Rehabilitation release of vervet monkeys (Chlorocebus pygerythrus hilgerti) in south coast Kenya: A Scientific Approach

ANDREA DONALDSON

Abstract

Rehabilitation release of vervet monkeys (*Chlorocebus pygerythrus hilgerti*) in south coast Kenya: A Scientific Approach

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Translocation is a tool for conserving animals and their environment. It is a complex process that involves detailed planning and preparation. The IUCN/SSC/RSG specifies the need for scientific employment in all animal translocation programmes pre-, during- and post-release. In this thesis, I aimed to follow and employ guidelines as detailed by IUCN/SSC Reintroduction Specialist Group for a rehabilitation release of vervet monkeys (*Chlorocebus pygerythrus hilgerti)* in Kenya. Additionally, I aimed to provide measures of post-release success, using verifiable indicators and criteria against which the release could be quantified. This was achieved by comparing biological and behavioural measures of a release vervet group with indigenous vervet control groups inhabiting the same anthropogenically modified landscape, within the same time period.

Data were collected on two habituated control groups of vervet monkeys over a 24-month observation period inhabiting an anthropogenically modified habitat in Kenya. In addition, data were collected over a 20-month pre- and post-release monitoring period on a group of released vervet monkeys, subjected to a rehabilitation release. Datasets included habitat assessments, behavioural ecology, survivorship and social networks. The control data were used to inform release site selection and provided comparable datasets against which the post-release monitoring data could be compared to assess release success.

The analysis of the release site selection process indicated that habitat assessments do not provide sufficient detail to be the only selection tool and need to be conducted alongside a minimum one-year food availability study. The behavioural ecology of the control vervet groups showed trends representative of other vervet groups living in anthropogenically modified habitat. Using the control groups behavioural ecology as a unique set of indicators

and criteria against which the release group could be monitored, proved to be invaluable. The release was deemed successful due to Release groups survivorship, activity budgets and general feeding ecology falling within the expected ranges set by the control groups. Social network analysis revealed that extended periods of captivity, where new infant individuals are introduced over time, could benefit group cohesion and ultimately post-release survival.

The findings of the study indicate that wild-born, rehabilitated vervet monkeys can be successfully returned into the wild, in close proximity to wild conspecifics. It is hoped that future translocations will follow a similar process of comparing biological and behavioural measures between indigenous control groups and newly released groups. Future translocations can benefit from the knowledge gained during this rehabilitation release, and each newly monitored and reported translocation will add vital information to the developing primate translocation model.

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A Scientific Approach

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List of Abbreviations

AZA:	American Zoological Association
BA:	Basal Area
CC:	Colobus Conservation
CI:	Confidence Interval
DBH:	Diameter at Breast Height
DJL:	Day Journey Length
FAI:	Food Availability Index
FDR:	False Discovery Rate Control
GFAS:	Global Federation of Animal Sanctuaries
GPS:	Global Positioning System
HR:	Home Range
HWI:	Human Wildlife Interaction
IUCN:	International Union for Conservation of Nature
KWS:	Kenya Wildlife Service
KVB:	Kenyan Veterinary Board
NACOSTI:	National Commission for Science, Technology and Innovation
NGO:	Non-Governmental Organisation
PASA:	Pan Africa Sanctuaries Alliance
PISp:	Phenological Index for the Species
RSG:	Reintroduction Specialist Group
SD:	Stem Density
SE:	Standard Error
sp:	Species
SNA:	Social Network Analysis
SSC:	Species Survival Commission
SSP:	Species Survival Plan
WVC:	Wildlife Vehicle Collision
WWF:	World Wildlife Fund

Statement of Copyrights

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From left to right: Top row, Rafiki; Kinky Tail, Face and Brooklyn; Frankie; Houdini, Fire and Happy. Second row, New Male; Houdini and Diego; Broken Arm. Third row, Malinidi and Mambi (used with the permission of Mona Al-Maarri); Diego; Al; Eye. Fourth row, Handy Joe; Emily; Short Tail; Kinky Tail and Kilele. Bottom row, Brooklyn and Kilele; Brooklyn, Kilele, Kinky Tail, Kelly and Rafiki; Happy.

