they are hunted they are stealthy, but usually common (Emmons 1997). Our mean group size (3) is within the given range of 2–5. Our prediction in 2009 was that we did not expect changes in population levels of this species in the future, although the species was encountered less frequently during 2011.

Saddle-backed tamarins are the most commonly seen tamarin in Peru and the most widespread species, occupying mature, disturbed and secondary lowland rainforest (Emmons 1997). Saddle-backed tamarins have territories between 16 and 100 ha (Emmons 1997). Our mean group size (6) is within the given range of 2–12. In other studies, tamarins have been found to be more abundant in areas where populations of large species have been compromised.

Why almost all species were recorded at lower rates compared to 2009 is not straightforward to explain. Both surveys in 2008 and 2009 took place exclusively during the start of the wet season, while prior surveys were conducted throughout the year. The impact of local movements on what may be encountered along the transects is little understood at this stage. At least with parrots it is known that dry season density estimates are higher in floodplain forest compared to terra firme forests (Lee and Marsden 2012). Monkeys, like parrots, must follow seasonal fruit availability, albeit within their territories. It may be the low number of transects placed in floodplain forest that resulted in our inability to account for these small-scale movements.

Alternatively, although we found no signs of hunting – no shotgun shells were found, and we heard no shots and saw no hunters – there has been little ecotourism presence at the study site since 2009. While Jose Duran, co-owner of the LPBS, says no hunting occurred under his watch during the harvest of Brazil nuts, it was clear that the person left to keep an eye on the station built traps in order to catch the nocturnal rodent paca. It is not thought he had a gun in order to pursue other forms of hunting. We could also hear the sounds of chainsaws in the concessions to the east of the ecotourism concession. We found evidence of hunting along a 3 km section of road leading from the settlement of Alegria to Puerto Lucerna (a shotgun shell and feathers of a Spix's guan). Hunting is a regular source of protein for timber extractors and local settlers, as stated earlier. To what degree hunting on the periphery of the protected concessions is having an impact on mammal abundance within the concession is unclear. Species such as most of the monkeys, which have relatively small territories, should not be impacted, but species that range widely, such as white-lipped peccary, may well be declining as they pass through areas where hunters are active.

According to Jose Duran, last year a jaguar was shot by the concession owner downriver. Apparently the jaguar could be heard regularly calling in the evenings from across the river, until the jaguar caught and killed the concession owner's dog. It is not thought the jaguar was sold for profit, as when asked what was done with it, Jose replied it was left to rot in the forest.

Recommendations for future studies and conservation efforts

This study could be further enhanced by a comparison of an undisturbed community of primates, such as those found in the Tambopata National Reserve at the Tambopata Research Centre. Follow-on surveys must increase the number of unique transects sampled, and should in addition conduct afternoon transects where possible in order to increase the sample size. A behavioural study following troops of saki and howler monkeys with special emphasis on movements and vocalisation patterns would help create a co-efficient to improve density estimates by determining a multiplier for g(0) (Bächler and Liechti 2007).

Conclusion

Under the conservation management policies of the company administering the three concessions associated with LPBS, all species that were targets of hunting (including large-bodied birds) by previous extraction concessions have recovered. Although the mahogany and cedar booms are more or less over at the time of writing, the demand for hardwood is soaring. Species such as ironwood *Dipteryx micrantha* and tornillo *Cedrelinga cateniformis* provide in-demand timber used for construction. According to local sources, the demand for these woods is being driven by economic growth in China. The impacts are being felt in the forests to the south of the conservation concession, where during the survey there was substantial timber harvesting activity going on from designated Brazil nut concessions and thus most likely illegal.

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5. Sentinel behaviour at a macaw claylick: Does anyone care?

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5.1. Introduction

Red-and-green macaws *Ara chloropterus* are the second largest of the 17 macaw species after the hyacinth macaw *Anodorhynchus hyacinthinus*, weighing 1,230 g and measuring up to a metre from head to tail (Forshaw 2006). In South America they are found in lowland Amazon rainforest and temperate deciduous forest, with a large range of over eight million square kilometres. They are classified as Least Concern by the IUCN (IUCN 2008), although populations have been reduced in parts of their range due to overharvesting for the pet trade (Juniper and Parr 1998). They are widespread in captivity (the aviculture name is green-winged macaw), as they are socially interactive with both people and other parrots (Abramson et al. 1995). They are regarded as common in lowland Amazon rainforest, with published abundance for the species ranging from 1.8 to 8 individuals per square kilometre (Terborgh et al. 1990, Haugaasen and Peres 2008). Like most of the macaws, red-and-green macaws eat unripe fruits and seeds, which may give them a competitive advantage over other frugivores, such as monkeys (Norconk et al. 1997).

Pairs of macaws defend nest sites viciously (Wilson and Brightsmith 2003), but form social foraging flocks and are seen in large numbers at riverside geophagy sites (from here on referred to as claylicks) where birds descend in large multi-species flocks to consume clay along exposed river banks (Emmons and Stark 1979, Brightsmith 2004). The claylicks are an important source of dietary sodium (Brightsmith et al. 2008, Powell et al. 2009). Red-and-green macaws are one of the most common large species of parrot seen at claylicks across South America (Lee et al. 2009). Patterns of claylick visitation are seasonal, with the largest numbers of macaws visiting claylicks during the wet season in southeastern Peru (Lee 2010), corresponding to the species' breeding season (Brightsmith et al. 2010). Although macaws can be observed around claylicks for much of the day, most feeding on the clay occurs around mid-morning in areas with low anthropogenic disturbance (Lee 2010).

From observations conducted on focal individuals (Lee 2009), it appears that behaviour changes according to three principal criteria: 1. position of the birds – the level in the vegetation or on the soil; 2. the number of birds in the area of the claylick; and 3. the number of birds in close proximity to an individual – notably aggression, which is observed very infrequently overall. It appears that while some behaviour types (such as playing, eating clay and preening) vary depending on the time of day, the state of vigilance of the birds remains relatively unchanged, but may increase with increasing flock size (Lee 2009).

Local tourism guides in southeastern Peru will occasionally point to individual macaws perched in the branches around a claylick not eating clay and claim that these birds are on the lookout for danger, i.e. sentinels. However, whether this is true or whether the bird is merely satiated or waiting a turn on the clay remains to be seen.

Sentinel behaviour can be described as coordinated vigilance. Individuals (usually of a social group) take turns acting as a sentinel for the rest of the group. Sentinel behaviour is characterised by staying in areas with clear views of the surrounding area in a high state of vigilance so as to be alert to danger. Sentinel behaviour is distinct from vigilance, which only includes the presence of vigilant animals watching for predatory activity, and not the coordination of vigilant individuals. Vigilance occurs in many species of birds and mammals (Yasukawa et al. 1992).

Sentinel behaviour has been attributed to a variety of taxa including: dwarf mongoose *Helogale undulata*, vervet monkey *Chlorocebus aethiops*, chacma baboon *Papio ursinus*, rock hyrax *Procavia capensis* and various bird species including babblers *Turdoides* spp. and Florida scrub jay *Aphelocoma coerulescens* (Newbold et al. 2008). Individual sentinels fluctuate but, in general, the overall number of sentinels present at any given time is fairly steady (Bednekoff and Woolfenden 2006). Sentinels usually make sentinel calls so as to inform foragers of their presence (Manser 1999).

Sentinel behaviour studies are normally facilitated by the researcher's ability to identify individuals or distinctive sentinel positions (e.g. Newbold et al. 2008). However, since macaw sexes are alike, no colour-banded flock of macaws exists and there are few physical characteristics that allow instantaneous identification of individual macaws, we explore sentinel behaviour from a group behaviour perspective. If sentinel behaviour occurs at a claylick we would predict the following:

1. There should always be vigilant birds in the vegetation while birds are consuming soil on the claylick.

2. The proportion of birds displaying vigilant behaviour should increase when birds are on the claylick.

3. The proportion of birds calling should increase when birds are on the claylick.

5.2. Methods

Study area

The study area lies in the Madre de Dios department of southeastern Peru, at the boundary between tropical moist and subtropical wet forest. Average elevation is 250 m and average rainfall 3,200 mm (Brightsmith 2004). Surveys were conducted at a riverside claylick of the Las Piedras River.

The expedition base used by Biosphere Expeditions was the Las Piedras Biodiversity Research Station (Piedras) (S 12º06' W 69º52'). The area is protected by an ecotourism, conservation and Brazil nut concession managed by the Heart of the Healer Foundation and boasts high biodiversity (Hammer and Tatum-Hume 2003, and this report). The claylick is a 20 m wide and 15 m high section of fluvial sediments of the western bank of the Las Piedras River.

Behaviour monitoring

Observations were conducted on 15 days, from 9 to 30 June 2011. Observations were carried out from 06:00 until 14:00 in two shifts, which lasted from 06:00 to 10:00 and 10:00 till 14:00 respectively. Using binoculars or a telescope, perch scans were conducted once every five minutes with an observer scanning all visible birds in the vicinity of the claylick, starting high in the vegetation (at a level indicated to be 15 m or higher); then scanning low (all vegetation below 15m); and then the surface of the claylick. The observation point was 106 m from the surface of the claylick. The field of observation visible from the observation point extended to roughly 100 m on either side of the claylick, and to isolated emergent trees less than 100 m behind the claylick.

Twenty-four observers participated in data collection, each one partaking in no more than four observation sessions. Observers ranged in age from 16 to 55 and were mostly from professional backgrounds. No observers considered themselves experts in macaws and only one described himself as a 'birder'. Observers were trained in macaw observation through provision of a training manual, a theory session, and one three-hour practical session. Observers were not aware of the research hypothesis, only of the research protocol. This was done so as not to bias observations towards any particular behaviour, or for any particular location around the claylick. A further aim of using multiple observers was to 'spread' any observer bias which may have occurred with a smaller team of observers.

One observer described what the birds were doing to another person acting as recorder, who scored all the relevant boxes on the data sheet (Appendix 4). Behaviours were listed as snap judgements based on the criteria below, i.e. no more than five seconds were spent observing any one bird, unless a bird was concealed, in which case either a best guess was made or the bird was exempted from the perch scan. This was different from the one-minute focal individual observations of previous Biosphere Expeditions studies (Lee 2009, 2010).

The following behaviour categories were recorded (photos are available in Lee (2009)):

Vigilant. Bird erect and actively looking around; head movement notable, often with head twisted at up to 90 degrees from the body.

Resting. Bird perched and hunched, looking forward, maybe looking slowly around, but not doing any of the activities below.

Panting. Beak open and tongue moving up and down.

Headshake. This is normally a quick movement of the head.

Sleeping. Eyes closed or head tucked beneath wing for long period of time.

Walking. Bird moving along a branch or between branches, or on the claylick.

Calling. Bird obviously vocalising – beak was open and call could be heard.

Begging. Juvenile birds emitting a slow 'erp, erp, erp…' noise, accompanied by fluffed up head feathers.

Kissing. Beak touching, possible prelude to allofeeding.

Regurgitation. A rapid up and down movement with the head to move food from crop to beak. This was sometimes followed by allofeeding.

Playing. Bird or birds engaged in robust movements, involving hanging upside down, squawking, gentle lunging.

Hanging. Bird hanging upside down, almost bat-like, from a branch or liana.

Aggression. Overt aggression only – i.e. bird lunging quickly, with beak open, at another bird.

Submission. Bird retreats from an aggressive bird, either backing away or flying off.

Fighting. Two birds engaged in an elevated aggressive encounter, typically with loud strident calls, lots of wing flapping.

Wingstretch. Bird opens wing(s) in a stretch and does not fly away, a behaviour associated with part of the preening process.

Preening. Bird grooming itself with its beak.

Allopreening. Bird grooming or being groomed by another bird (includes simultaneous allopreening and non-simultaneous allopreening).

Scratch. Bird using its foot to groom.

Branch biting. Bird using its beak to bite the branch it is on.

Eating. Bird is either on the claylick eating or is perched in the vegetation with a lump of clay.

Defecation. Observed bird defecates.

Sex. Two birds approach each other, each lifts a leg and join momentarily from a side-on position balanced on one leg.

Short flight. A bird takes off and perches within the five seconds allocated to an observation.

Flight away. A bird takes off and either clearly leaves the area, or is airborne for more than five seconds (and therefore will presumably perch outside the area of observation).

As previous research has shown that boat traffic can have an impact on bird behaviour (Burger and Gochfeld 2003), all boats passing the claylick were recorded in five-minute intervals. In addition, weather may have an impact on claylick activity (Brightsmith 2004). The amount of cloud cover was scored to the closest 25% (0 = clear sky, 100 = overcast). Wind was recorded as either none (little or no breeze as based on leaves moving in upper canopy), light (leaves obviously moving in upper canopy) or strong (leaves and branches moving, wind can be felt by observer in the subcanopy).

Analysis

The proportion of each behaviour category (from here on referred to as behaviour) was calculated by dividing the total number of observations for that behaviour by the sum total of all behaviours scored, either on the five-minute interval or daily basis (see below). Chi-squared tests were used to check for significant differences between proportions of birds scored as vigilant between hours across the day; the number of birds expected to be vigilant in the presence of boats; and the proportion of birds expected to be vigilant in relation to flock size. Spearman's rank correlations were used to determine correlations between the proportion of all birds displaying a particular behaviour on a daily basis and the mean daily cloud and weather scores. For cloud, the daily score was based on the mean of the percentage of cloud cover, while for wind the mean was taken for the three classes scored as follows: none = 0, light = 1, strong = 2. Results are presented as mean ± standard deviation.

5.3. Results

A total of 1,455 perch scans were conducted over the 15 days of observation, of which macaws were present during 1,164. resulting in 11,326 observation scores of red-and-green macaws (755 ± 280 behaviour scores per day). The mean number of macaws observed per scan was 9.7 ± 10.5. The number of birds in the vicinity of the claylick (based on total behaviours coded and thus an underestimation of the true number of birds in the area) was highest from 09:00 to 11:00 (Figure 5.3a). Birds were scored most often as being vigilant (37%, n = 4,191), resting (14%, n = 1,598) or preening (16%, n = 1,801). In contrast, begging, regurgitation and sex were never scored, and defecation was observed only once. Social bonding interactions scored low (allopreening: 5%, n = 567; kissing: 1%, n = 78; playing: 1%, n = 68), but far outscored antagonistic interactions (aggression: <1%, n = 39; submission: <1%, n = 20; fighting: <1%, n = 6). On a daily level, there was a negative correlation between the proportion of birds scored for social activities (total proportion of all birds kissing, allopreening and playing) and aggression (r_s = -0.6, p = 0.04, n = 15).

Most birds were scored while perched high in the vicinity of the claylick, with fewest recorded on the claylick (high 56%, n = 6,404; low 36%, n = 4,094; clay 7%, n = 824). Of the 1,164 perch scans, at least one bird was perched high on 72% of scans, while birds were only recorded low on 32% and on the clay 7%. By contrast, group sizes appeared to be greatest for low scans (11.1 ± 9 scores per scan), then on the clay (8.7 ± 7.2) and then high (7.6 ± 6.2).

How accurate were the observations?

In order to determine whether the observers scored activities accurately, key behaviours scored for different positions were assessed. For instance, playing, preening and allopreening are almost never observed on the claylick (Lee 2009). Results are presented in Table 5.3a below. Scores for claylick are considered errors for the purpose of this exercise (although it is impossible to say categorically that these observations were incorrect and some errors may also result from scribing). The mean potential error rate was 1%, i.e. not great enough to be statistically significant.
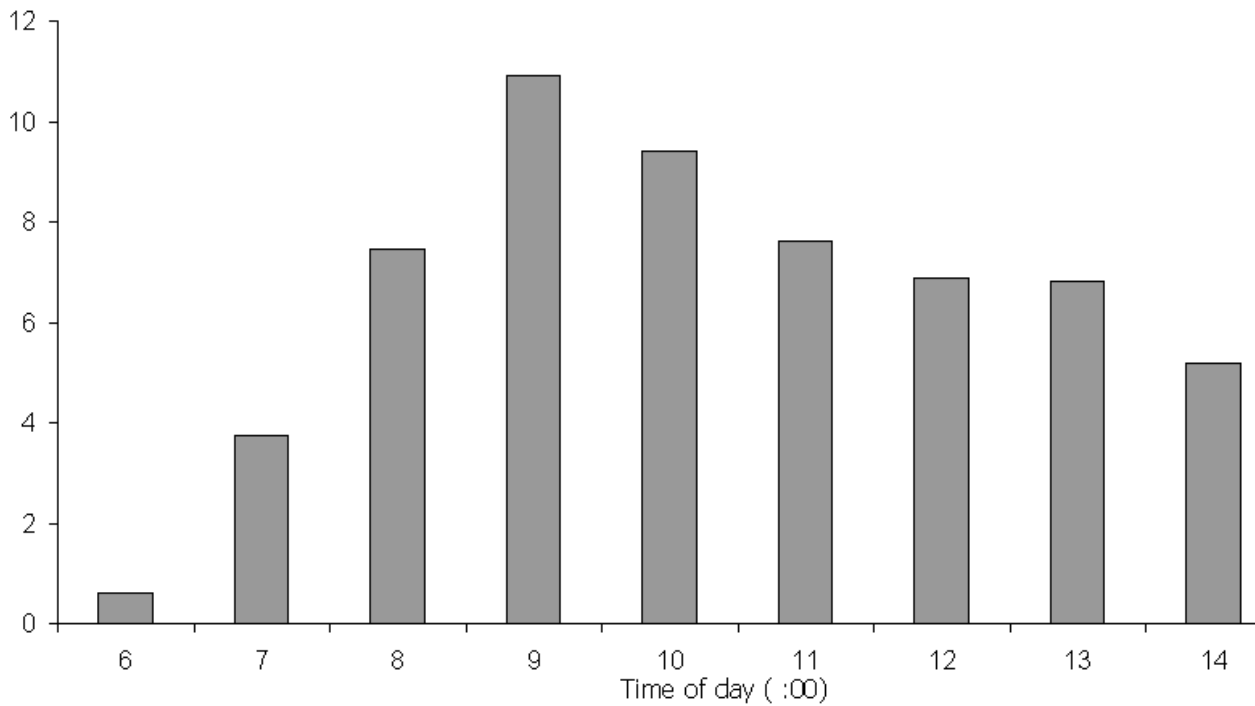
Figure 5.3a. Mean number of macaws in the area of the claylick based on the mean number of total behaviour scores per hour period.

Table 5.3a. Potential observer error matrix based on unlikely behaviours to be observed on the surface of the claylick (. Counts represent number of observations per strata, with error based on Clay/(High+Low).

	Clay	High	Low	Error
Playing	1	29	20	0.02
Resting	13	382	155	0.02
Kissing	1	25	13	0.03
Preening	2	445	177	0.00
Allopreening		188	47	0.00
Branch biting	1	100	51	0.01
Sleeping		60	14	0.00
			Mean error:	0.01

In addition, there may be difficulties scoring between vigilant and resting birds. In order to tell if there was any bias towards either category, the number of birds scored here for resting and vigilant were compared to the proportion of birds scored as vigilant and resting from previous studies undertaken by observers with more experience, but based on focal individual observation studies and for the most part where vigilance was recorded as a state (ranging from sleeping to very vigilant) and then re-categorised as either resting or vigilant (Table 5.3b). The proportions of resting to vigilance are deemed to be acceptable between the studies, given the difference in methods used – where in a one-minute focal observation most macaws were assigned to either a resting or vigilant state.

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Table 5.3b. A comparison of the ratio of vigilant to resting birds, comparing results from this study to previous focal individual studies (from Lee 2009).

	This study N = 11,326	Lee 2009 N = 5,117
Vigilant	37%	47%
Resting	14%	28%
Ratio: Rest/Vigilant	0.4	0.6

Patterns of vigilance

The mean proportion of birds scored as vigilant was 37%. There were no differences in the proportion of birds scored as vigilant for different hour intervals, i.e. from 09:00 to 09:59 compared to 11:00 to 11:59 (X^2 = 0.8, df = 5, p = 0.9). There was a significant difference for the proportion of birds scored as vigilant depending on the location around the claylick, with macaws low in the vegetation scored as vigilant more often (clay = 17%, high = 34%, low = 46%; X^2 = 13.1, df = 2, p = 0.001). The proportion of vigilant birds did not change in relation to the total number of macaws present when grouped into five flock-size categories (Figure 5.3b; X^2 = 0.4, df = 4, p = 0.98).
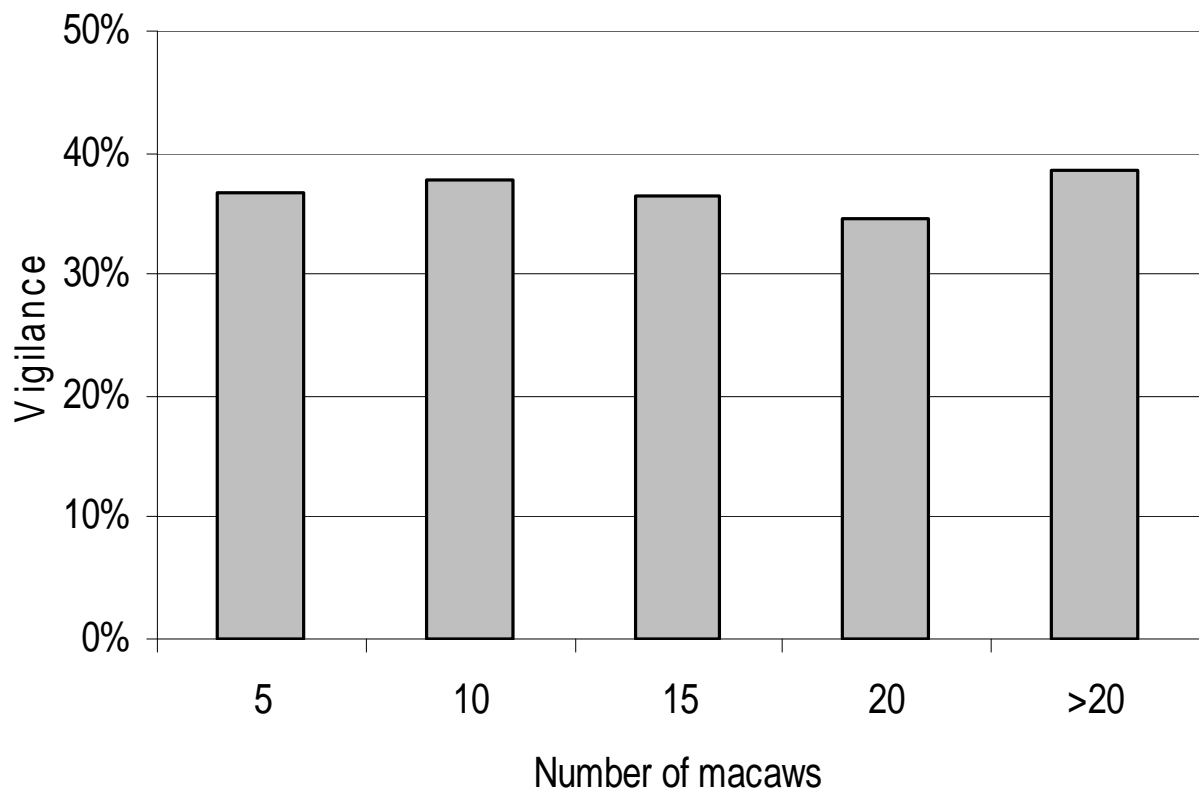
Figure 5.3b. The proportion of macaws scored as vigilant in relation to increasing flock size (based on the total number of all birds scored for any behaviour).

What was the impact of boats on behaviour patterns?

During the 120 hours of observation, 34 boats were observed passing the claylick (0.3 boats per hour, during 33 perch scans, <3% of all observations) of which 15 were driven by outboard motors and 19 by peke-peke (long-shaft) motors. Vigilance as a proportion of all behaviours was superficially lower for intervals where boats were present (no boats: 37%; boats present: 26%), but only as these intervals had a greatly different number of birds recorded as 'flying away' (no boats: 4%; boats present: 40%). When only the proportion of perched birds was considered, vigilance was higher (but not significantly so) for intervals when boats passed the claylick (no boats: 39% (n = 344); boats present: 44% (8); X^2 = 0.4, df = 1, p = 0.5). The number of birds classed as 'resting' was also lower (no boats: 16%; boats present: 9% (1.7); X^2 = 1.1, df = 1, p = 0.3).

The impact of weather on macaw behaviour

Wind was not correlated with any macaw behaviour around the claylick (Table 5.3c). Mean daily cloud cover was negatively correlated with the proportion of birds scored as vigilant (Table 5.3c; r_s = -0.7, p = 0.01, n = 15) – i.e. more cloud, lower vigilance – and positively correlated with the proportion of birds scored as eating (r_s = 0.6, p = 0.02, n = 15).

Table 5.3c. Correlation matrix for the daily proportion of birds scored for a behaviour against average cloud and wind scores for the day, as well as the proportion of birds observed eating. N = 15 days. Significant p values (p < 0.05) are indicated in grey.

	Cloud		Wind		Eating	
Behaviour	r_s	P	r_s	P	r_s	p
Vigilance	-0.651	0.009	0.070	0.804	-0.407	0.132
Resting	0.184	0.511	-0.382	0.160	-0.304	0.271
Panting	-0.302	0.274	0.293	0.290	-0.083	0.769
Walking	-0.086	0.761	0.022	0.939	0.271	0.328
Calling	-0.054	0.849	0.004	0.990	0.561	0.030
Playing	0.177	0.528	0.462	0.083	0.225	0.420
Kissing	0.219	0.433	-0.195	0.485	-0.047	0.868
Aggression	-0.062	0.827	-0.142	0.612	-0.022	0.938
Eating	0.604	0.017	-0.310	0.260		
Preening	0.218	0.435	0.154	0.583	-0.064	0.820
Allopreening	0.082	0.771	-0.208	0.457	-0.104	0.713
Sleeping	0.504	0.055	0.103	0.716	0.100	0.722

Evidence for sentinel behaviour when birds are on the claylick?

Macaws fed on the clay on 11 days (73%), but were recorded on the clay during only 95 perch scans (7% of all perch scans). The mean number of perch scans per day when birds were on the soil was 9 ± 5, i.e. feeding occurred cumulatively per day for around 45 ± 25 minutes. The largest count of birds on the clay was 36, although the mean was 8.5 ± 6.

1. The position of birds around the claylick

On 97% of scans while birds were on the clay, there were birds either high or low in the surrounding vegetation. However, 44% of the time birds were on the clay with no birds high in the vegetation (compared to 7% with no birds low in the vegetation). There were birds both high and low on 25% of occasions when birds were also on the clay.

2. The amount of vigilance while birds are on the claylick

The total proportion of birds that were scored as vigilant was significantly lower on the claylick compared to low or high in the vegetation (clay: 16%; low: 45%; high: 37%; X^2 = 16.5, df = 2, p < 0.01), but this was because 69% of all birds were eating clay (Table 5.3d). Vigilance for birds not eating clay on the lick was 50% of the remainder of activities – but for 30% of scans no birds were recorded as vigilant. There was a significant difference in vigilance for birds in the trees (high and low combined) when birds were on the clay compared to when birds were not on the clay (proportion of birds vigilant when birds on clay: 45 ± 25%; no birds on clay: 38 ± 31%; X^2 = 6.2, df = 1, p = 0.01).

Table 5.3d. Sum of behaviour scores for macaws on the claylick

Eating	553	69.0%
Vigilant	120	15.0%
Resting	23	2.9%
Walking	22	2.7%
Calling	2	0.2%
Aggression	17	2.1%
Submission	5	0.6%
Scratch	5	0.6%
Short flight	25	3.1%
Flight away	27	3.4%
Fight	2	0.2%

3. The relationship between calling birds and feeding on the claylick

Detecting a calling bird was very difficult. Nevertheless, calling was recorded a total 131 times, most of which was recorded for birds perched high (59%), then low (40%), and lowest on the claylick (2%). On a daily basis, there was a positive correlation between the proportion of birds scored as calling and those scored as eating (Table 5.3c; r_s = 0.6, p = 0.03, n = 15).

5.4. Discussion

This observational study provides support that sentinel behaviour (as opposed to just heightened vigilance) occurs with a flock of red-and-green macaws at a riverside claylick in southeastern Peru. The study was able to avoid observer bias by using persons not familiar with the hypotheses in question. Observations were not unduly impacted by boat traffic or weather (although there was more feeding with more cloud, and lower vigilance with more cloud, these influences were negligible when considering that overall vigilance increased with feeding). That there should be support for all three hypotheses for sentinel behaviour at a population level came somewhat as a surprise to the author, although caveats apply to all three, as discussed below.

Firstly, to within an acceptable margin of error, there were always birds in the vegetation when there were birds positioned on the claylick. Contrary to expectations for the sentinel hypothesis, birds did not always perch high when feeding occurred, but rather low – where the proportion of birds that were vigilant was higher. This may be because for the majority of the time birds do perch high, and so may consider the area free of aerial predators in the vicinity once feeding commences. Meanwhile, terrestrial predators such as vine snakes *Xenoxybelis* spp., ocelot *Felis pardalis* and jaguar *Panthera onca* would all be closer to the level of the clay. It may be that the birds are not actively watching for predators, but perhaps while more vigilant to the activity on the claylick they would be better able to detect predators should they be present.

Secondly, the proportion of birds vigilant was higher for birds in the vegetation when birds were on the clay compared to when no birds were on the clay. Again, what degree of this vigilance is related to predator scanning is unclear, and predator scanning may be an added benefit to higher vigilance related to birds simply communicating to each other for social or other reasons. However, that this heightened vigilance occurs would mean that birds which are unable to be vigilant on the claylick would gain a benefit from any alarm calls emanating from birds in the vegetation.

Thirdly, the amount of calling is proportional to the number of birds eating. We assume that these are not alarm calls. Alarm calls generally elicit anti-predatory responses which would result in less feeding and so a negative correlation between calling and feeding. We therefore presume the calls were social contact calls, uttered almost exclusively by birds in the vegetation. Increased call volume from above would give confidence to birds on the clay, which may remain longer and feed with the presumption that should danger arise at least one of the birds present around would utter an alarm. However, we are unable to confidently say that more birds calling results in more birds eating, or whether more birds eating results in more birds calling.

This study took place during the 'low' season of macaw visitation at claylicks and hence we are able to say that birds in the trees were not waiting for space on the claylick as the capacity for the claylick to carry more macaws is much greater than the overall number of macaws observed there. Macaws feed most on the clay during the start of the region's wet season from November to February (Lee 2010). During this time, up to 46 macaws have been observed perched on the surface of the clay compared to our recorded average of eight.

How and why macaws engage in sentinel behaviour needs to be examined in the light of theories for sentinel behaviour. The benefits of sentinels to a group are clear. It has been shown that foragers who can see or hear sentinels are more likely to forage in high-nutrient areas with less consideration for the amount of cover or protection available (Manser 1999, Hollen et al. 2008). They spend less time looking for predators and have been shown to increase their biomass gain in the presence of sentinels (Hollen et al. 2008). For macaws the benefit extends to coming to the ground and spending time in a vulnerable position where vigilance is low due to time invested in biting clay off the soil surface.

While coordination is important to how effectively sentinels keep watch over the groups, there have been no studies which suggest that there is a regimented and concrete order of rotation for sentinels. Foragers are more likely to become sentinels if there are no sentinels present or if they have recently fed. Meerkat sentinels are only active about 55% of the time (Manser 1999). Group members depend upon the awareness of other individuals to the location and physical state of fellow members in order to optimise sentinel effectiveness – and the same scenario appears to apply to macaws at a claylick.

Sentinel behaviour can be categorised as compensatory, i.e. the behaviour of one individual within the group is observed by, and affects the behaviour of, other individuals. Scrub-jays coordinate their behaviour in such a way that individuals who do not need to feed are more often sentinels and those who have consumed fewer calories do not take up the responsibility of protecting the other foragers (Bednekoff and Woolfenden 2006). Sentinel behaviour in prairie dogs is affected by the behaviour of their group mates. If more individuals are present, more sentinels are active, especially when young are present. Individuals who have recently fed are more likely to spend time as sentinels than are those who have yet to forage (Hoogland 1979). Similarly, birds which have fed or obtained clay from the claylick often perch in the vicinity of the claylick thereby assuming sentinel roles.

Kin selection has been proposed as a cause for sentinel behaviour in some species (Maynard Smith 1964). In crow family groups, the parents and older offspring guarded the younger offspring in a rotating system (D'Agostino et al. 1981). Sentinel behaviour has appeared in many species where relatedness is low within the group (Wright et al. 2001), and since macaws are unlikely to be closely related as they live as paired couples or small family groups of parents with no more than three offspring for up to a year only, it is unlikely that kin selection is a motivator for sentinel behaviour around a claylick as most macaws will be only distantly related.

Sentinels placing themselves in danger by presenting alarm calls and positioning themselves in easily observed areas to watch and guard the other foragers has been called reciprocal altruism (Trivers 1971). If a sentinel places itself in harm's way for the sake of other members of the group, this is because it expects that another group member will reciprocate in the future, i.e. a potential sacrifice is later repaid by another altruistic act (Trivers 1971). There are few scenarios whereby macaws could repay altruistic actions away from the claylick. In addition, the costs of being a sentinel are significantly less than the benefits – and in the case of red-and-green macaws there have been very few confirmed fatalities in many years of observation of claylicks, i.e. there is little evidence for altruism at all.

Instead, the current paradigm is that sentinel behaviour arises out of selfish behaviour. For instance, by being alert to the approach of predators, meerkats give themselves better opportunities to see them and escape since they are often posted near the entrance to burrows and therefore require less time to escape. The sentinels utter low sentinel calls to nearby foragers in order to alert them to the sentinel's presence. These calls have not been shown to increase their risk of being caught by predators. After 2,000 hours of observation, not one sentinel was successfully attacked by a predator (Clutton-Brock et al. 1999). Similarly, in a study of dwarf mongoose, 92% of sentinels escaped predation even though they vocalised an alarm to other group mates (Bednekoff 2001). This paradigm fits our observed behaviour of the macaws, whereby it is more likely that macaws will leave the surface of the clay and become sentinels if call rate drops below some threshold and perhaps once they have obtained clay to consume in the trees; i.e. the number of birds on the clay is a fine balance between feeling secure and the need to consume soil.

The behaviour of acting as a sentinel is selfish. Sentinels benefit from being higher in the trees or away from predators even if they might make themselves slightly more obvious to predators by making alarm calls. The coordination of sentinel behaviour is cooperative, but supported within the social system since it is essentially a series of selfish behaviours which work for the benefit of all (Bednekoff 2001, Wright et al. 2001). A sentinel cannot remain on guard forever and must feed, even if this puts it in increased danger of predation. When a bird on the claylick is full and sees that there are fewer sentinels present, it may take up the position in order to increase its survivorship, which thereby helps the rest of the group. It is unlikely that sentinels stick to strict rotation of individuals, so it is more likely that individuals are acting for their own benefit in accordance with the behaviours of the birds around them.

Suggestions for further research

Future studies should include a category 'unknown' for behaviour to better capture the total number of macaws present. In this study the total numbers are undoubtedly under-represented due to the protocol involving excluding macaws for which behaviours could not be determined. Behaviour categories could be consolidated, e.g. wingstretch and scratching could be included in preening. Even in perch scans, it may be possible to use states of vigilance – these can later be recoded into the binomial 'vigilance vs. resting' as undertaken here. Using a standardised recorder to measure noise volume may obtain a better correlate measure of vocalisations as opposed to trying to identify calling birds.

5.5. Acknowledgements

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6. A comparison of human impacts on large and medium mammal presence

Sara Rehman

6.1. Introduction

Mammal abundance can fluctuate naturally due to a variety of factors, such as competition, predation, disease, etc. Usually these effects would eventually come to equilibrium again, with all mammal species reaching appropriate saturation levels. More difficult to determine are ongoing effects of growing human pressure on animal habitat, and the possibilities of recovery in these cases.

This is of special concern within developing countries, where infrastructure change and human population booms occur uncontrolled, without real knowledge of the effects they have on any natural habitat. In Madre de Dios, human population growth occurs in two forms: permanent settlers and tourism. Both causes spread into primary habitat, in the search for new space in which to live, mine, farm or place a tourism lodge and trails.

In terms of permanent settlement by Peruvian migrants looking for land, it is a common practice for people to move to the lowlands from the highlands to begin agriculture or mining ventures. Hunting, as a secondary activity, usually follows this and is common practice for local people with primary economic activities that occur on forest land. It was estimated that in one year alone over 150,000 monkeys were hunted in accessible areas of Madre de Dios (Schulte-Herbüggen and Rossiter 2003). The effectiveness of regeneration after populations have been so heavily impacted is still relatively unknown, with few studies done on this subject (Fimbel 1994, Sorenson and Fedigan, 2000, Fedigan and Jack 2001). Previous Biosphere Expeditions studies at Las Piedras Biodiversity Station suggest that hunting in the area, as a secondary activity to previous timber extraction before 2002, has not depleted species richness, but has reduced numbers (Hammer and Tatum-Hume 2003.) In terms of land recovery after human use, more studies are needed to determine to what extent populations are able to recover on land that has been previously exploited for timber, agriculture and other human activities. It is thought that 20–40 years are needed for land to recover to a state where it can carry natural levels of species richness after human abandonment (Dunn 2004). However, this can only occur where nearby areas remain unaffected, so that source-sink dynamics can come into play, and where forest clearance has occurred at a small-scale level only and with low intensity.

Tourism is considered the lowest impact economic activity of the area, generating income via protecting small stands of forest in order to show tourists the biodiversity that resides within. Indeed, the 'standard model' of ecotourism (Yu et al. 1999) suggests a long-term cycle of self-sustaining income that provides local incentives for conservation, in essence benefitting all. However, as a relatively new practice in Madre de Dios, with certification only appearing recently from Rainforest Alliance, it is uncertain to what extent 'good practices' are genuinely employed in order to reduce impacts on the surrounding forest.