Chapter 1 Introduction

1.1 Rehabilitation Release

Rehabilitation release is the attempt to return individuals of a given species to a natural, wild environment, and is primarily motivated by welfare of the individual, rather than conservation of the species or habitat (IUCN/SSC 2013). However, rehabilitation releases are not always entirely free of conservation benefits (IUCN/SSC 2013). A rehabilitation release generally focuses on confiscated pets, orphans or displaced animals, and involves a level of human intervention in the treatment of medical ailments or physical disabilities and/or the training of individuals to develop latent or missing skills that will be required in the wild (Beck *et al.* 2007; Cowlishaw and Dunbar 2000; Guy and Curnoe 2013). Previously referred to as welfare reintroduction (Baker 2002; Beck *et al.* 2007), rehabilitation release projects are considered outside the scope of the IUCN reintroduction and translocation guidelines, because they are not primarily conservation oriented (Baker 2002; Beck *et al.* 2007; IUCN/SSC 2013). Nevertheless, a growing illegal wildlife trade and increasing anthropogenic disturbance in once natural habitats, has contributed to a rise in animal confiscations, as well as orphaned and displaced individuals (Cowlishaw and Dunbar 2000; Peterson and Annamm 2003). As a result, there are an growing number of sanctuaries being established in habitat countries, and rehabilitation releases are on the increase (Farmer and Courage 2008). Despite not advocating the practice of rehabilitation releases, IUCN recognise that they are occurring and in the absence of specially tailored guidelines it is recommended that rehabilitation release practitioners follow and adhere to IUCN guidelines for conservation focused translocations and reintroductions (Baker 2002; Beck *et al.* 2007; IUCN/SSC 2013).

1.2 Definition of Terms

Terms relating to translocation and reintroduction are used in the literature to cover an increasingly wide range and diverse number of activities and their use is inconsistent, resulting in confusion (Armstrong and Seddon 2007). In addition, the most recently published IUCN general guidelines 'Guidelines for Reintroductions and Other Conservation Translocations' (2013) updated the definition of translocation to 'the human-mediated movement of living organisms from one area, with release in another' (pp2). In previous guidelines, translocation was defined as 'the deliberate (human-mediated) movement of wild animals from one natural habitat to another for the purpose of conservation or management' (Baker 2002; Beck *et al.*

2007; Dublin and Niskanen 2003). With the new, clearly articulated definition, translocation is now the overarching term for a spectrum of terms relating to the movement of living organism. Translocations may move living organisms from the wild or from captive origins, and can be accidental (e.g. stowaways) or intentional. Intentional translocations address a variety of motivations, including reducing population size in one area, or increasing them in another, for welfare, political, commercial or recreational interests, or for conservation purposes (IUCN/SSC 2013). Table 1.1 details the most current definitions of translocation approaches and the ones used throughout this thesis. These definitions are to be read in conjunction with Figure 1.1 which shows a typology of the conservation translocation spectrum based on the definitions in Table 1.1. Finally Table 1.2 details the definition of translocation related terminology, such as 'soft-release'.

1.3 Translocation Biology

Translocation and reintroduction biology is the field of research that aims to improve the outcome of programmes within the translocation spectrum (Armstrong and Seddon 2007). For more than 100 years conservationists have been attempting various types of translocation projects (Kleiman 1989), but the field of translocation and reintroduction biology was established much later in response to poor outcomes. It became evident during the 1980s that most translocation attempts were failing and that little was being learned in the process (Griffith *et al.* 1989; IUCN 1987; Lyles and May 1987), most likely due to poor monitoring and a reluctance to share information between programmes (Farmer and Courage 2008). This situation led to the formation of the IUCN Natural Resources Species Survival Commissions Reintroduction Specialist Group (IUCN/SSC/RSG) in 1988.