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Objectives

Determine differences in encounter rates for all large and medium mammal species that occur at two sites in Madre de Dios.

Ascertain to what extent the different human activity levels cause any differences observed in mammal presence.

6.2. Methods

Using data collected during this 2011 Biosphere Expeditions study, we are able to compare data collected from a site of permanent trails (Madwi) on the lower Tambopata River and part of Posada Amazonas Lodge (PAL), administered by Rainforest Expeditions. This is the lodge that probably sees the highest numbers of tourists to enter this river (observation – Ministerio de Turismo, Puerto Maldonado).

The Las Piedras Biodiversity Station (LBPS) study site and methods are detailed in chapter 4. PAL, on the other hand, is located at GPS 12°48.102'S, 69°18.022'W, on the land of the Infierno native community, making up a reserve of 3,000 ha, including the lodge and trails. Surrounding land is used by the community for agriculture, Brazil nut collection, hunting and mining. Forest types include terra firme and floodplain. Established in 1994, PAL is located approximately 25 km from Puerto Maldonado, the capital town of the region. Average rainfall is approximately 2,800–3,500 mm with temperatures ranging in the dry season from 12 to 38°C.

Transect

PAL transect monitoring had occurred regularly for the past year, where the same standard protocols are used as at Las Piedras with the Biosphere Expeditions group, following those outlined by Peres (1999). Monitoring of transects usually occurs at PAL as a 3–3½ h activity. To ensure that the data compared have as few variables as possible (other than study site), only data from morning transects at PAL were used. These data were also recorded during this year's dry season. Early morning surveys start between 5:30 and 6:00, running until 9:30 as the latest finishing time; late morning surveys then go on until 12:30. For the purposes of this comparison, data from May and June are used from the PAL data set, making up 112 km of monitoring to compare to the 103 km monitored at Las Piedras by Biosphere Expeditions.

At PAL two main transects are used, both 3.5 km long. One is in floodplain forest and consistently close to the lodge (within 1.2 km), including stretches used by tourist groups. The other main transect at PAL, all on terra firme and ending at a large mammal claylick, encompasses less than 1 km used by tourists, plus another 1 km rarely walked by anyone other than researchers, plus the final kilometre showing signs of use by Brazil nut collectors from January to May. During the time of Brazil nut collection a number of signs indicated low levels of hunting around the claylick. Two smaller tierre-firme transects at PAL were also monitored, together covering 3.5 km, and walked eight times.

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6.3. Results

Primates

Data used in this report are taken from the Madwi data set collected from Posada Amazonas Lodge (PAL) during the months of May and June 2011, following the same standardised transect protocol as used at LPBS and covering 112 km. Thirty-two transect walks led to 87 encounters of the five monkey species recorded, to be compared with the same five species at LPBS. Average encounter rates total 0.65 individuals per kilometre, somewhat lower to that found at LPBS (0.89). However, when we consider only the species that can be found at both sites (monk saki monkey, white-fronted capuchin monkey and black spider monkey are not found at PAL), LPBS gives a 0.55 encounter rate – 10% lower than found at PAL.

Those species most frequently encountered at PAL include red howler monkey and dusky titi monkey, which occur at significantly higher encounter rates when compared to results from LPBS. Although seen much less frequently at PAL, the squirrel monkey also has significantly higher encounter rates than found at LPBS. Brown capuchin monkey and saddle-backed tamarin were the only species to be found less frequently at PAL, with approximately half as many encounters as at LPBS. Group sizes of all five monkey species are larger at PAL, though only very slightly for dusky titi monkey. The largest mean group size was for squirrel monkey, with groups that reach, on average, over double that found at LPBS. It should be noted, however, that squirrel monkey observations at PAL were probably mostly of the same large group, where exact observations of group size proved near impossible due to constant movement and foliage cover; and so minimum number estimations were made.

Table 6.3a. Primate encounter rates for LPBS compared to PAL including average groups per kilometre, average individuals per kilometre and average group sizes.

	Groups per km			Individuals per km			Average group size		
	LPBS	PAL		LPBS	PAL		LPBS	PAL	
Red howler monkey	0.05	0.2	75%	0.19	1.03	82%	4	5.17	23%
Brown capuchin	0.14	0.07	-100%	0.56	0.65	14%	4.1	9.25	56%
Dusky titi monkey	0.06	0.2	70%	0.12	0.43	72%	2	2.17	8%
Squirrel monkey	0.02	0.05	60%	0.46	3	85%	23.5	60	61%
Saddle-backed tamarin	0.28	0.13	-115%	1.67	1.37	-22%	5.9	10.5	44%

Percentage increases in individual occurrence at PAL are consistency higher for all monkey species, except saddle-backed tamarin, which shows a 22% decrease. Although there is a much lower frequency of encounter for saddle-backed tamarin groups in terms of group occurrence, their average group size is almost twice that found at LPBS.

Group sizes of dusky titi monkey and red howler monkey remain similar, though group presence at PAL is much higher for both species. Squirrel monkey shows the strongest increase in group size at PAL, even with minimum number estimations. Group encounter rate is also significantly higher than that found at LPBS. Group sizes of brown capuchin

are twice as high at PAL, though group encounter rates, along with those of saddle-backed tamarin, are the only two to decrease, and quite significantly.

Terrestrial mammals

Of other mammals found at LPBS, green acouchy and grey brocket deer do not exist at PAL. While ocelot and tamandua sightings were made by the Biosphere Expeditions team at LPBS (one ocelot sighting and two tamanduas), these species were not recorded at PAL. Conversely, tayra and coati were recorded once each at PAL, but not at LPBS. This leaves four species with sufficient sightings for a viable comparison: white-lipped peccary, collared peccary, brown agouti and red brocket deer. For these species, average encounter rates are 0.18 at LPBS compared to 0.34 at PAL – almost double.

Table 6.3b. Terrestrial mammal encounters for LPBS compared to PAL, including average groups per kilometre, average individuals per kilometre and average group sizes.

	Groups per km			Individuals per km			Average group size		
	LPBS	PAL		LPBS	PAL		LPBS	PAL	
Collared peccary	0.04	0.05	20%	0.12	0.28	57%	3	5.6	46%
White-lipped peccary	0.02	0.07	71%	0.95	2.37	60%	47.5	33.8	-41%
Brown agouti	0.11	0.19	42%	0.11	0.22	50%	1	1.18	15%
Red brocket deer	0.01	0.03	67%	0.01	0.05	80%	1	1.5	33%

For the peccary species, collared peccary group encounters remain fairly constant between both sites; though with slightly larger group sizes found at PAL. White-lipped peccary encounters at this site show a significant increase despite the much smaller average group size. Brown agouti and red brocket deer show an increase in encounter rate at PAL, though keep similar average group sizes.
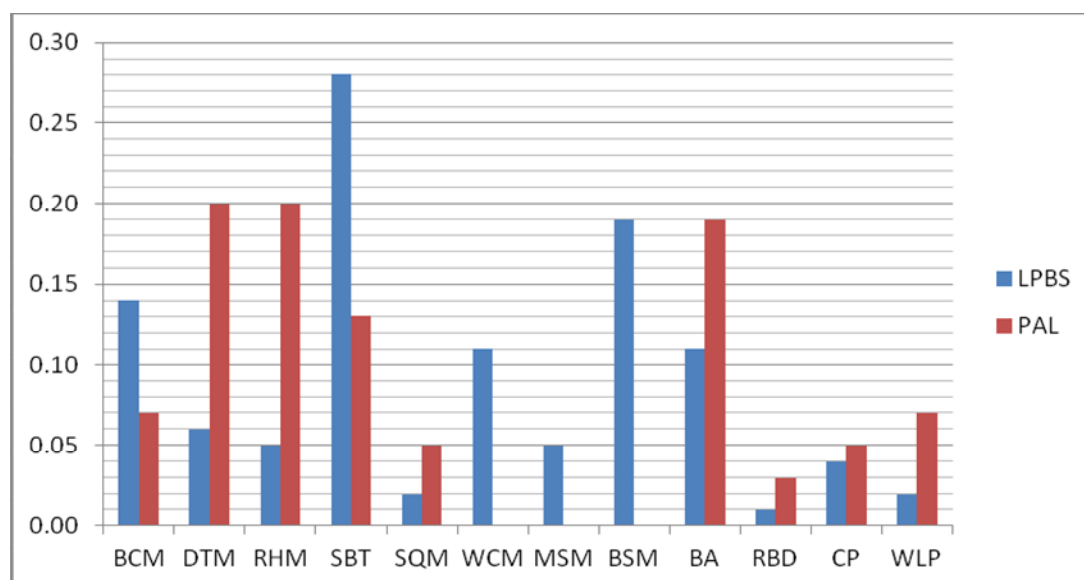
Figure 6.3a. Average groups per kilometre results for LPBS and PAL during the dry season. Group encounter rates as shown in Tables 6.3a and 6.3b. BCM = brown capuchin, DTM = dusky titi, RHM = red howler, SBT = saddle-backed tamarin, SQM = squirrel monkey, WCM = white-fronted capuchin, MSM = monk saki, BSM = black spider monkey, BA = brown agouti, RBD = red brocket deer, CP = collared peccary, WLP = white-lipped peccary.

Previous data

In order to get a fuller idea of abundance differences between sites, wet season data from the 2009 Biosphere Expeditions project (Lee at al. 2010) are also compared. That expedition took place at LPBS during November and early December, covering 84 km of transects. The data for the corresponding period from PAL also cover 84 km.

Dusky titi monkeys are the mammals most frequently encountered during the wet season at PAL, while brown capuchin monkeys, saddle-backed tamarins and black spider monkeys take the lead at LPBS, all with higher encounter rates than at PAL. In general, monkey species show higher encounter rates than terrestrial mammals at both sites; LPBS gives a 0.99 average encounter rate for monkey species (0.71 for those found at both sites), compared to 0.18 for terrestrial mammals. PAL gives a 0.61 encounter rate for primate species and 0.15 for terrestrial mammals. However, dusky titi monkeys still give one of the lower encounter rates at LPBS, while at PAL this is held by saddle-backed tamarins. Species with the lowest encounter rates at PAL were saddle-backed tamarins, white-lipped peccaries and red brocket deer. Species with the lowest encounter rates at LPBS were red brocket deer, collared peccary and monk saki monkey. Overall encounter rates at PAL are 0.76, and at LPBS are 1.17 including three monkey species not found at PAL, or 0.88 including only species found at both sites.

Table 6.3c. Terrestrial mammal encounter rates for LPBS Biosphere Expeditions 2009 (November expedition, Lee at al. 2010) compared with PAL (November and December data of 2010), including average groups per kilometre, average individuals per kilometre and average group sizes.

|	Groups per km			Individuals per km			Average group size		
	LPBS	PAL		LPBS	PAL		LPBS	PAL	
Brown capuchin monkey	0.23	0.15	-53%	1.4	0.91	-54%	6.2	5.9	-5%
Dusky titi mokey	0.08	0.18	56%	0.22	0.45	51%	2.6	2.5	-4%
Red howler monkey	0.10	0.13	23%	0.33	0.58	43%	3.5	4.4	20%
Saddle-backed tamarin	0.20	0.02	-900%	1.4	0.13	-977%	6.9	5.5	-25%
Squirrel monkey	0.10	0.12	17%	1.85	2.92	37%	19.4	24.5	21%
White-fronted capuchin monkey	0.05			0.8			16.8		
Monk saki monkey	0.05			0.25			5.25		
Black spider monkey	0.19			1.33			7		
Brown agouti	0.06	0.08	25%	0.06	0.09	33%	1	1.1	9%
Red brocket deer	0.01	0.01	0%	0.01	0.01	0%	1	1	0%
Collared peccary	0.04	0.04	0%	0.13	0.17	24%	3.7	4.7	21%
White-lipped peccary	0.07	0.02	-250%	3.59	0.43	-735%	50.2	18	-179%
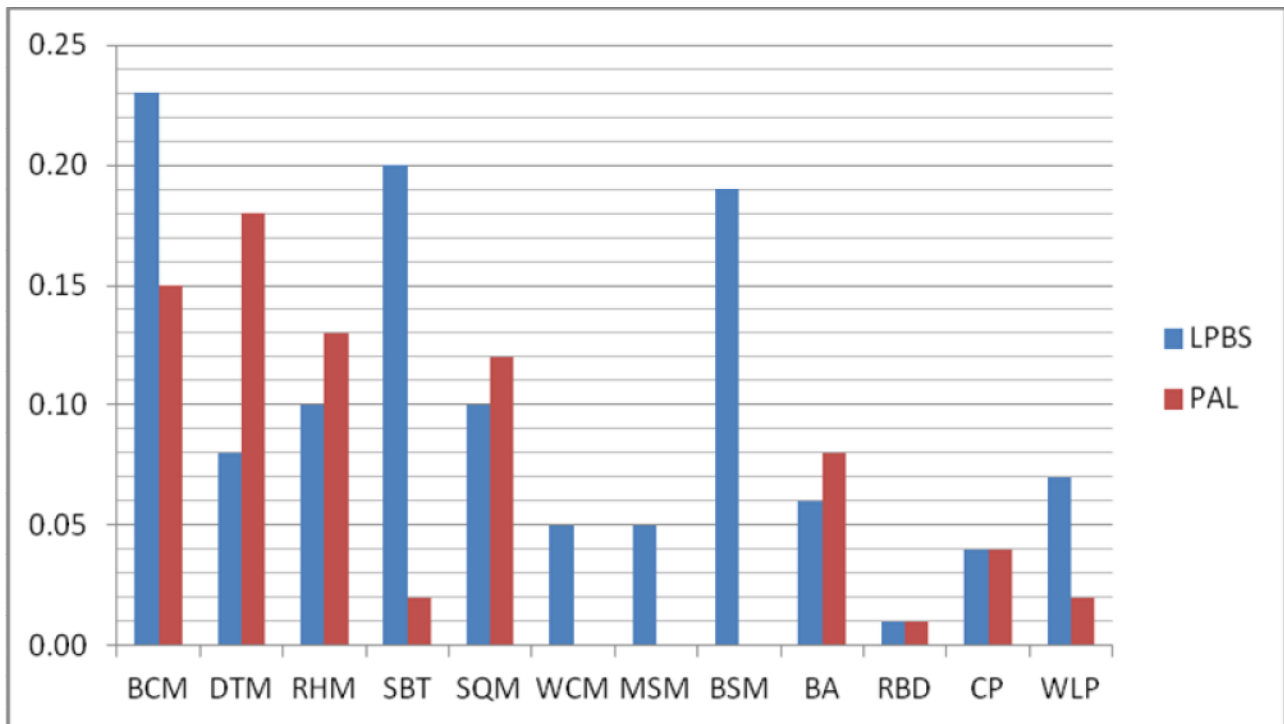
Figure 6.3b. Average groups per kilometre results for LPBS and PAL during the wet season. Group encounter rates as shown in Table 6.3c. BCM = brown capuchin, DTM = dusky titi, RHM = red howler, SBT = saddle-backed tamarin, SQM = squirrel monkey, WCM = white-fronted capuchin, MSM = monk saki, BSM = black spider monkey, BA = brown agouti, RBD = red brocket deer, CP = collared peccary, WLP = white-lipped peccary.

During the wet season, squirrel monkey, red brocket deer and collared peccary encounter rates are similar between both sites. The average group size for all mammals apart from white-lipped peccary also remains similar between sites. Higher encounter rates at PAL occur for dusky titi monkey, red howler monkey and brown agouti; while LPBS gives a higher encounter rate for brown capuchin monkey, saddle-backed tamarin and white-lipped peccary. The largest differences between sites are encounter rates of white-lipped peccary (250% difference) and saddle-backed tamarin, with the largest difference of 900% more encounters at LPBS (see Table 6.3c).