The past 20 years have seen a substantial increase in planning and monitoring, and a related increase in the number of translocation related papers in peer-reviewed journals (Armstrong and Seddon 2007; Beck 2016; Seddon 1999; Seddon and Soorae 1999). Although the growing translocation literature is a valuable source of information, it mainly consists of descriptive accounts of translocation programmes or retrospective analyses (Seddon 2007). The research questions addressed have often been driven by the monitoring data available rather than the monitoring being driven by the research questions (Armstrong and Seddon 2007; Nichols and Williams 2006). Failure to identify questions, research tasks and monitoring targets before data collection begins has often resulted in the most important data not being collected or in

Table 1.1 Definitions of intentional translocations and the various approaches within the translocation spectrum, as direct citations from IUCN/SSC/RSG publication. This table is to be read in conjunction with Figure 1.1.

Translocation	**The human-mediated movement of living organisms from one area, with release in another**			
	Conservation translocation	The intentional movement and release of a living organism where the primary objective is a conservation benefit: this will usually comprise improving the conservation status of the focal species locally or globally, and/or restoring natural ecosystem functions or processes		
		Population restoration	Any conservation translocation to within indigenous range	
			Reinforcement	The intentional movement and release of an organism into an existing population of conspecifics
			Reintroduction	The intentional movement and release of an organism inside its indigenous range from which it has disappeared
		Conservation introduction	The intentional movement and release of an organism outside its indigenous range	
			Assisted Colonisation	The intentional movement and release of an organism outside its indigenous range to avoid extinction of populations of the focal species
			Ecological replacement	The intentional movement and release of an organism outside its indigenous range to perform a specific ecological function

Table 1.1 continued Definitions of intentional translocations and the various approaches within the translocation spectrum, as direct citations from IUCN/SSC/RSG publication. This table is to be read in conjunction with Figure 1.1.

Translocation	**The human-mediated movement of living organisms from one area, with release in another**		
	Non-conservation translocation	The intentional movement and release of a living organism where the primary objective is not a conservation benefit. IUCN recognise these types of translocation may have conservation benefits, but that conservation benefit is not the primary objective for translocation	
		Rehabilitation release	The release of individuals for the sake of their welfare, or for rehabilitation from captivity
		Commercial or recreational	The augmentation of a population for the purposes of recreational or commercial off take
		Mitigation translocation	The removal of organisms from habitat due to be lost through anthropogenic land use change and release at an alternative site. The release site will dictate the nature of the mitigation measure; population restoration or conservation introduction
		Removal for intensive protection	The removal of organisms from their natural environment into conditions of intensive protection, as provided by zoological and botanic gardens and other dedicated facilities
		Least risk, least regret translocation	The translocation of species that are neither naturally scarce nor declining, nor with high probabilities of extinction. These often occur as partnerships between local communities and conservation professionals, in which the principle motivation is the restoration of a component of local cultural heritage