Overall results of individuals per kilometre show varied differences, with only red brocket deer and collared peccary showing similar numbers, encounter rates and group size. PAL gives a higher overall presence of dusky titi monkey, red howler monkey, squirrel monkey and brown agouti, mostly due to higher encounter rates, though the difference is less pronounced for squirrel monkey, where the slightly higher group number boosts more significantly the higher overall individual numbers. LPBS favours brown capuchin monkey, saddle-backed tamarin and white-lipped peccary. Differences in individual presence are also much more pronounced, due to greater differences in encounter rate, and in the case of white-lipped peccary also an extremely large difference in average group size.
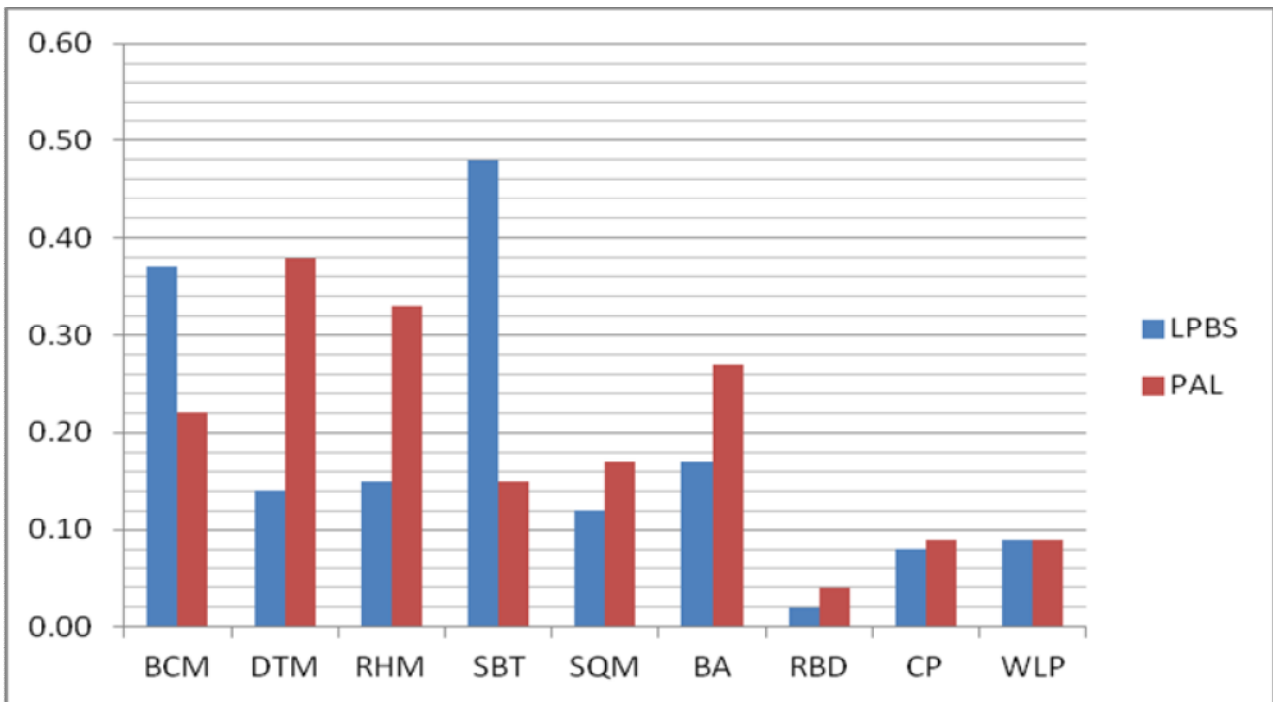
Figure 6.3c. Overall average encounter rates between sites using LPBS / Biosphere Expedition data from 2009 and 2011, and PAL / Madwi data from 2010 and 2011, as shown in Tables 6.3a–c. BCM = brown capuchin, DTM = dusky titi, RHM = red howler, SBT = saddle-backed tamarin, SQM = squirrel monkey, BA = brown agouti, RBD = red brocket deer, CP = collared peccary, WLP = white-lipped peccary.
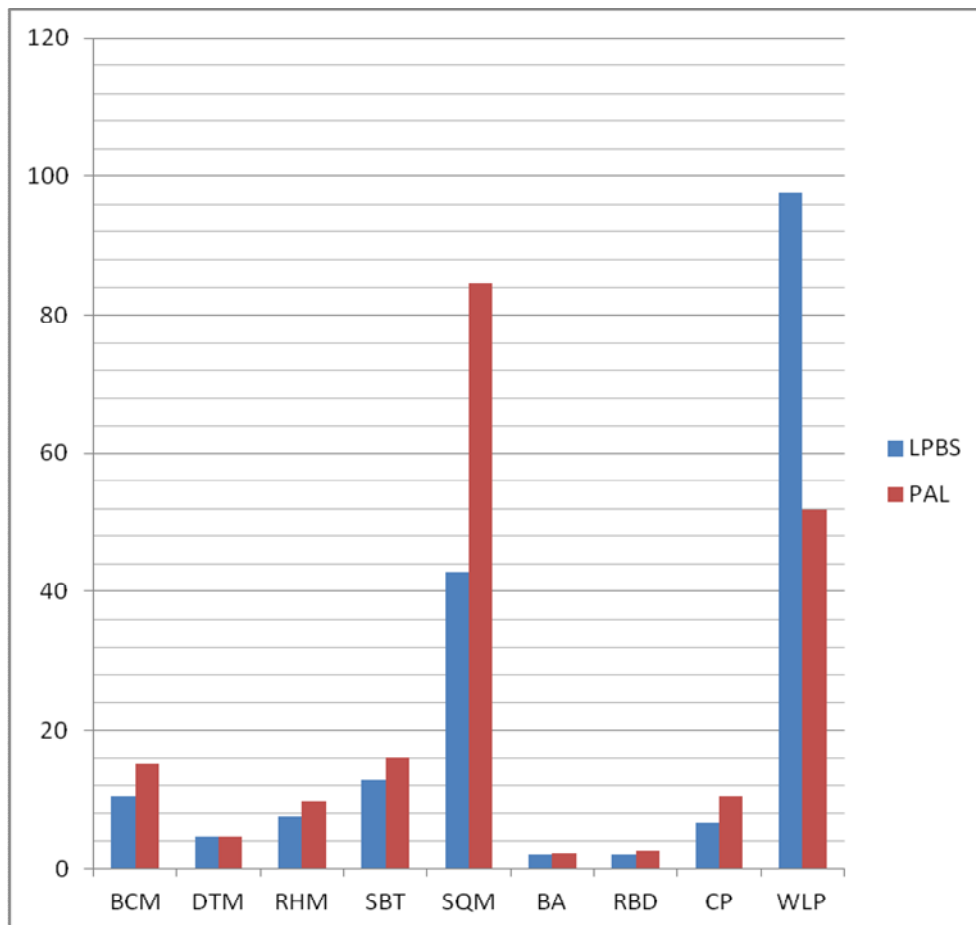
Figure 6.3d. Overall average group size at sites using LPBS / Biosphere Expedition data from 2009 and 2011, and PAL / Madwi data from 2010 and 2011, as shown in Tables 6.3a–c. Species codes as per Figure 6.3c above.

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Overall, we see that different primate species show site-specific preferences. While dusky titi, red howler and squirrel monkey dominate at PAL, saddle-backed tamarin and brown capuchin monkey are more frequently seen at LPBS. Primate species show the greatest differences in encounter frequency between sites, while terrestrial mammals appear to be seen with similar frequency at both sites overall, excluding brown agouti, which shows higher frequecies at PAL.

Group sizes show further differences between sites. Dusky titi and red howler monkeys are the only primate species to be found in similar group sizes at both sites. Brown capuchin and saddle-backed tamarin show small increases in group size at PAL, while squirrel monkey shows a huge group size increase at this site. For terrestrial mammals, group size remains relatively similar, with collared peccary showing a small increase at PAL, though white-lipped peccary group size increases greatly at LPBS.

6.4. Discussion

As mentioned in chapter 4, black spider monkeys are locally extinct on the Lower Tambopata River / PAL, due to overhunting and the high levels of land conversion to agriculture in close proximity to Puerto Maldonado. Monk saki monkey has never existed on the Tambopata River, being outside of its range in Madre de Dios. White-fronted capuchin monkey is also not found there, though it is unclear why, as the habitat appears suitable and the closely related brown capuchin monkey, with similar dietary and spatial requirements, thrives in the area.

The above species are therefore not discussed further in this comparison, though it is noted that while black spider monkey and monk saki monkey encounters remain similar during both seasons, rates of encounter for white-fronted capuchin monkey surge during the dry season. This is probably due to foraging strategy, as mentioned in chapter 4 – food is more scarce during the dry season and monkey species tend to spread out further when foraging, therefore increasing the likelihood that they are observed during transects.

Because data collected at PAL make up the first year of a long-term study, we are still unable to see real trends in populations in the same way as can be demonstrated by data collected at LPBS. Therefore we are unable to detect any population stabilisation that may have occurred. After 17 years of 'private reserve' protection through tourism and very little impact through hunting and other forms of destructive human influence, the assumption is that species richness and abundance at PAL have already reached saturation and are now acclimatising to human presence.

The purpose of this comparison is then to contrast the different ways a previously impacted forest may regenerate while still experiencing lower-impact human presence.

Both sites have a history of hunting. It is probable that hunting pressure was stronger at PAL, due to sustenance hunting by the local community on whose land it is situated, before they became involved in the lodge project with Rainforest Expeditions. Since this project was established in 1994, the native community has agreed not to use this reserved area for hunting activity, so that animals are present to show to the high volumes of tourists that visit this lodge.

LPBS was established in 2002, bringing protection to an area that had previously held loggers who also hunted in the area. Logging was done selectively, leaving the site relatively intact, while hunting would have been at low levels, to feed fewer numbers of people. This site currently hosts low numbers of tours or expedition groups and as such currently has a much lower impact on its surrounding forest.

Primates

The brown capuchin monkey consistently showed a higher encounter rate at LPBS. Overall encounter rate increased at both sites during the wet season, showing seasonal preference despite differences in site impact. During the wet season, group sizes generally appear similar at both sites, though in the dry season there is a drop in average group size at LPBS and an increase at PAL. Group size is also consistently higher at PAL. This may be an indicator of high reproductive success at this site, where the majority of transects occur close to the Tambopata River, giving a large stretch of edge habitat, for which Plumptre and Johns (2001) report that capuchin monkeys are well adapted. High detectability at LPBS may be due to the monkeys needing a greater spread of group members when foraging. The transects monitored at LPBS moved further away from the river than those at PAL, meaning less of the preferred edge habitat and associated food sources.

Dusky titi monkeys are found more frequently at PAL, with a significant increase in encounters at this site. Group sizes for both sites remain similar, though it is obvious from personal comparison that dusky titi monkey group numbers are booming at PAL. This may be due to small species density compensation in the face of an absence of large, hunted species. Peres and Dolman (2000), as well as Lopes and Ferrari (2000), report that with a lack of competition from usually large-grouped spider monkeys, there is a competitive release by which smaller species with a similar diet and higher reproductive rate undergo a boom in numbers, compensating for biomass that is usually dominated by large species.

Red howler monkeys are found more frequently at PAL throughout the year, with a greater difference in numbers between sites during the dry season, where encounters increase at PAL, though drop at LPBS. Group size remains similar, with possibly just one individual more per group at PAL. Group size increases slightly at both sites during the dry season. Red howler monkeys typically populate areas in high densities and require small home ranges due to their primarily folivorous diet, meaning that many groups may be found in one region (Horwich 1998). Therefore, the findings at PAL showing high encounters indicate many groups, as would be expected with this species. Recovery at this site is therefore extremely successful, as these were probably some of the most targeted species for hunters, owing to their large size and therefore high meat yield for hunting effort (Redford and Robinson 1987, Bodmer et al. 1997). Despite a slow reproductive rate, it appears that the protection provided by ecotourism at PAL has allowed this species to recover extremely well. The similarly vulnerable black spider monkey was probably so overexploited at this site, due to its larger size, that it has been unable to recover.

Squirrel monkeys consistently have a slightly higher encounter rate at PAL, with encounter rate increasing during the wet season at both sites. Average group sizes are similar during this season, though slightly higher at PAL. During the dry season this difference increases at PAL, despite larger groups also being found at LPBS at this time. The higher encounter rate at PAL may be related to these larger group numbers, making them more detectable. Overall increase in abundance of this small species can be expected at sites such as PAL, which have depleted larger monkey species due to previous hunting, in this case causing local extinction of black spider monkeys that were once found on this part of the river. As a lower abundance of hunted species remains, it is common to see an increase in small species abundance, in order to compensate for lost overall biomass (Lopes and Ferrari 2000). By contrast, species richness remains at LPBS due to surrounding undisturbed forest, meaning that monkey species that might have dropped during hunting were able to enter and repopulate the area again, as observed elsewhere by Dias (1996) and Peres (1999), so that overall monkey biomass is restored along with species richness. At PAL these source-sink dynamics are unable to take place due to the surrounding land primarily belonging to communities that use it for agriculture, mining and hunting. Biomass is hence regulated internally by boosting small species numbers (with a younger age of sexual maturity and shorter gestation rate, numbers are able to increase rapidly compared to larger, hunted species), but losing out on overall biodiversity (Novaro et al. 2000).

Saddle-backed tamarins show the largest difference in encounter rates between sites, with higher encounters at LPBS throughout the year, and increasing in the dry season. During the wet season, group numbers between sites are similar, with slightly more at LPBS, though the dry season shows a much more significant increase at PAL. The jump in group size at PAL during the dry season indicates a high reproductive rate for this species. This may be due to density compensation as suggested for dusky titi and squirrel monkeys. The overall higher presence at LPBS may be explained by its newer protected status, and therefore a lesser rate of recovery of removed larger tree species. Those that were removed by the more recent selective logging will have left behind light gaps that still have to be repopulated by young tree species. Saddle-backed tamarins are known for their preference of second growth forest and vine-rich habitat (Plumptre and Johns 2001) that would be more abundant in newly logged areas, allowing them to thrive at LPBS. It is thought that older, logged forests are comparable to primary forest in terms of overall carrying capacity of primate biodiversity. This may therefore be why numbers are lower at PAL, which is currently considered an older impacted forest that is well recovered, therefore possessing less of the secondary habitat that saddle-backed tamarins prefer.

Terrestrial mammals

The brown agouti has a slightly higher encounter rate at PAL year round, with encounters increasing at both sites during the dry season. Group sizes remain similar. Slightly higher encounters may be due to the lack of competition at PAL from similar species such as the green acouchy or paca, which were found at LPBS. While paca is found at PAL, it appears that they are uncommon, providing much less competition for resources and allowing a greater population of agouti, without competitive control.

Red brocket deer shows an increase in encounter rate at PAL during the dry season, though consistently shows low numbers of total encounters from both sites. Group size remains similar between sites. It appears that the very small increase in encounter rate at PAL may also be due to lack of competition from grey brocket deer, which were only found at LPBS.

Collared peccaries are encountered with equal frequency at both sites throughout the year. This either indicates little effect on this species from human impacts, or that low-scale hunting and high-scale tourism give the same effect. Hunters most probably targeted the noisier and larger white-lipped peccary, leaving a smaller impact on collared peccary abundance. General sensitivity to humans may explain why they are not more commonly seen at LPBS, with large groups of tourists frequently impacting the surrounding forest.

White-lipped peccaries give the most decisive results in terms of assessing human impact. LPBS gives more encounters in the wet season, while PAL more in the dry, with almost opposite effects between sites. In terms of group size, this was much higher throughout the year at LPBS, while PAL demonstrated smaller group sizes that showed a stronger dry season increase than that of LPBS. While LPBS is presently protected, current hunting activity at PAL occurs during the Brazil nut harvest from December to March. This concentrates around the large mammal claylick at which white-lipped peccaries were most frequently found, and probably accounts for their absence at this time of year. During the dry season, when Brazil nut harvesters and their hunting activities are gone from PAL, white-lipped peccary presence once again increases. The fluctuation is less at LPBS, where larger group numbers also indicate low hunting pressure. It is therefore possible that if hunting were also to be banned at PAL, group sizes could grow similar to those found at LPBS.

A note on predators

The biggest difference between these sites was probably predator presence. While a predator was only seen once on transects at LPBS (ocelot), evidence from footprint traps, cat sign traps, camera traps and walks other than transect monitoring indicate a high level of big cat presence at LPBS. It is estimated that minimum numbers were three jaguar, one puma and two ocelot. At PAL, no big cat has ever been seen on transects. In footprint traps, ocelot can be found relatively regularly (at least once every three months, indicating at least one individual); but jaguar signs were found here only recently, in May 2011. Before this date, there had been no sign of jaguar at PAL since 2008. The current jaguar is one juvenile male. Therefore we can safely assume that the high levels of current tourism have the strongest negative effect on big cat presence, which appears to have recovered well in LPBS after only nine years of protection (see chapter 3).

6.5. Conclusion

Previous human effects leave impressions as much as 17 years after protection has been put in place, in the case of PAL. We see here high density compensation of small species such as dusky titi monkeys, which thrive in terms of numbers of groups, and squirrel monkeys, which show much greater total group size. The increase in numbers of groups of red howler monkey also indicates a lack of competition from other large primate folivores, which at PAL could include both black spider and white-fronted capuchin monkeys. Internal equilibrium then becomes skewed, where large primate biomass (of species weighing over 4 kg; in this area spider and red howler monkeys) should make up to 80% of the total primate biomass in unaffected forest, but in hunted sites makes up less than 30%. It appears that this is the case at PAL, where real biodiversity recovery is unable to occur due to the lack of surrounding source sites. Without the formation of corridors through the surrounding community and agricultural land, perhaps joining other lodges of the lower Tambopata area, it is probable that small ecotourism sites of protected secondary forest, such as PAL, will never be able to recover full species biodiversity, and can only support an increment in numbers of the species that have been left behind.

In contrast, it is believed that the surrounding protected areas of LPBS have undergone full recovery (see chapter 4), demonstrating full saturation of complete mammal species biodiversity at equilibrium. As previously predicted, the impacts of selective logging and associated hunting did not deplete species richness, but did reduce numbers (Hammer and Tatum-Hume 2003). And after just nine years, these species numbers have been able to recover. The benefits at LPBS, as a site much further from the capital town of Puerto Maldonado and its associated populations and agriculture, include lower impacts on the forest and a surrounding area that remains undisturbed, allowing source-sink dynamics to restore population biodiversity.

Primate species in this case then act as a strong indicator for previous damaging impacts, even after years of private protection which would be expected to allow recovery from prior human disturbance (Hanlon 2007). Terrestrial mammals appear to show effects of more recent human hunting, especially in the case of white-lipped peccary. The significantly smaller group sizes at PAL act as an indicator of recent hunting, where signs have been found of hunters at one part of the trail system (see chapter 3), meaning that group sizes are unable to recover from the effects of hunting at this site even after 17 years. The large group size at LPBS shows that this species can recover numbers rapidly, as soon as nine years later in continuous protected or low-impact forest. It therefore depends on managing bodies as to the level of protection they wish to place on reserve sites, and the level of recovery that could be afforded to species.

Tourism as a protective activity depends on real management in the face of opportunist hunting from nearby human populations, and also corridors as a connection to low-impacted forest, in order to promote full biodiversity. Because of the high numbers that can still be seen at PAL, it seems that primate species abundance can still recover well with this activity. However, it is difficult to tell the extent to which tourism can also promote success of terrestrial mammals at this site. Future studies should include sites that have no current human hunting, in order to compare this. But for now it seems safe to assume that tourism still shows a high impact on the presence of predators, which appear timid of all human presence. Whether this is only true of sites with high numbers of tourists also needs further study.

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7. A comparison of primate behaviour reactions towards human presence

Sara Rehman

7.1. Introduction

Determining human effects on animal survival rates as both tourism and the permanent population of Madre de Dios increase becomes more important as human presence continues to extend into important primary habitat. Human conflict in terms of hunting, on or near logging and Brazil nut concessions, must also be monitored in order to control its effects as these activities continue to grow in the area. Mammal tolerance for decreasing habitat area and quality must be determined in order to understand the areas needed for their conservation.

To understand what primate species need from their forest habitat, it is important to determine their level of suitability within different forest types and the feeding and spatial sources available to them, as well as any human-generated impacts. Travelling frequency, socialising time and feeding all indicate the suitability of forest variables found in the region, such as canopy size (affected in Madre de Dios by logging and agriculture) and human disturbance (in the areas studied this includes tourism, hunting and Brazil nut collection) (O'Brian and Kinnaird 1997, Rosenbaum et al. 1998). Of particular concern are threatened species, which need management plans to be made according to their requirements, to keep up viable populations. This becomes especially important in the sizing of protected areas, and the correct combination with human use of their forest (MacKinnon 1986).

For successful management of small protected areas, concessions such as Las Piedras Biodiversity Station (LPBS) and the numerous tourism lodges of the area, ecology and behaviour data provide important information on species' needs, adding significantly to the findings of population surveys (O'Brien and Kinnaird 1997). Data produced by behaviour studies can lead to better understanding of habitat requirements, both naturally in terms of diet and breeding, and in terms of human conflict and its control (Sutherland 1998).

Knowledge of exact habitat needs for maintaining species and their populations becomes increasingly important in the region as the human population booms, and forest resources and land are further exploited through habitat-destructive activities such as mining, logging and agriculture. In turn, the local tolerance for animal populations has waned as more outsiders arrive in the region, with little knowledge and plenty of fear of 'the jungle' and the animals that reside within it. As migrants continue to flock to Madre de Dios from other regions of Peru, human settlements continue to spread throughout the department, destroying its natural habitat, without care for preserving the forest in its natural state.

With tourism as one of the main hopes for forest conservation in the area, potentially bringing long-term economic benefits with protection of small patches of forest, it is important to assess the real viability of these ventures as a low-impact activity. We therefore wish to compare sites that have this protective impact with hunted areas that have previously or presently had the strongest impact on primate stress and abundance. We believe that looking at stress levels may determine the suitability of sites and their level of recovery from past human impacts.