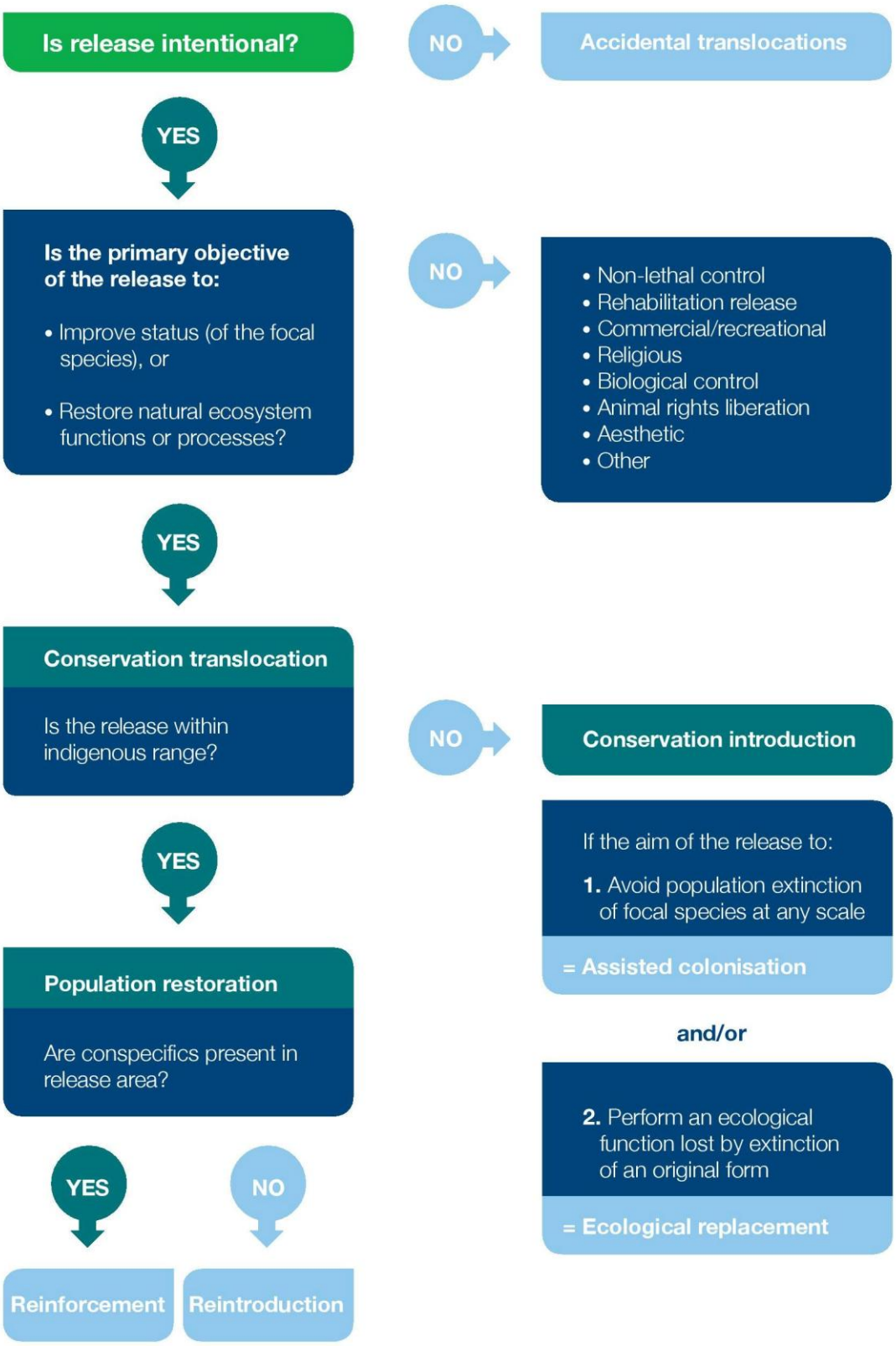


Figure 1.1 The translocation spectrum (IUCN/SSC 2013) pp23

Table 1.2 Definition of translocation related terminology as direct citations from IUCN/SSC/RSG publications

Term	Definition	Reference
Soft Release	Animals are held in an enclosure at or near the release site prior to release, to assist them in adjusting to their new environment. Post-release support, such as supplemental feeding and protection from predators is usually provided	(Baker 2002; Beck *et al.* 2007)
Hard Release	Animals are not held in an enclosure prior to release, except during transportation. Animals are immediately released at the release site and generally there is no post-release support. However, medical intervention is sometimes required to vaccinate animals and guard against parasite transfer, in which case, short term medical rehabilitation may be required	(Baker 2002; Beck *et al.* 2007)
Rehabilitation	The process by which captive animals are treated for medical and physical disabilities until they regain health, are helped to acquire natural social and ecological skills and are weaned from human contact and dependence, such that they can survive independently in the wild. Rehabilitation is generally restricted to the soft release strategy as it requires periods of extended captivity	(Baker 2002; Beck *et al.* 2007)
Release	Placing an animal in a natural environment, under conditions that replicate those experienced by the animal in their natural habitat, including density, sex ratio, group size, breeding systems, environmental conditions, dependence on provision and selection pressures	(IUCN/SSC 2013)
Captive born	Animals born in captivity	(Baker 2002; Beck *et al.* 2007)
Wild born	Animals born in the wild (natural habitat) to free living parents	(Baker 2002; Beck *et al.* 2007)
Captive	Animals held in captivity, such as in enclosures, private homes, or semi-wild environments, for a prolonged period. Captive individuals can be wild-born or captive-born	(Baker 2002; Beck *et al.* 2007)