The importance of behavioural assessments reflects on all levels of forest impacts, from intensity of removal of individuals via hunting, to success of reforestation done by primates as principal natural seed dispersers. Understanding what is needed for continued survival of these species means protecting the forest in terms of establishing adequate reserves and also ensuring that the internal equilibrium is such that the forest remains naturally self-sustaining. Rosenbaum et al. (1998) argue that secondary forest, where low regeneration has occurred after deforestation, leaves behind a low quality habitat in which primate populations become less social and eat less fruit than troops that are found in high quality primary forest, with a high canopy and low human impacts. It is important to determine to what extent this may be true, as this would in turn lower the success of reforestation by these same primates, as well as their own population success. This would lead to lower abundance of all the biodiversity that attracts ecotourism to the region.

In order to determine what is needed for primate stability, we can determine their habitat use, behavioural ecology and stress in reaction to human presence. A comparison of the ecology of primates living in different forest types may indicate the level of protection that is necessary to ensure their continuance. We wish to determine what level of impact is still acceptable to primate species, where low stress can be observed and monkeys have a good diet, leading to better health, higher reproductive rates and increased socialising.

This study aims to collect behavioural data in order to understand habitat use and overall social and behavioural ecology of primate species, leading to an understanding of their spatial needs in differing forest types and with differing past human impacts. It is hoped that we can add to knowledge of protected area management and allocation, leading to stronger conservation and sustainable use of the rainforests of Madre de Dios.

Objectives

1. Observe the most common behaviours of primate groups, at three differently human-impacted sites.

2. Assess any differences in stress reaction towards human presence at study sites.

3. Determine to what extent each human impact, either present or previous, has an effect on stress levels of primate populations in their current environments.

7.2. Methods

A study of primate behaviours was introduced for the first time this year, with the aim of closer monitoring of all primates species, in order to determine behavioural differences between various human-impacted sites. Data collected from the surrounding forest of LPBS will be compared with Madwi's permanent site on the Tambopata River by the Posada Amazonas Lodge (PAL), where much higher levels of human presence occur due to tourism in this area, and a claylick site (CL) a little distance away from the main tourism lodge, where low-level hunting occurs.

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With the extremely low levels of human disturbance currently around the protected area of LPBS, it may be possible to determine effects of human presence in terms of previous hunting and present low-level impact tours or expeditions. Knowledge of this becomes increasingly important in the area as tourism booms, especially on the Tambopata River, where some lodges are known to receive over 60 people per day during the high season (June–October).

Behaviour

All primate groups encountered on specific behaviour monitoring walks were described to species and group size, with the subject of observation described according to age (adult, juvenile, young). Where males and females could be differentiated, this was also noted. The subject was observed and recordings of behaviour made using instantaneous scan sampling every five minutes. Primate groups were observed opportunistically for as long as a clear view was maintained, with the individual subject of observation changing only when their behaviours became difficult to determine. Biosphere Expeditions citizen scientists were encouraged to undertake behaviour monitoring as an optional activity at LPBS, lasting for a duration that they felt comfortable with, and walking without field leaders (who in the afternoons were occupied with the large footprint-trapping arrays), taking observations from trails and not following monkey groups as they moved out of view into the forest. This led to a relatively low amount of comparable data, but provides a baseline for comparison. At the permanent PAL site, project Madwi volunteers were encouraged to leave trails, following primate groups to continue taking observations. Specific behaviour monitoring was a three-hour activity during which time monkey species were actively searched for and followed.

During observation, behaviours of the individual chosen for monitoring were selected from a list, and classified as follows:

Foraging: actively searching for food, with attention focused on searching around a potential food source and manipulating branches of a fruiting tree.

Carrying food: carrying food away from the point of foraging; may indicate a discomfort level with the vulnerability of being exposed while foraging.

Eating: ingestion of a food item.

Movement: walking or running to a new location.

Climbing: vertical movement, potentially to put distance between them and human observers, as monkeys may feel safer at higher levels of trees, where a human threat cannot follow.

Resting: sitting or lying down, relaxed and not observing anything in particular.

Autogrooming: grooming its own body.

Allogrooming: grooming another monkey in the group.

Groomed: groomed by another individual; may indicate status level within the troop.

Vigilant: scanning surroundings with attention, or actively observing humans.

Playing: short skirmishes between two individuals with no obvious dominant or submissive stances.

Fighting: a skirmish between two individuals where the loser is chased a short distance or harm is being done during the interchange.

Scratching: monkey stops anything it is doing and scratches for a short while.

Drinking: drinking from a fork in tree branches.

Defecating: drops faecal matter or urinates.

Alarm calling: strong and urgent calling that alerts other troop members.

Calling: chitters in communication with other group members, with no associated nervousness.

This behaviour list provided data on relative time engaged in social activities, self-care or stressed behaviours. Percentages of time spent on each activity were made for species at each site, in order to compare possible different reactions to the selected human impacts we wish to assess, hunting and tourism.

Flight: As an extra category in the transect monitoring, flight from human observers was also measured. This was assessed on a scale of 0–5: 0 – indicates no difference in their behaviour, 1 – animals show nervousness and vigilance, may freeze, 2 – animals begin to call to one another and move away slowly while looking back at observers, 3 – animals move away from observers at a moderate pace and may settle again at a short distance, 4 – animals move quickly away from observers, only to settle again soon a short distance away, 5 – animals completely flee from human presence.

These flight reactions to human presence may show the level to which species associate humans with potential harm, from previous experience of being hunted.

The overall data set therefore allowed us to determine stress or habituation levels associated with hunting and tourism activities at their varying intensities, and any differences between the species monitored.

7.3. Results

Behaviour

At PAL, it proved relatively easy to find and follow primate species and record a total of 217 behaviour observations during the month of June 2011. Behaviour monitoring at this site took place around the lodge trails, within 1.5 km of the main lodge itself. The second site, CL, is at the end of one of our main transects, 3.7 km away from the lodge, at a site with two large mammal claylicks and where low-level hunting occurs at certain times of the year (see chapter 6). Here it was somewhat more difficult to encounter monkey species, leading to 92 behaviour observations made during the same month, all within 500 m of the claylicks. During the Biosphere Expeditions project at LPBS, behaviour monitoring was an optional afternoon activity, leading to a total of 103 behaviour observations.

Percentage frequencies for each behaviour for the species monitored are shown in the figures below. Black spider and white-fronted capuchin monkeys are not found at PAL and CL, so results are only shown from LPBS. Monk saki monkey only had one record of behaviour, and so is not included.
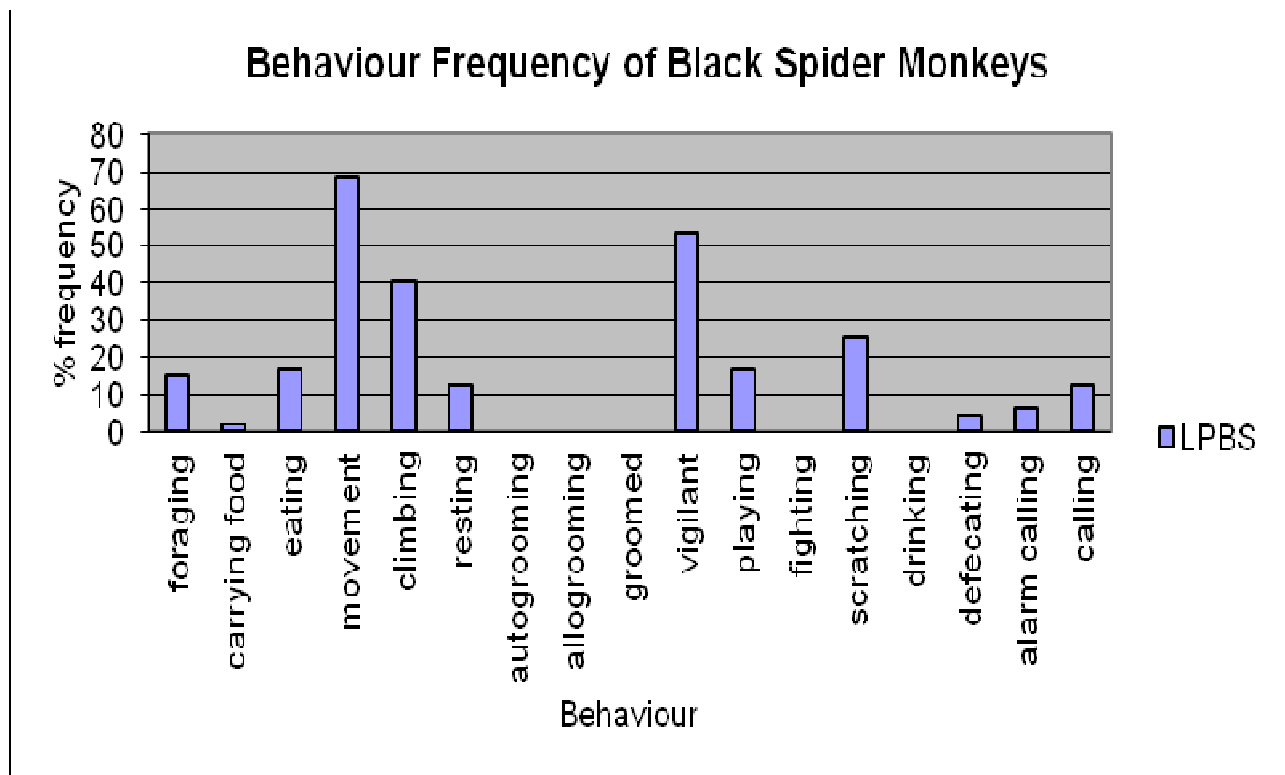
Figure 7.3a. Black spider monkey behaviours collected from 47 scans over eight days at LPBS.
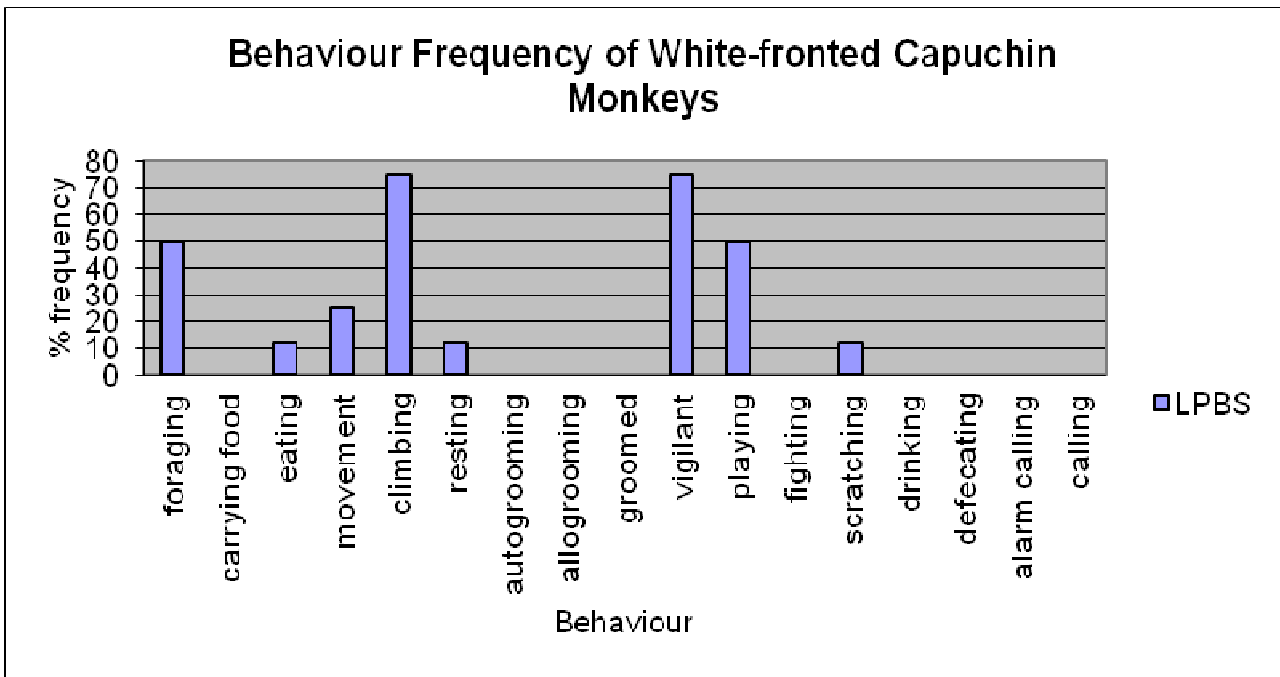
Figure 7.3b. White-fronted capuchin monkey behaviours recorded from eight scans over three days at LPBS.
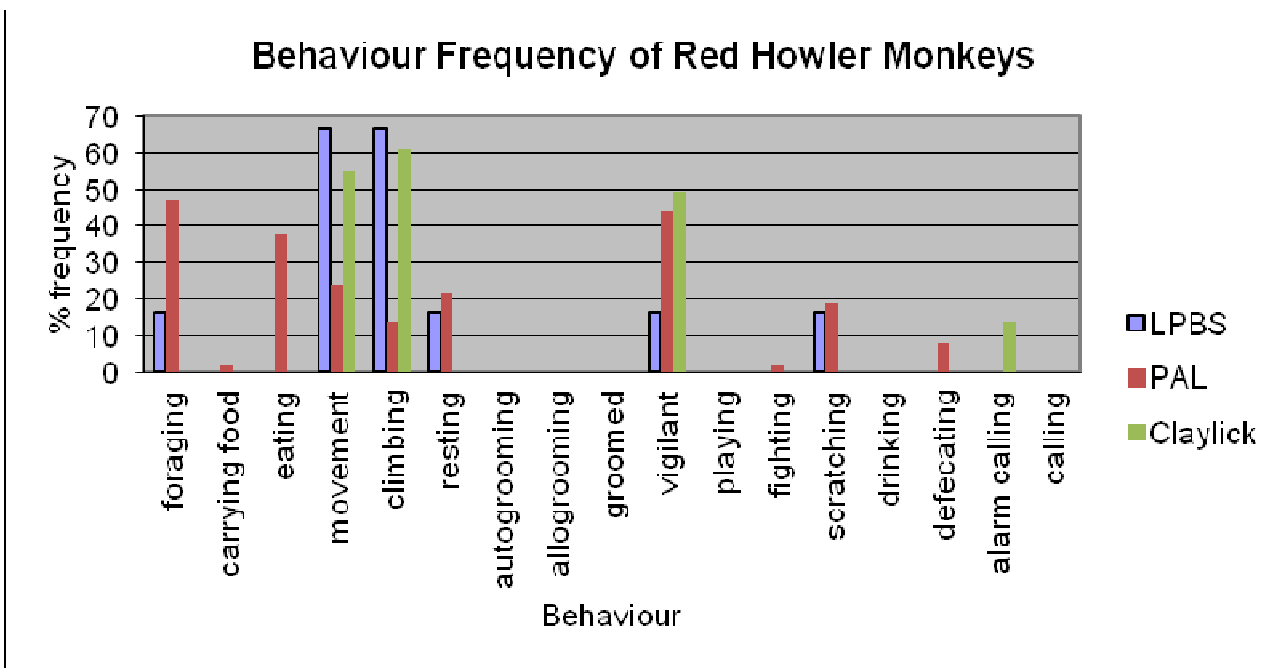
Figure 7.3c. Red howler monkey behaviours from six scans over four days at LPBS, 23 scans over six days at PAL, and five scans over two days at CL ('Claylick' above).

At LPBS, the most frequent behaviours of red howler monkeys include movement and climbing. At PAL, foraging, eating and vigilance were most common, while at CL movement, climbing and vigilance were most frequently observed. The least frequent behaviours at LPBS are vigilance, resting and foraging; at PAL carrying food, fighting and climbing; and at CL alarm calling. Carrying food and fighting were behaviours only witnessed at PAL, while alarm calling was only noted at CL. Grooming and playing behaviours were not observed.
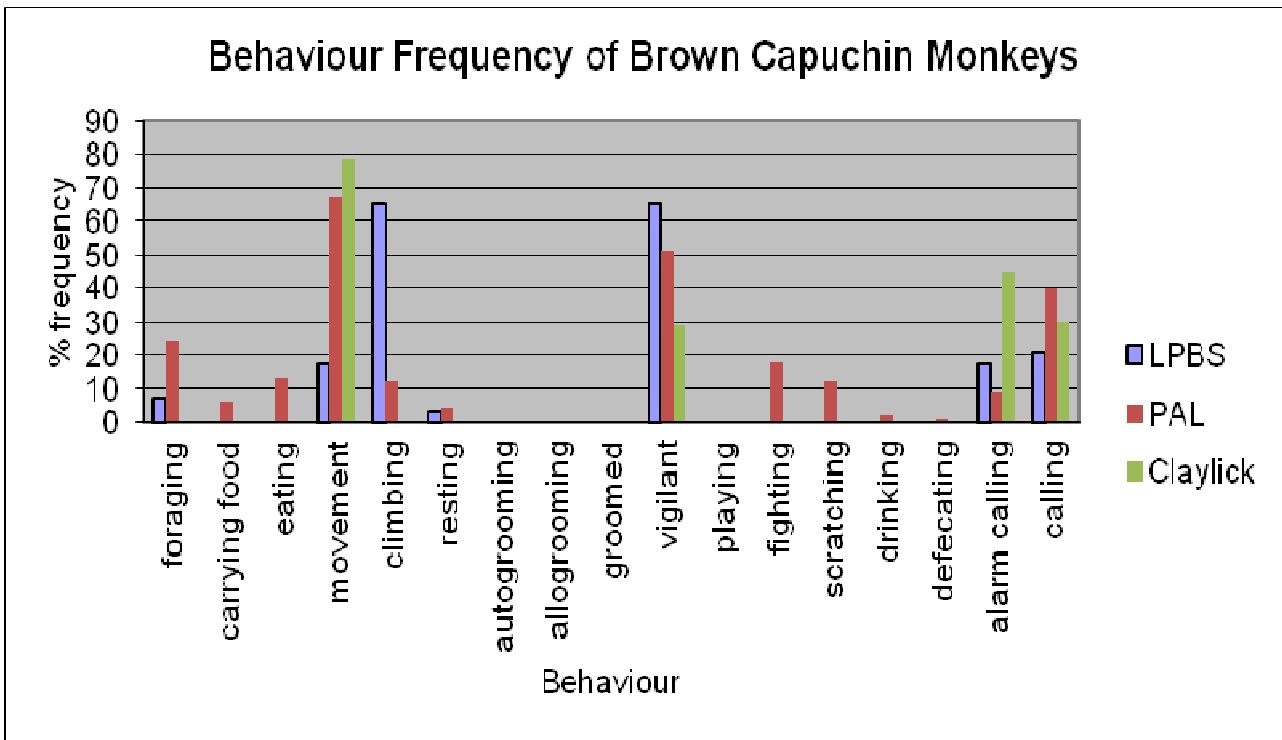
Figure 7.3d. Brown capuchin monkey behaviours from 29 scans over seven days at LPBS, 49 scans over five days at PAL, and five scans over two days at CL (Claylick).

LPBS shows the highest frequencies of vigilance and climbing in brown capuchin monkeys. At PAL, high frequencies of movement and vigilance were observed; while at CL, movement and alarm calling were observed most frequently. Lowest behaviour frequencies included carrying food, eating and fighting, observed only at PAL; and resting, observed at both PAL and LPBS. Grooming and feeding behaviours were not observed.
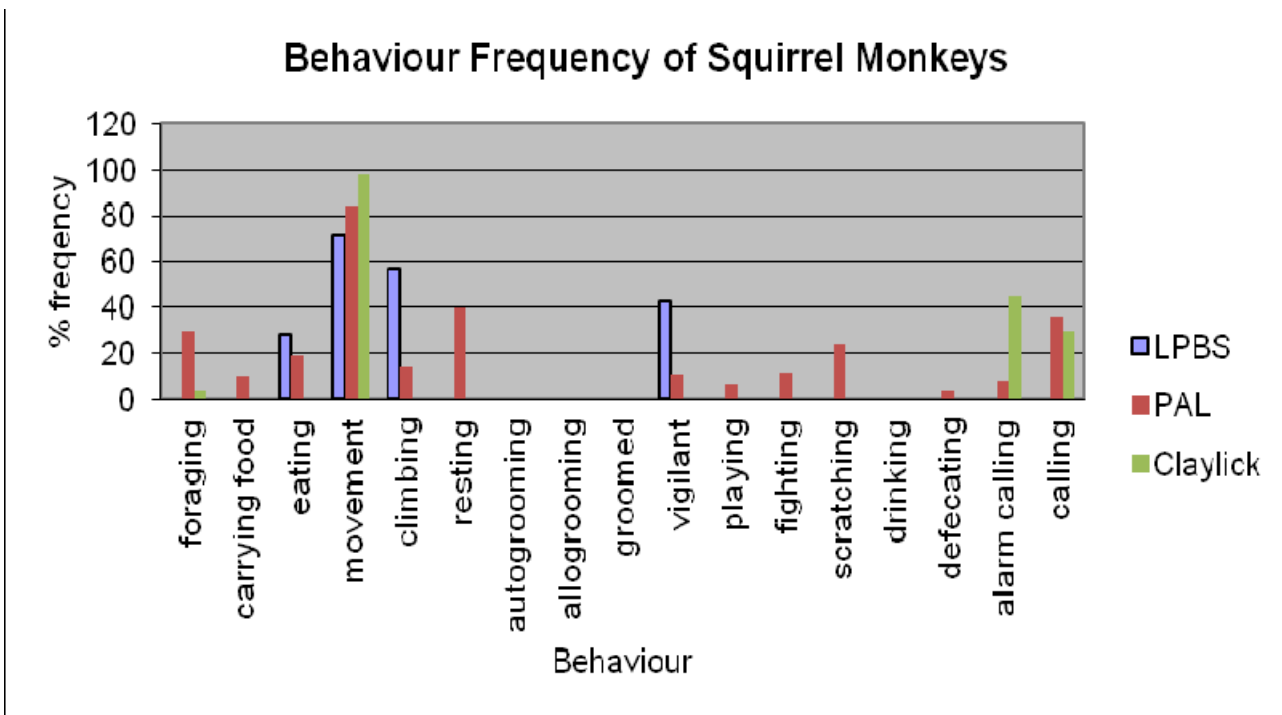
Figure 7.3e. Squirrel monkey behaviour frequencies from seven scans over three days at LPBS, 37 scans over four days at PAL and five scans from two days at CL (Claylick).

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Squirrel monkeys show the highest frequency of behaviour for movement at all sites. Food carrying, playing and fighting were observed infrequently and only at PAL. Feeding behaviours were seen as some of the most infrequent behaviours at all sites. Grooming behaviours were not observed at any site.
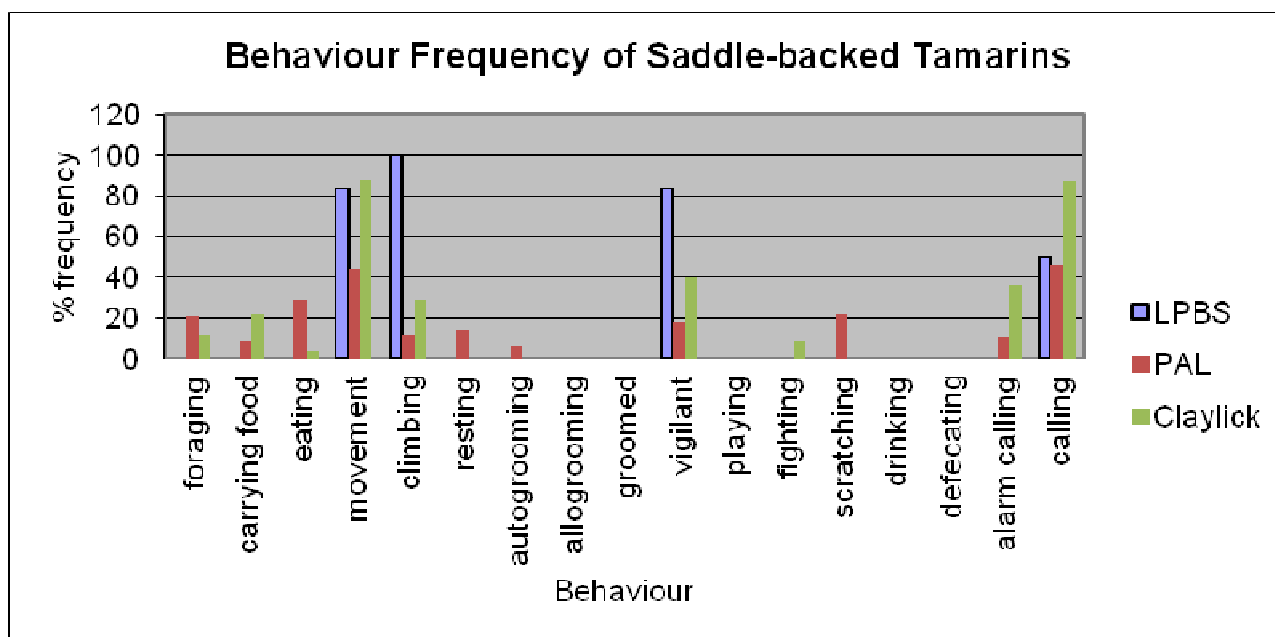
Figure 7.3f. Saddle-backed tamarin behaviour frequency from six scans over five days at LPBS, 12 scans over four days at PAL and five scans over two days at CL (Claylick).

LPBS shows high frequencies of movement, climbing and vigilance in saddle-backed tamarins. At PAL and CL, the most frequent behaviours are movement and calling. Resting, autogrooming and alarm calling were some of the most infrequent behaviours, observed only at PAL. Feeding behaviours were seen infrequently at both PAL and CL; while CL also shows low levels of fighting. No observations were made of social grooming involving other individuals, or of playing.

Dusky titi monkey behaviour was only recorded during two scans on one day from LPBS and so there were not enough data available for a viable comparison.

Flight

Black spider, white-fronted capuchin and monk saki monkeys are only recorded from transects at LPBS.

Black spider monkey flight reaction to humans at LPBS was relatively low (average of 1.7); while the smaller white-fronted capuchin and monk saki monkey showed a stronger reaction (averages of 3.2 and 3.7, respectively). For all common monkey species, the strongest reactions were seen at CL, apart from for dusky titi monkeys, which gave stronger flight at LPBS, while very little at PAL. Red howler monkeys showed a low reaction at both LPBS and PAL. Brown capuchins showed medium flight reactions at all sites, though strongest (3.5 average) at CL and lowest (2.2 average) at PAL. Squirrel monkey was not noted to have a flight reaction at all at LPBS and a very low reaction at PAL (0.4 average), while a very different result was seen at CL, with a much stronger flight reaction of 3.5.

Saddle-backed tamarins gave their lowest reaction at LPBS, with similar results at PAL and CL (averages of 2.6 and 3.2, respectively). Dusky titi monkeys had the lowest reaction of all at PAL (0.2) while reactions towards humans at LPBS and CL were much higher (3.7 and 2.8).
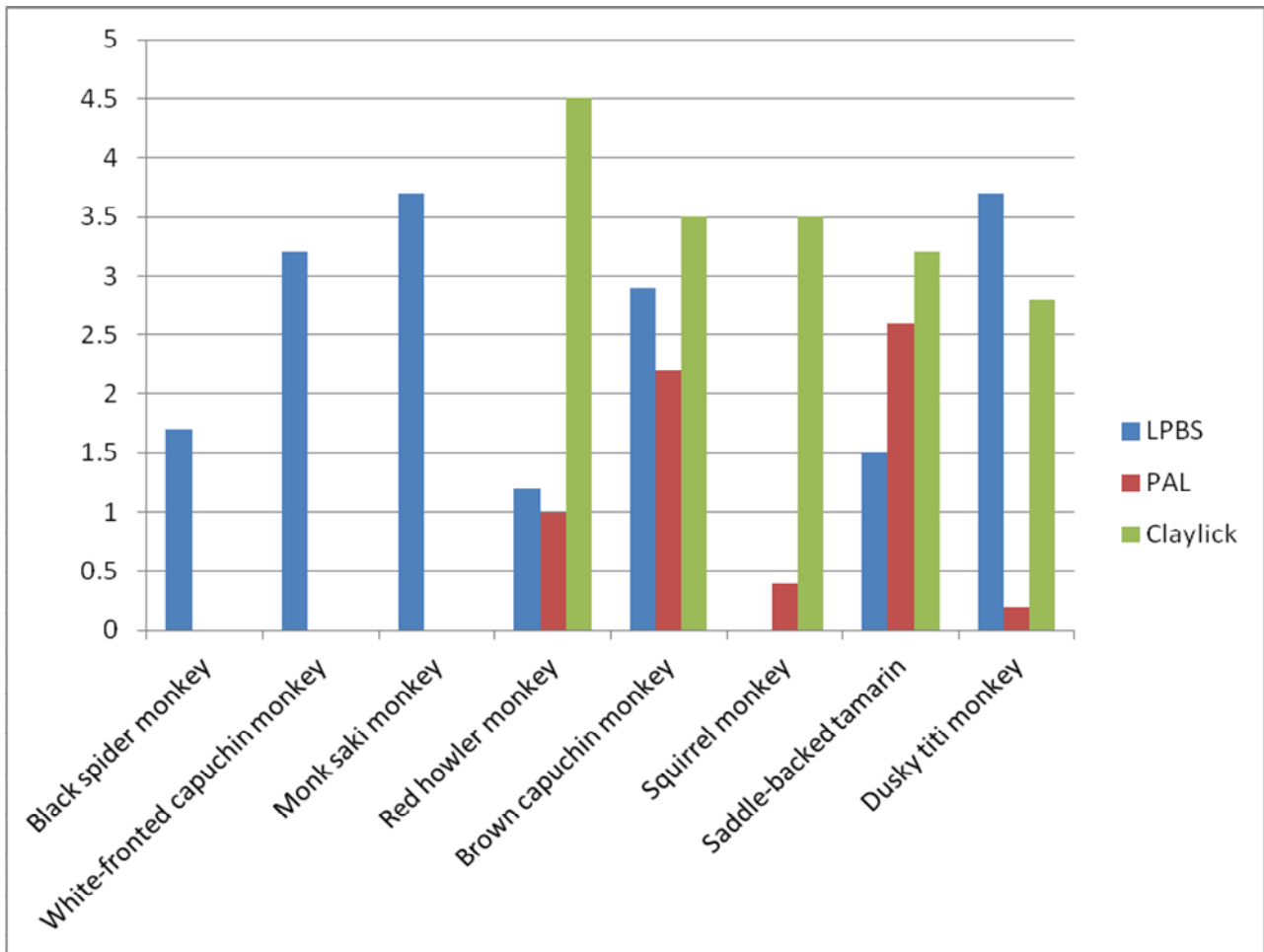

Figure 7.3g. Average flight reactions of recorded monkey species at all three monitored sites.

7.4. Discussion

While the black spider and white-fronted capuchin monkeys have no external comparisons to LPBS, it appears that their behaviour at LPBS does show stress. The most common reactions from these two species include climbing, movement and vigilance, indicating that it appears worthwhile to them to place energy into escaping from human presence, which also elicits alertness as though towards a potential threat. The low time budgets allocated to resting and feeding while under observation also show that more interest is put towards self-protection when faced with humans, harmful or not. White-fronted capuchin was, however, also recorded with significant time playing, indicating some sociability. Flight reactions are medium for white-fronted capuchin at LPBS while lower for black spider monkey, which as a canopy species would most probably climb higher to escape from threats rather than move away.

In terms of site comparisons for other species, CL showed the highest frequency of escape and vigilance behaviours, indicating that all species feel most threatened there. Flight behaviour was also highest overall at this site. Red howler, squirrel and dusky titi

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monkeys show the lowest flight at PAL, showing more feeding behaviours at this site than at others, a level of self-care that demonstrates a comfort within this environment. Red howler monkeys and saddle-backed tamarins also showed low flight at LPBS, though frequent behaviours include movement, climbing and vigilance. This probably indicates a level of discomfort at this site, but not so great as to invest too much energy in escape. This could be due to the sudden presence of humans when usually this is a rare occurrence at LPBS, leading the animals to become discomforted at a strange, unknown presence. In contrast, at PAL the relative comfort levels appear related to acclimatisation towards human presence, showing that after a time exposed to non-harmful, high tourist traffic, primates can overcome associated fears and return to relatively natural behaviour. This is in sharp contrast to CL where hunting still occurs and primates show the highest levels of nervousness and flight. This indicates that hunting presence, even at a low level and not necessarily targeted towards monkeys, still appears to cause an association between human presence and harm. When we consider that hunting and consumption of primates is a common practice of local people throughout the neotropics (Bodmer et al. 1994, Redford & Robinson 1987, Novaro et al. 2001), it follows that at a known hunted site so close to a local community, the fear of humans would remain. As to how long this discomfort lasts, further studies in newly protected forest with no further hunting would need to be done.

Species-wise, while hunting and habitat fragmentation are known to have significant effects on overall primate populations (Peres 2001), it appears that individual species all react differently to the different conditions at PAL and LPBS. Hunting mostly targeted primate species of over 5 kg (Redford and Robinson 1987). Therefore black spider and red howler monkeys were probably common targets of human hunters, while also being species that take the longest to recover in terms of abundance, due to a slower reproductive rate and longer life history compared to other species, often leading to overexploitation (Bodmer et al. 1997). While it would therefore be expected that these species show the highest levels of nervousness, results show that at LPBS these were among some of the least stressed, with the lowest flight reactions and a good time budget spread, where resting and feeding behaviours were observed even though overall behaviour focused on vigilance and escape. This indicates that while large-bodied primates are the most vulnerable to hunting, they are also some of the fastest species to recover.

The medium-sized and lower-canopy capuchin monkey species both show moderate flight responses at all sites in which they were observed. It appears at LPBS that there is still wariness from both species towards humans, while brown capuchins will show wariness, though to a lesser extent, at PAL. At this site, acclimatisation has occurred to the stage that applying energy to escape from humans is deemed less necessary. Nervousness at LPBS that is reflected in the greatest time budgets being allocated to vigilance and climbing is, however, offset by some foraging and playing behaviour in white-fronted capuchins. At both sites previous hunting pressure is recorded, where capuchin monkeys were probably hunted to a lesser extent than larger-bodied primates. It may be that their occupancy of a lower level of the canopy brings about nervousness in terms of proximity to human threats. Their relatively high population growth rate should mean a better recovery from hunting pressure (Peres and Dolman 2000), though they appear to remain equally wary of humans at all sites. Whether there is any difference at sites with no previous hunting and also lower tourism needs further study.

While it is thought that logging disturbs the natural conditions that determine primate population densities (Plumptre and Johns 2001), saddle-backed tamarin species appear to be most comfortable with the forest at LPBS. We see here their lowest flight reaction of all sites, despite the more recent logging impacts. As mentioned in chapter 5, their highest group numbers are also seen at this site. It appears that saddle-backed tamarins thrive in recently low-impacted forest, where low human presence remains. In contrast, PAL shows a higher flight reaction, despite a more rounded allocation of time budget activities. This may be due to the lower monitoring done at LPBS and needs further study for confirmation. However, tamarins showed the highest flight response of any primate at PAL. It appears that their occupation of the subcanopy and close proximity to humans leads to immediate investment in escape, almost to the same extent as at the hunted CL site, despite the differing nature of human presence. This species, as well as the dusky titi monkey, does show the lowest flight response at CL. It appears that at a hunted site, sensitivity towards humans increases with animal size. These two small species were probably mostly overlooked by hunters, due to the low meat payoff for ammunition used when compared to any of the other, larger primates (Peres 1991).

There currently appears to be a correlation in terms of species size at hunted sites and canopy level of high human traffic sites. At CL, larger-bodied species show highest stress, while at PAL with high tourist traffic, high canopy dwellers show the lowest stress reactions. To confirm this association, behaviour surveys will need to be continued at all sites in order to compare data from a much higher sampling effort. Future studies will need to include high tourism sites that occur near other low impacted forest, in order to confirm that high tourism presence can occur without lowering primate success. It may be that species at PAL that are experiencing high stress are simply unable to escape due to the low quality of surrounding forest. This kind of pressure on species can lead to lower feeding, sociability and parental care of young, eventually lowering survival and reproductive success (Gill et al. 2001, Priston 2004). It may also mean that heightened levels of human traffic at LPBS would lead to primates moving away from the site into the surrounding forest (Ydenberg and Dill 1986). Further studies need to be done in order to determine the true levels of acclimatisation possible towards human tourists, and the extent to which this can occur without affecting the health of local primates. Future sites should therefore include areas that currently have high tourism and good quality surrounding habitat.

The lack of social grooming seen in all of the primate species may indicate that sociability of New World primates is not as important to their survival as with Old World primates. Further study at sites with no previous or current negative human impacts will be needed to determine this, as neither of our sites can be guaranteed as 'good' habitat, due to their histories of hunting. Even after 17 years of recovery, small levels of stress may be present at PAL.

Behaviour studies of primates in Madre de Dios will need to be furthered at all levels of impacted habitat in order to determine acceptable levels of human pressure. Also, previous effects on habitat resources need to be confirmed for optimal use and protection of primate presence. Further study into parental care, overall health and survivability of young would be useful as guidelines for care of tourism trails and impacts, in order to protect a region that shows some of the most diverse primate assemblages in the world (Terborgh 1983).

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Appendix 1: How to make a track trap in terra firme sandy-soiled forests.

Step 1: Clear the forest floor or trail of all loose debris, leaves, branches etc. Using a machete as necessary, remove vegetation.

Step 2: Dig deeply into the forest floor, using a sharp instrument such as a machete, aiming to break through the roots which are in the surface and to loosen the soil to a depth of 2–3 cm.

Step 3: Remove all roots and organic matter from the soil by scraping the soil into a pile in the middle of the track trap.

Step 4: Smooth the soil, which should now be loose and as free of roots as possible, to an extent of 1 m x 1 m. The soil must be firm, but not compacted. If the soil is too loose or too firm, tracks will not show or will be difficult to interpret.

Appendix 2: Camera trap photos of jaguar, puma and ocelot, as well as other terrestrial mammals and birds, taken during the expedition at the mammal claylick or on transects and other camera trap locations.