the monitoring effort not being allocated to the projects where it is most needed (Armstrong and Seddon 2007).

Translocation is a complex process and involves detailed planning and preparation. The goals, objectives and actions of a translocation program need to be defined, economic and political limitation considered, suitability of a species and of individuals for translocation assessed, methodology explored (veterinary protocol, quarantine, capture, transfer and release) and established, risk assessments conducted, potential release sites surveyed, extensive post-release monitoring conducted, an exit strategy planned and a measure of success defined (Baker 2002; Beck *et al.* 2007; IUCN/SSC 2013). This list is not exhaustive, as every aspect and eventuality needs to be considered because inadequate planning can cause a translocation to be unsuccessful (Baker 2002; Farmer and Courage 2008).

1.4 Consideration of Translocation Programmes

Translocation programmes can be disastrous to individual animals, entire populations, species and ecosystems if not conducted correctly (Kleiman 1989). It is for this reason that an in-depth feasibility study must be carried out prior to initiating a program to ensure that all criteria necessary for a successful translocation can be met (Baker 2002; Beck *et al.* 2007; Britt *et al.* 2004; IUCN/SSC 1995, 2013; Kleiman 1989; Sarrazin and Barbault 1996; Stanley-Price 1989). All IUCN translocation and reintroduction guidelines are summarised with a decision tree to enable practitioners to assess whether the proposed programme can meet the basic recommended criteria (Figure 1.2).

1.4.1 Is there a need for translocation?

The goals, objectives and actions of a translocation programme must be clearly defined prior to embarking on the project (Beck *et al.* 2007; IUCN/SSC 2013). In the case of conservation translocation programmes the primary aim must have a conservation benefit, and is likely to include re-establishing a viable, self-sustaining population in the wild (Baker 2002; Beck *et al.* 2007; IUCN/SSC 2013), with possible secondary objectives to promote community conservation awareness, enhance protection and law enforcement efforts and/or improve psychological or physical well-being for individual animals (Beck *et al.* 2007). Rehabilitation releases will have differing primary objectives, however, IUCN conservation translocation guidelines must be adhered to as closely as possible (Baker 2002; Beck *et al.* 2007; IUCN/SSC 2013). Reintroductions, and more broadly, translocations are complex and expensive