HCO ScoutGuard   6.19.2011 9:18:10

The jaguar 'Matthias' passing the mammal claylick. The inset shows the markings of the rear end, which allowed for identification.

HCO ScoutGuard   6.16.2011 15:47:05

The puma at the mammal claylick. This was the only occasion puma was recorded on camera. Inset shows back end of the puma taken 1 second later after displayed time.

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An ocelot passes close to the mammal claylick. Sex unsure.

Jaguar 'Jerry' – right flank.

Jaguar 'Jerry' – left flank.

Jaguar 'Matthias' – right flank.

Jaguar 'Matthias' – left flank. Photo taken at 17:24 on 23 June 2011. Note wound behind left leg.

Female jaguar – photo taken by Jiri Haureljuk on 25 June 2011 (see diary, Appendix 5). Also used as report cover page.

Female jaguar on Brazil nut trail, excerpt from an infra-red flash photograph from a Bushnell Scoutguard camera trap.

Male ocelot.

Female ocelot.

Red brocket deer – probably female.

Tapir (male).

Brown agouti.

93

Southern Amazonian red squirrels and Spix's guans.

Red howler monkey.
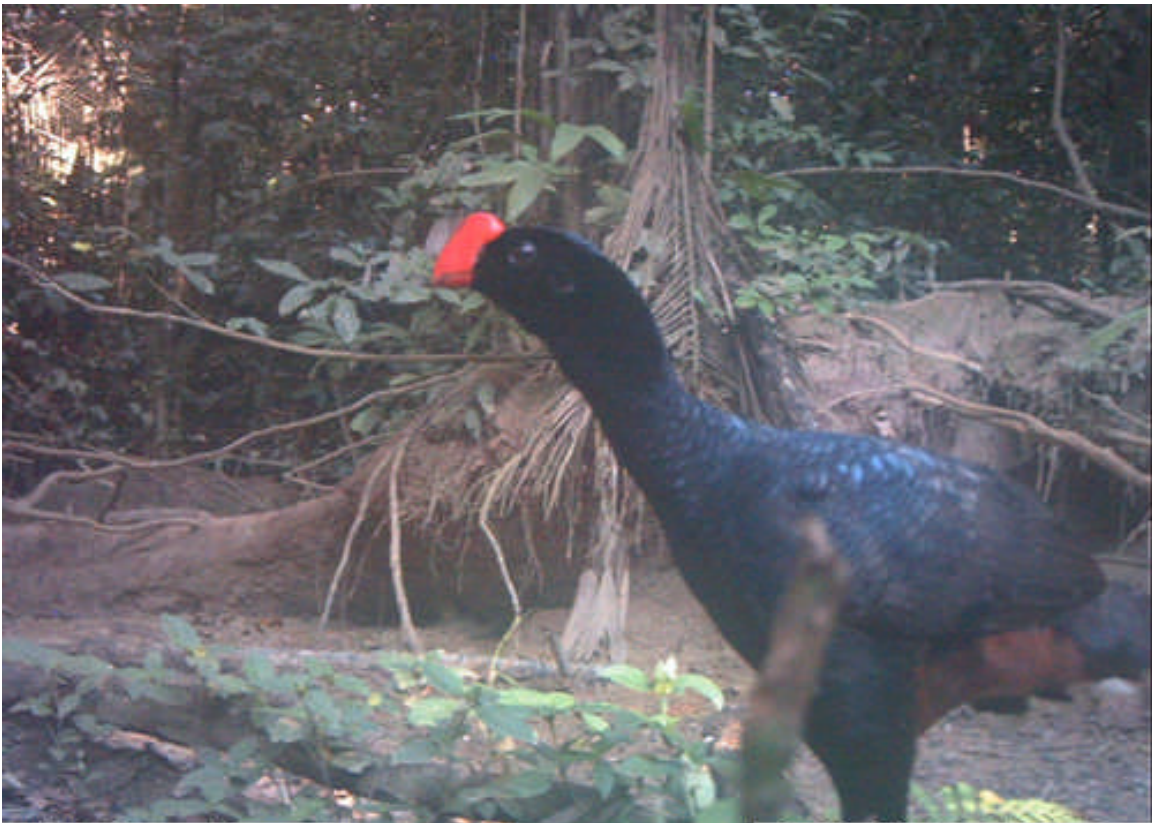
Razor-billed curassow.

Pale-winged trumpeter.

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Spix's guan.

Greater yellow-headed vulture.

Appendix 3: Some terrestrial animal tracks of the Las Piedras Biodiversity Station.

Jaguar: 9–10 cm long. Main pad is very large compared to toes. Toes and pad close together.
Back foot narrower than front foot (front foot is on the left in the photo).

Puma: Up to 8 cm long. Main pad is more angular, toes are more pointed and slightly spread out compared to jaguar.

Ocelot: Up to 5 cm long. Roundish appearance. Difficult to distinguish from smaller margay, where hind foot and front foot are roughly the same size and both rounded.
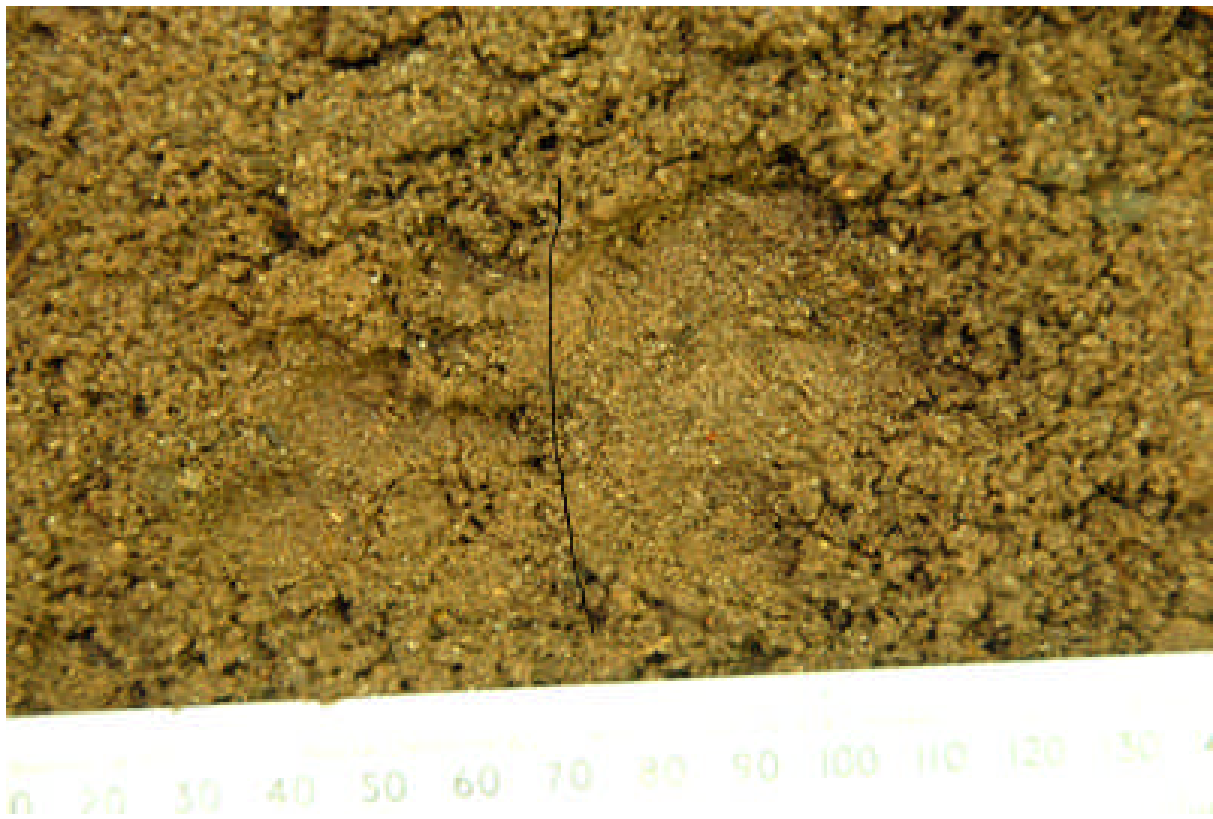

Tapir: Largest rainforest track – 15 cm or more. Three broad, forward-pointing toes.
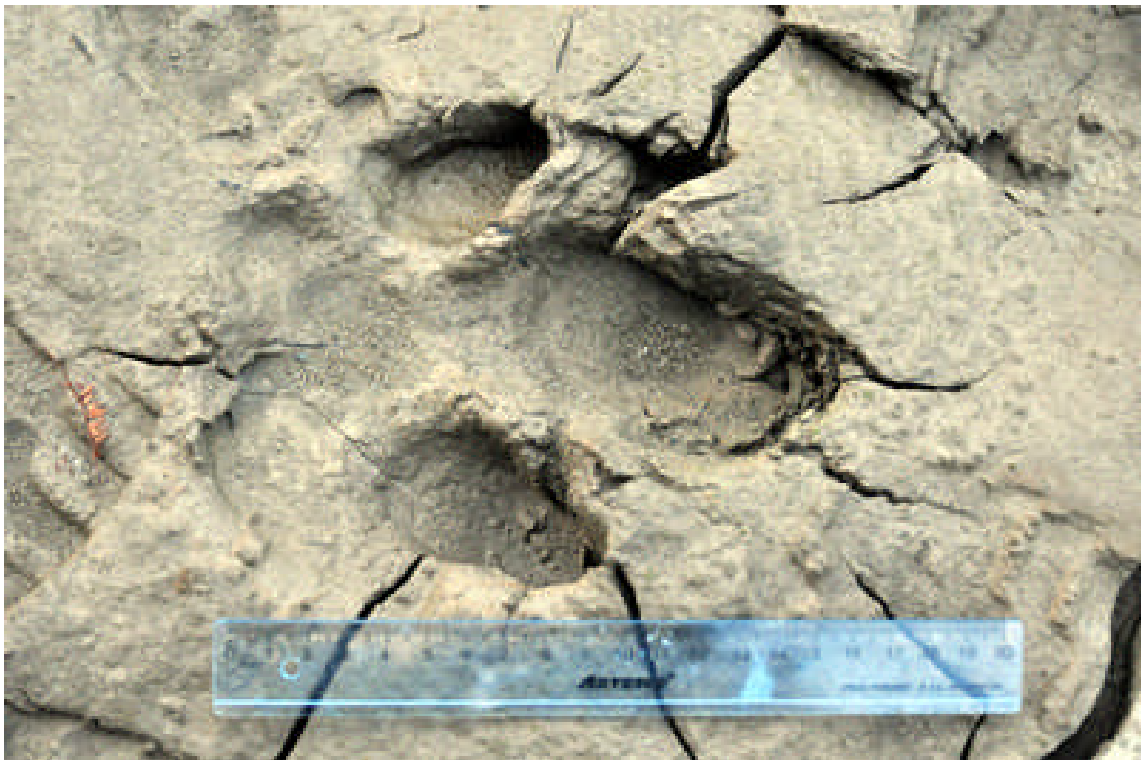
Capybara: Up to 10 cm, three or four toes visible, more pointed than tapir and abundant along river edges
.

Armadillo: 3–4 cm. Front foot (on left of black line) shows two disjointed parallel claws, while back foot (right of black line) has a three-toed impression (like a miniature tapir).

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Giant armadillo: Up to 10 cm. Hind foot (featured) is superficially similar to tapir, but more squat with middle toe very blunt. Front track dominated by the large claw.

Paca: Up to 4 cm. Very commonly encountered track with uneven, long pointed toes, found especially along streams and the claylick. Here the hind foot is superimposed on the front foot. Brown agouti is smaller (2–3 cm) with a distinctively long middle toe. Green agouchy is similar, but ±1.5 cm long.

Pale-winged trumpeter: This large, common, terrestrial bird is found in groups of up to eight birds and tracks are often found in track traps. Tracks with three toes pointing forward, one toe pointing backwards.

Yellow-footed tortoise: Tracks of this common terrestrial reptile are close set on the left and right side, with the left and right tracks separated by 10–20 cm. Hind legs drag, indicating direction of travel.

Neotropical otter: Scat, full of fish scale and bits of crab, and track of Neotropical otter were found along a small stream by Andy Stronach, the first evidence of this species at the study site.
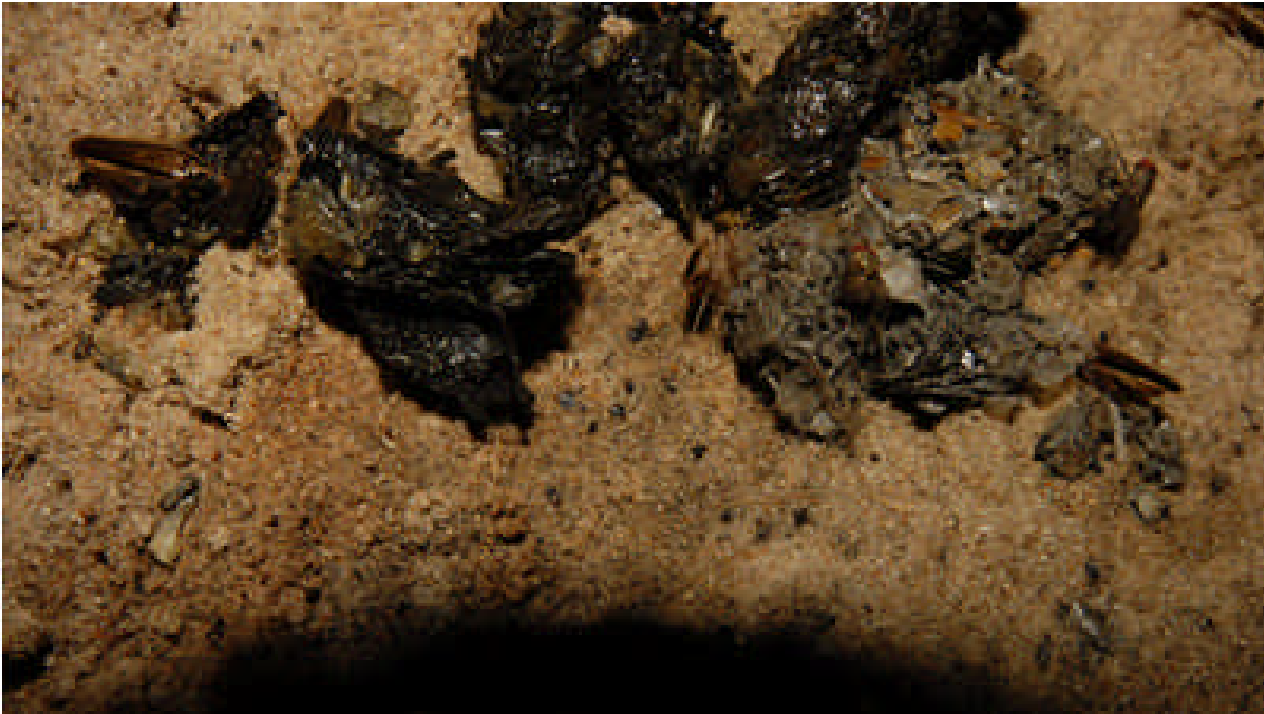
Photos by Andy Stronach

Appendix 4: Data sheet used for the macaw behaviour study

Biosphere Expeditions Parrot Behaviour Study

Date:
Start Time:
Species:

Observers shift 1:
Shift change:

Observers shift 2:
End Time:

Time:	Cloud:	Wind:	Position	Vigilant	Resting	Panting	Walking	Calling	Playing	Kissing	Aggres-sion	Submis-sion	Eating	Preening	Allopree-ning	Scratch	Short Flight	Flight Away	Other
Ob: Peke:			High Low Clay																
Ob: Peke:			High Low Clay																
Ob: Peke:			High Low Clay																
Ob: Peke:			High Low Clay																
Ob: Peke:			High Low Clay																
Ob: Peke:			High Low Clay																
Ob: Peke:			High Low Clay																
Ob: Peke:			High Low Clay																

Other = Sleeping (S), Wingstretch (W), Branch Biting (BB), Headshake (H), Begging (B), Regurgitation (R), Defecation (D), Fighting (F), Sex

Appendix 5: Expedition leader diary by Jiri Haureljuk.

3 June

Hello there. This is the first diary entry for Biosphere Expeditions' Peru 2011 expedition and I am Jiri Haureljuk, your expedition leader.

I have just arrived in Puerto Maldonado and met with Biosphere director, Dr Matthias Hammer, and our two scientists, Dr Alan Lee and Sara Rehman. We are all getting stuck into sorting out last bits and pieces, printing all the data sheets, organising local guides and just making sure everything is ready by the time you all get here.

As it is my very first time in this part of the world, I am already in awe of this very special place with its lush vegetation, strange sounds, beautiful birds flying around and sloths hanging around in the trees. No, I am not in our research station yet, but just in the Wasai hotel!

I hope all you team members are as excited as I am and I am very much looking forward to meeting you. As I am heading upriver on Saturday, it will be Alan who will take you to Piedras research station on Sunday. If there is any problem, his mobile number is +51 973170252. Please make sure you are at the assembly point at 6 am. We need to leave on time in order to make it to the base before dark.

Safe travels and see you soon.

P.S. A video diary entry is now also at www.facebook.com/biosphere.expeditions1. Just click on the link and go to the 'Wall' (you do not need to be a member of Facebook to see the video).

3 June

Nothing is as constant as a change of plan on expedition, so today I have some kind of good news and some bad news.

First, the bad news. A road is being built through the forest towards Brazil (including a massive bridge at Puerto Maldonado, which you will see from Wasai). This is an ecological disaster that we and many others have been arguing against. We've lost this battle, sadly, but we continue to fight on for biodiversity in this region. One consequence of this road, which is kind of good news, is that it cuts down our travelling time to base by several hours, so THE ASSEMBLY TIME FOR ALL SLOTS OF THE EXPEDITION HAS NOW CHANGED FROM 06.00 TO 08.30. The place (lobby of Wasai hotel) is still the same, but the time is new. Breakfast starts at 07.00 at Wasai, so please make sure you come to assembly well fed & watered, ready for departure.

I have attached a rough plan so that you all have an idea of what will be going on. Remember to stay flexible with timings and expect the unexpected, though!

Also, Alan will be in the Wasai lobby at 19.00 tomorrow (Saturday) for anybody who wants to meet up beforehand. We'll do the same for the next slot, so anybody who wants to go out for a drink or dinner is welcome to join in.

We look forward to meeting up with slot 1 soon and slot 2 later.

4 June

Last entry before I head into the forest. As you can see on www.facebook.com/biosphere.expeditions1 I am busy with paperwork and Peruvian coffee ;) Sara, Matthias and I will be 24 hours ahead of you and Alan will collect you at 08.30 at Wasai.

See you soon.

4 June

We're 24 hours ahead of the first team and my first sight of the river is enough to realise we have arrived at a very special place. Sandy banks lined with towering trees, thousands of butterflies sucking up moisture (and sodium) from the mud, two macaws resting on a giant Brazil nut tree and a rather unwelcome committee of biting sand flies.

5 June

On the journey upriver team 1 watched spectacled caiman resting on the sand banks and schools of turtles sunbathing on the tree logs, with butterflies decorating their heads. Gloria, our cook, made us some welcoming refresco and the team members had their first chance to look around base. Matthias then delivered a health and safety briefing, followed by an introductory walk in the forest. Alan was impatient to see his favourite macaw colpa and took me across the river to have a look and build a new hide. I was very excited to see numerous tracks of capybara on the beach and tapir footprints in the forest. We then headed across to the Brazil nut trail to assess the state of our trail system and shortly after found our first jaguar footprints.

6 June

Training day. The team first learnt how to use GPS, compass, binoculars, rangerfinders, and the telescope. We then tested their newly acquired skills on a short navigation walk. It was quite amusing to watch everyone disappear into the thick forest, armed with just compasses and hoping they will all come back. They did, the training paid off.

Alan and Sara then gave us a talk on mammal identification and we could test it immediately as Sara (team member) spotted a troop of saddle-backed tamarins and some dusky titi monkeys behind the kitchen. Our first monkeys! Things got much more serious after lunch, when the team was introduced to data collection, observation techniques and data sheets. Alan then explained all about macaws, their behaviour, conservation and how the data will be used. I think by then everyone suffered form serious theory overload and as a reward, I took everyone down to the river for a night walk.

7 June

Practise day. In the very early morning, half of the team went to the macaw claylick for a training session with Alan, whilst the other half went with Sara, to do some training on the mammal transect. I have completely fallen in love with the macaw colpa. Seeing macaws in the wild has been a dream since I was a child. I wasn't the only one. From the moment the macaws finally arrived, everyone was hogging the telescope and refusing to let go!

The mammal transect was equally rewarding. In order to learn how to record mammal behaviour, I had to pretend to be an animal. That wasn't very difficult. I think I made a decent impression of tamarin, tapir and brocket deer. But I felt rather insulted when my jaguar impersonation was described as a peccary!

After lunch, Matthias took Sara and Ege to assess the state of the Waterfall trail and the rest of us headed across to the mammal colpa with Alan to start working on 'The Matrix', which is a network of footprint traps.

Matthias's team returned to base with tales of jaguar prints and our first sighting of spider monkeys. An excellent day was followed by an excellent dinner.

8 June

Split into three groups, we had a very early start again, rising with the sun. Deepika and Flavio's data sheet was full of amazing encounters, but the one that stood out the most was their encounter with white-lipped peccaries. They literally walked into a herd of at least fifty animals. I am sure they will remember their stench forever! Another group went with Matthias to look for cat signs up a river, first getting into mud up to their waists and then getting soaked to the bone, but did not find any. All the rest worked on The Matrix until everybody was exhausted. Great effort everybody!

9 June

I went with Matthias (who left us today) through all the important paperwork and, finishing earlier than expected, I then headed for a walk to Transect A, to clear my head. And what a walk! Within an hour, I came across howler monkeys, a red squirrel, spider monkeys, capuchin monkeys, saddle-backed tamarins and a fresh puma footprint.

The macaw colpa team was also beaming upon their return. They managed to observe and record well over fifty macaws feeding on the clay click. The Matrix team arrived shortly afterwards, with blisters, blunt machetes, and exhausted looks in their faces, but smiling. Job well done, no more making footprint traps! The Matrix is done.

10 June

A video of an expedition day (looking for cat signs, pretending to be a jaguar to test a newly installed camera trap, and a well deserved 'power shower' after the day's work) is now up on www.facebook.com/biosphere.expeditions1.

When I arrived back at the station there were lots of stories of interesting sightings I had missed. Everyone was in good spirits and pleased with what they have achieved so far. Rain followed me to the station and we spent the whole afternoon under the roof. Then a friaje arrived, jackets came out and everyone was asking for extra blankets. Luckily the rain stopped late in the evening and we even managed to squeeze in an extra night walk. What a crazy day!

11 June

My mission of the day was to find the stream at the end of Brazil nut trail and set up some camera traps there. Rita and Sara joined me and on our way back we had an amazing David Attenborough moment. We heard a loud noise coming out of the trees, as if someone or something was trying to crack the brazil nuts. We went in to investigate and found a troop of white-fronted capuchins, hard at work. Two of them had a nut each and kept bashing it against the branch, trying to open it. I managed to record a bit of footage, before the capuchin dropped the nut to the ground. He did look quite embarrassed and left us in stitches. What great fun!

Everyone else got back from their activities, full of stories of numerous jaguar footprints, all over the transects and trails. We have named the largest male 'Matthias' – his footprints were reported from both Transect C and the Brazil nut trail.

After dinner we learnt that Gloria, our cook, has spent some time observing us and giving us names of animals we are meant to resemble. Everyone was bit worried, but in the end she was spot on. Among those that fitted the most was a sloth (Cornelius, for his love of spending most of his days in the hammock), a male howler monkey (Alan, apparently for an army of followers, female to be precise, not sure where Gloria got this from), a pair of macaws (Flavio and Tina, very fitting), a spider monkey (Sara for her vegan diet) and Amazonian red squirrel (Charlie, in Gloria's words for being small but quick and good with a machete).

12 June

Gloria just couldn't wait. The whole morning she was asking when the soccer game would start. After all it was Sunday and we had to put science on hold.

Today we were out to have lots of fun. The kick-off was scheduled for 11 and the appointed captains, Gloria and I, chose their teams carefully. Well, Gloria clearly went for all the good-looking guys and left me with all the girls. As much as everyone was looking forward to the game, it wasn't as easy as it looked. Playing in the sand in high heat and humidity, I had to order a break every ten minutes or so. And the score? It was 3:3 for a very long time until Ege scored a golden goal. Alan, Eric and I then jumped into the river and drifted on the current all the way to the waterfall. Others took a boat and arrived shortly afterwards, very keen to jump into cool water, wash off the sweat and escape the sand flies. Gloria showed us how to jump through the waterfall and soon everyone joined in. Refreshed, everyone felt the itch to do more on this 'day off' and after lunch most team members departed for their little private walks. I think they have started to realise that they

only have few days left and the presence of the jaguars around the base was enough to motivate everyone to go explore, rather then spend another afternoon in the hammock.

After dinner, another fun activity followed. This time we had to keep quiet as we slowly drifted down the river in our boat, looking for caimans. We found a healthy and thriving population along the banks of Las Piedras and even managed to spot our first capybaras. Like shadows, they suddenly appeared on the river bank, a tiny herd, with a few babies. What a fantastic day!

13 June

One survey was spiced up with our first dramatic encounter with white-lipped peccaries, whose stench we could smell before we could hear them. Completely surrounded by a foraging herd some fifty strong, I had no choice but to bash my machete against the tree to scare them off. They were too many and were a little too close for comfort.

The macaw team reported numerous macaws on the claylick. And yet again, Matthias's footprints were everywhere, including on the Brazil nut trail and Transect C. I feel it is just matter of time before someone is going to bump into him.

14 June

Survey teams came in one by one, tired, but with full data sheets. Sara and her team confirmed yet another female jaguar footprint and it started making more sense that she really might have a cub somewhere there and is therefore not moving around much. Matthias could then easily be the cub's father. Or as Alan speculated there could have been a large kill somewhere. Aside from our wild thoughts, most impressive were the footprints themselves. In one track trap, nicknamed 'jaguar's dance matt', Martha counted over 20 footprints, belonging to the same animal!

15 June

On the macaw colpa we recorded some 25 red-and-green macaws. Among them was one scarlet macaw, who seemed to have a somewhat close relationship with one of his red-and-green cousins, something which even Alan found hard to believe, until we produced a photo. We also saw a couple of capybaras, wading through the shallow water right in front of the colpa.

16 June

Alan, Charlie and Sara bagged an elusive saki monkey on Transect A!

Nick and Martha retrieved the memory card from one of the camera traps and finally. The jaguar!

Flavio, Tina and Nick did their best to enter the rest of the data sheets. To keep them sane, Nick read out all the numbers in various voices – his imitations of Roger Moore and Sean Connery were pretty impressive. Alan then took charge, went through the data and presented us with the results in the form of various graphs, happy – we have done well! Gloria made her last amazing dinner and the time to reflect has come. Our last feedback session lasted for hours, with the help of Gloria's rum, and it was great to hear how much everyone enjoyed their time here. It was a great team effort and from day one everyone worked incredibly hard to make their time here worthwhile. Well done team and a real showcase for 'the more you put in, the more you get out'.

17 June

Some last walks in the jungle and an unexpected bonus. A picture of a puma on the mammal colpa camera trap! Great result for the very last day of this slot 1 and a great inspiration for slot 2!

19 June

Team number two assembled at Wasai lodge with the mountain of food I had bought the previous day. Everyone was in high spirits and after organising our load, we were finally on our way. The journey upriver was, as always, amazing, yet a little slower, due to a drop in the water level. We managed to spot an endangered black caiman, not far from the station.

20 June

Everyone was up at 5:20 when a troop of howler monkeys set off their alarm clocks and started howling very loudly just next to the lodge. During training, team members got to know more about navigation, how to use a GPS and a compass. This was later put into practice on a short walk, which also included a brief introduction on machete use and track trap making. Sara then introduced the team to the mammal world around Las Piedras and how to recognise its various members.

During a walk in the afternoon, Matthias' footprints were everywhere, and there were even a few tapir prints around. Probably the most significant find on the walk was a strong presence of white-lipped peccary; I came across three large herds, numbering at least 150 animals. This time I stood my ground and let them come quite close. As I returned back to the base, the entire team was heading out for night walk. Glad to have such keen team members with us!

21 June

Another day of training started with a very early start. Howler monkeys yet again provided the perfect alarm clock. Alan and Aldo took Savannah, Tristan, Uwe, Anne and Marina to the macaw colpa and Sara headed over to Transect C with Ines, Ken, Mark, Connie, Thomas and Lisa. Good luck with your monkey impressions Ines!

22 June

With the training over, the entire expedition team headed to the forest to practise their new skills and hopefully bring back some useful data. I took Tristan and Savannah to explore transect B. The monkeys we managed to spot fled instantly and we felt that being out of our concession, hunting was still going on here.

Sara took Lisa and Marina on the river trail, Connie and Mark managed to spot their first tamandua on Transect C and Uwe with Anne spent a quiet morning observing some spider monkeys and brought back some good data. Sam and Tamara had their first training session at the macaw colpa with Alan.

After dinner, Alan gave his favourite speech on parrots and everyone felt like a macaw expert.

23 June

We made our priority on this slot to discover a mysterious, hidden mammal claylick Alan had heard so much about. It was clear to us that the peccaries had to go somewhere else as our old claylick was becoming pretty much deserted. As soon as we left the Brazil nut trail, Alan navigated us through dense vegetation. After crossing a stream with crystal clear water, we knew we were not far and half an hour later, we reached our Shangri-La. We found a new mammal claylick and judging by the footprints all around, it was the one the peccaries were going to. Alan installed his camera trap, Tristan shared his ever popular trail mix and we headed back. From the footprints, we found that Matthias was still suffering from diarrhoea.

24 June

Thomas, Connie, Tamara and I left early in the morning to retrieve camera trap data. I was certain we would have a good result in our camera traps as there were jaguar footprints everywhere. There were also plenty of monkeys, who kept us entertained throughout our long walk, and we even managed to find another mammal claylick. I ventured inside the forest to have a look at the swamp nearby, but instead discovered a claylick, at the base of an overturned tree. Alan explained to us that these are temporary claylicks and are quite common.

Sara, Tristan and Savannah went out on Transect A, with Sara all smiles, as she finally managed to spot her first monk saki monkey.

Mark and Sam volunteered to head over to the control matrix. The camera traps finally revealed their secrets before dinner and yes, jaguars were the highlights. I was particularly excited to see them sniffing at a Davidoff scented patch of dirt and wondering what they thought of it. Sara's camera had ocelot pictures on it and some great shots of trumpeters. Gloria cooked yet another magical dinner, crowned with ever popular rice pudding, and when Tristan pulled out his bottle of pisco we could only toast to yet another great day.

25 June

Sara was keen to see the new colpa herself and took Savannah and Sam to install a mini matrix and one more camera trap. Aldo crossed the river with ever keen Uwe and Anne, to explore Transect B, while Alan had a very early morning on Transect A with Mark and Tristan. I went to the macaw colpa with Tamara. With the weather on the verge of a dramatic change, the birds were keen to feed and were there at the claylick in huge numbers. Blue-headed parrots, mealy parrots and both scarlet and green macaws. In the end it was a hawk and a pair of vultures who scared all the birds off.

But this was only the beginning of the day I would remember forever. With a mammal matrix planned for the afternoon, I decided to climb up the hide earlier and wait for the team to arrive. This is a brief entry to my diary:

"The wind rushes through the jungle and drowns all the life. Then silence, nothing moves. New sound arrives. Faint growl, panting, growl again. Peccaries? More growling, more panting, loud crack of the branch. Closer, closer. And then first, short glimpse of a large spotted body. A jaguar! For a moment it is gone. A glimpse? A mere glimpse lasting no more then a millisecond. Is it all I am allowed? I lean out of the hide, hoping for more. Jaguar, a female, jumps on a fallen fig tree and walks across. She stops and sniffs an old bromelia plant. Picture! Take a picture? My heart is pumping, my hands shaking. She walks on without noticing me. And then out of nowhere, a second jaguar appears. A majestic male jumps on the log and follows his partner. Where did he come from? How could I have missed him? He pauses, briefly looks at me and disappears into the bush. I can hardly breathe. Amazing! The whole moment lasted not more then a minute, but it seemed like an eternity. How deep were his eyes. Did I get any pictures? Are they in focus? I couldn't care less. My hands are still shaking. What just happened? Was it real? I check the camera. Wow! I could have at least extended the zoom and turn the video recorder on. Who cares. A jaguar! Two jaguars!"

26 June

Sunday marks the day off and arrival of a friaje. Overnight the temperature has dropped dramatically. Jackets and warm hats come out after lunch and everyone leaves for various walks. In the strange weather the forest is quiet. I head down to Transect C, believing jaguars will be there. And they are! At the 2,400 m marker I can hear loud growls and hissing. They are mating! I leave them to it and return to base. Alan immediately plans a reverse Transect C for the morning and Connie and Thomas volunteer to go with him. If only they knew...

27 June

Who better to describe the events of the morning, then Alan himself:

"We set off at 04:00, the weather cool and the forest still. After about 20 minutes we encountered night monkeys. Then, rounding a corner the flash of a big cat's eyes were highlighted in the trail for a second. The cat did not stay, turning around and disappearing quickly along the trail. Tom and Connie had not seen it – but not to matter. Within minutes after continuing, big cat eyes were seen rapidly advancing down the trail towards us. In the bright beam of the maglite we could see it was a large jaguar coming rapidly towards us. We stepped off the trail and took the light off it in order not to blind it – but when it got to 5 metres away, I stamped my foot as it showed no signs of stopping. We stared at the massive animal and he stared at us. After a few seconds of this I said to the stunned Connie and Thomas – 'Take a photo!'. After some unzipping of bags and fumbling around in the dark, the bemused, maybe bored, jaguar turned around and started up the trail. Tom was too awestruck to figure out how his video recorder worked.

But by now we could hear the female jaguar calling. We knew we would have another chance – if we were brave enough to follow. And we were. Sneaking down the trail as quietly as the dry leaves would allow, approaching the intimidating snarls and growls of the lovestruck jaguars, we finally saw another jaguar on the path in our lights. It was smaller and more wary – the female. Over her low growls, we could hear the male behind her.

Unfortunately she was just beyond the reach of the capacities of Tom's video camera. Soon she turned and headed away, and we followed her plaintive 'meows'. After a while we could hear the jaguars moving off the path to our right. We thought the fun was over, and started to move forward quickly in order to make up lost ground. Despite this I managed to spot a curled up vine snake resting in the undergrowth – a much easier target for Connie and Thomas. But while they snapped away, the jaguars could be heard again close by. We moved forward slowly, listening to distant territorial roars and the female's plaintive calls and I caught a glimpse of a jaguar crossing the path, moving right. Then the roaring got louder and louder. A battle of the titans of the forest commenced, Matthias vs. Jerry, out of view from us in the shadows of the forest, but recorded for posterity on a Dictaphone."

And how lucky we have it all recorded. Jaguars themselves captured on the camera. What an expedition!

Aldo, Ken and Uwe returned later with some solid shots of white-collared peccaries and Marian observed and recorded some great tamarin behaviour. Even the macaw colpa was busy, despite rather chilly weather, and Mark and Sam reported well over 30 macaws feeding on the clay. Sara then took Ines, Tamara and Ken to check the control matrix and as expected, traps were full of jaguar footprints. Ken even managed to spot a rare glimpse of a king vulture sitting on the top of a tree.

28 June

Reverse transects ruled in the cool early morning. Sara took Uwe and Anne on Transect A; Aldo left with Tamara and Marina hoping for a bit of jaguar action on C; and Alan went to see what was left of the well-forgotten Transect C2. Armed with machetes, this was the activity of choice; the slashing will certainly keep both Mark and Sam warm.

I then took Uwe with Anne to check the footprint traps on the mammal colpa, but the jaguars were well gone. There were not even prints along the main trail. On the way back, we noticed a lone spider monkey sitting on the top of the tree and calling her friends. Aldo explained to us that it got probably left behind and is now keen to get back to her family. Tristan and Savannah showed up as well, like two ghosts, their camouflaged tops working perfectly. They found a young sloth swimming across the river. Jose picked it up and they then took it to the base to recover. When we got back, however, it was gone.

29 June

The reverse transect appears more popular than ever; the base is almost empty in the mornings. Alan couldn't wait to leave – his wish to explore remote Loretillo River was just about to be fulfilled. We dropped off Uwe and Aldo at the macaw colpa and carried on further upriver, stopping at the beaches, looking for cat signs. The banks were full of tapir footprints. We also found signs of both Neotropical and giant otter. Apart from one very old track, jaguars were not as present, but footprints of margays and ocelots were numerous. Spider monkeys were hopping from one bank to another, using long jumps from branch to branch, totally oblivious to our presence. Tristan even managed to spot his first white-collared peccary. What a great little adventure.

30 June

The last full day of expedition started early in the morning, with Alan taking Ken and Sam on reverse Transect A, shortly followed by Aldo with Tristan and Savannah. The collection of camera traps was entrusted to Ines, Anne and Connie. Mark went on his own to collect the mosquito net and spot jaguar at the mammal colpa. On this last free afternoon, everyone disappeared into the forest and the base was pretty much empty until our final meeting. Alan ran through the results – there were some great pictures on camera traps as well. A superb ending to the day was a 'caiman cruise', with a great sighting of a herd of capybara, not far from the base. And then we just drifted down the river, without the engine, quiet, looking at the stars and dreaming about coming back.

1 July

We left the base after lunch, with very big knots in our stomachs. Taxis were waiting and, with reverse culture shock, we have arrived back into Puerto Maldonado with mixed feelings. If we just could go back once more...

Great expedition, great team, great results. Thank you everybody!

Jiri