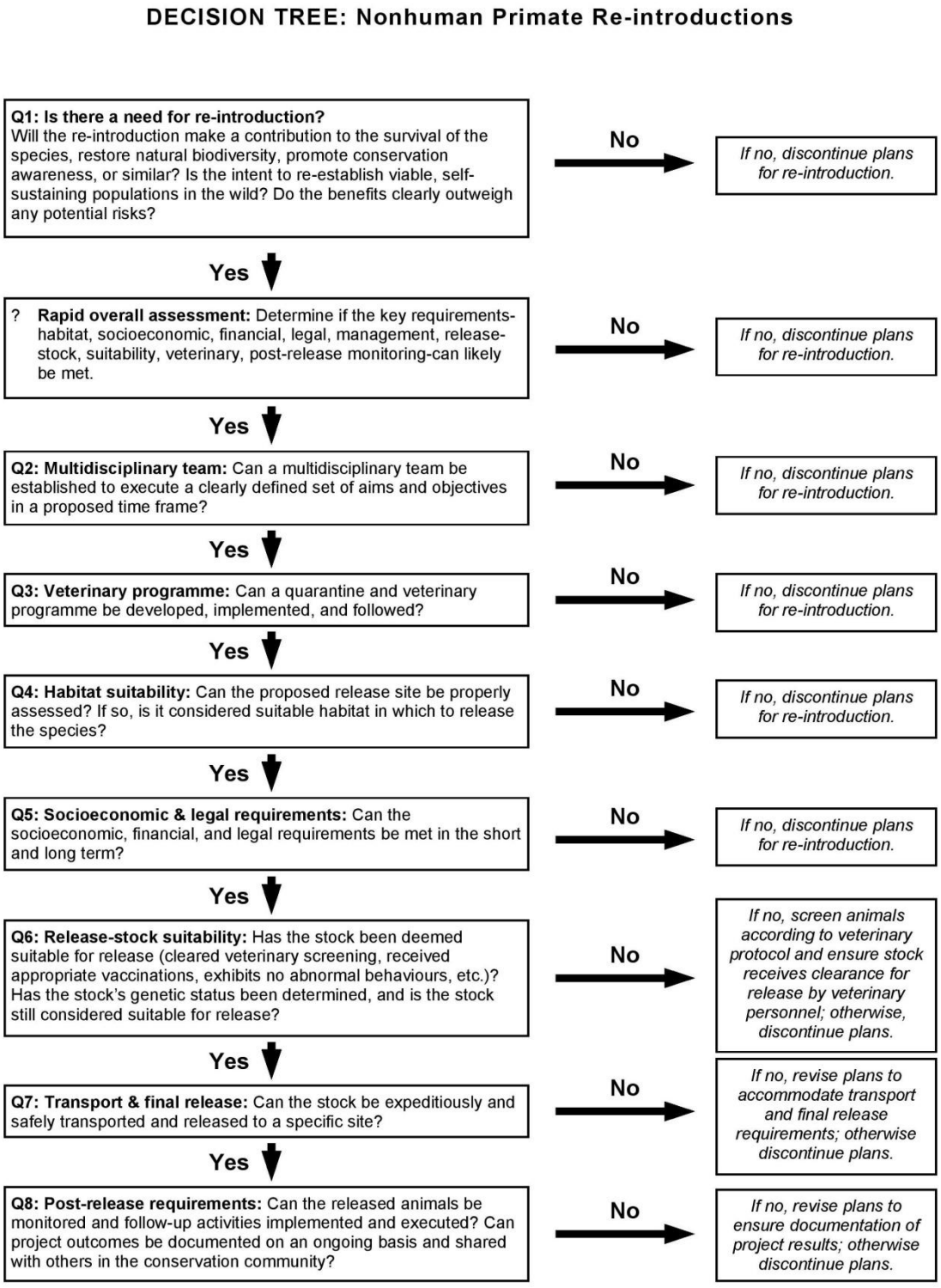


Figure 1.2 An example of an IUCN decision tree for reintroduction assessment. The example shown is specific for non-human primate reintroduction (Baker 2002) pp31.

processes, and each programme must be reviewed on its individual merits. Consideration of whether allocating available funds to alternative projects would be a better use of the finances must be made, i.e. protection of current wild populations, habitat protection, law enforcement

or sanctuary expansion (Baker 2002; Beck *et al.* 2007). Ultimately, "reintroduction must aim to be an effective component of an overall conservation scheme or an alternative to other ineffectual conservation efforts" (Beck *et al.* 2007, pp 6).

1.4.2 Multidisciplinary Team

Translocation programmes require a multi-disciplinary approach involving a team of people from a variety of backgrounds, with a range of expertise (Baker 2002; Beck *et al.* 2007; IUCN/SSC 2013). The team should include taxon specialists, animal care experts, veterinarians with species appropriate experience, and representatives from governmental natural resource agencies, non-governmental organizations, local communities, and funding bodies. A detailed veterinary programme must be established to manage the issue of potential disease transmission, both anthropozoonotic and zoonotic (Baker 2002; Beck *et al.* 2007; IUCN/SSC 2013).

1.4.3 Risk Assessment

Translocation bear risks (IUCN/SSC 2013). In order to preserve the safety of the translocated species, the personnel involved, and maintain the integrity of the project, it is essential that a full array of possible hazards, pre- during- and post-translocation, are assessed in advance. There are seven main categories of risk relating to translocations highlighted by the guidelines. (1) Risk to source population, except under rare conditions the integrity of the source population should not be compromised by the removal of individuals for translocation. (2) Ecological risk, translocated species may have major impacts on other species, and on ecosystem functions in the release site. (3) Disease and parasite risk, no organism is entirely free of infection or parasites and transmission within the new habitat is always a risk. (4) Associated invasion risk, care should be taken that potentially invasive species are not accidentally released with individuals of the focal species. (5) Gene escape, genetic exchange may be the purpose of reinforcement, however, when historically isolated populations are mixed, or individuals moved outside their indigenous range there is a risk of hybridisation, which may result in lower fitness of offspring and/or loss of species integrity. (6) Socio-economic risks, the livelihood of people may be negatively impacted upon, directly by the released organism or indirectly by impacts which affect the ecosystem services. (7) Financial risk, funding for the life of the translocation project needs to be secured, with contingencies in place in case of discontinuation of the translocation or damages caused by the translocation species (IUCN/SSC 2013).

1.4.4 Habitat Assessment and Release Site Selection

A primary requirement of a translocation project is securing a suitable release site. The site must be able to provide sufficient year-round resources for the released individuals, without negatively impacting the ecological resources of the species already present (Armstrong and Seddon 2007; Moinde *et al.* 2004). Releasing into areas with wild conspecifics raises questions about disease, parasite and gene transmission (Baker 2002; IUCN/SSC 2013) and must be fully reviewed as part of the veterinary programme and risk assessment. In addition, the site must offer adequate protection from human threats, such as logging and hunting, and not expose the released animals to situations of conflict with humans, by being located too close to human habitation (Farmer and Courage 2008; King *et al.* 2005; Tutin *et al.* 2003). Limited knowledge of the subject animal and habitat requirements, accompanied with inadequate understanding of the selected release habitat are reasons why translocations may be ultimately considered unsuccessful (IUCN/SSC 2013). Take, for example, the reintroduction of the Alpine marmot (*Marmota marmota*) in Friuli-Venezia Giulia started in 1960. Marmots have been released in many isolated areas since then, but reintroduction was only successful in a few of them. The principal cause of failure seems to have been the unsuitability of the release sites. There is a lack of research on the habitat requirements of the Alpine marmot in the Eastern Italian Alps even though such studies are particularly necessary because of the local extinction, and subsequent reintroduction of the species in this area (Borgo 2003). It is therefore essential that any translocation project is informed by an assessment of habitat quality at release sites. The availability of food, water and sleeping sites safe from predators are the most important habitat features and must be available throughout the year (Britt *et al.* 2004; Harrison 1983a; Isbell 1990; Nakagawa 1999).

Carrying capacity of the release site must be determined or at least scientifically estimated (Baker 2002; Beck *et al.* 2007; IUCN/SSC 2013). The release site needs to be sufficient to sustain growth of the translocated population and support a self-sustaining population in the long run. For reinforcement projects, the size of the resident population relative to carrying capacity, density, habitat use, and social structures must be determined (Baker 2002; IUCN/SSC 2013).

1.4.5 Socioeconomic and Legal Requirements

Conservation translocations are long-term projects that require continued public, political and financial support (Baker 2002; Beck *et al.* 2007; IUCN/SSC 2013). Consultation with other translocation practitioners and a review of the costs of previous projects are advised so that

the actual monetary investment, time commitment, and similar requirements are fully understood before a translocation is initiated. In cases of reintroductions involving captive populations, and rehabilitation releases it may be that providing lifetime care for the animals in captive colonies or sanctuaries is less expensive than the associated translocation process (Beck *et al.* 2007). Expensive conservation programs have long been controversial and the cost related to translocation and reintroduction programmes is no exception. Conservationists critical of reintroduction projects maintain that the funds would be better spent on in-situ conservation measures (MacKinnon and MacKinnon 1991; Snyder *et al.* 1996), whilst supporters emphasise that additional benefits arise from reintroduction projects other than those related to the animals/species involved (Farmer *et al.* 2006; Goossens *et al.* 2005; Tutin *et al.* 2003). For example, the reintroduced species may act as a flagship, attracting funding for related projects such as habitat protection and community education (Kleiman *et al.* 1991). Conservation biology by its nature can be inexact, and to rely on the single strategy of in-situ conservation, without development of alternative strategies such as translocation may actually increase the risk of extinction (Lindburg 1992).

Translocation programmes must gain full permission and involvement of all relevant government agencies in addition to a socioeconomic understanding of the impact, costs and benefits of the translocation to local human populations (Baker 2002; Beck *et al.* 2007). Local communities should understand, accept and support the translocation programme and opportunities for project-related employment and training should be offered preferentially to members of the local communities (Beck *et al.* 2007). Action plans for managing post-release conflict and/or interactions with humans must be in place and fully understood by all project staff prior to the release commencing (Beck *et al.* 2007).

1.4.6 Release Animals, Rehabilitation and Captive Care

The translocation of animals that have spent significant periods of time in captivity is complex (Earnhardt 2010; Tutin *et al.* 2003). However, if those individuals have spent some time in the wild, regardless of how little, survival rates are greatly increased (Fischer and Lindenmayer 2000; Griffith *et al.* 1989). Actively stimulating captive animals is essential to prevent the development of stereotypic behaviours (Kreger *et al.* 1998), preserve the full range of natural behavioural responses and maintain an animal that is viable for translocation. Such objectives are achieved through environmental enrichment (Kreger *et al.* 1998). For captive animals scheduled for translocation, enrichment includes the provisioning of a naturalistic environment and of specific foraging tasks. Structurally, the captive environment can be

designed to provide an experience of the habitat the animal is likely to be exposed to in the wild (Miller *et al.* 1996; Sheperdson *et al.* 1993). For example, zoo-housed lion tamarins were given an opportunity to move around on natural vegetation prior to release (Beck *et al.* 1991). Similarly, wild cats were provided with live fish or hidden food to encourage natural predatory tendencies and discourage stereotyped pacing (Sheperdson *et al.* 1993). Translocation programs must provide captive animals foods similar to those they will encounter in the release site (Baker 2002; Beck *et al.* 2007; IUCN/SSC 2013), as well as avoid feeding crop foods grown by near-by communities in order to reduce human-wildlife interactions and crop raiding (Beck *et al.* 2007). Translocated animals that have exposure to live prey or native food items develop an enhanced ability to survive once released (Morgan-Davies 1980; Phillips *et al.* 1995). Food items can be hidden around the enclosure, encouraging the animals to work for their food. Using this method, animals can be primed to search actively for and catch live prey upon release. For example, lion tamarins were given an opportunity to search for and extract hidden food items (Beck *et al.* 1991; May 1991).

1.4.6.1 Life Skills Training

The behaviour of captive mammals is influenced by the confinement of captivity (Carlstead 1996). Many skills essential for survival in the wild are not needed for captive survival and may be lost via genetic changes resulting from adaptations to captivity (Earnhardt 2010), or may be missing through reduced developmental opportunities (Stoinski *et al.* 2003). As captive individuals lack behavioural skills to survive in wild habitats, using captive populations as a source will invariably reduce the probability of success of a translocation programme. There are, however, methods available to address the problems of behavioural incompetence. Pre-release screening protocols may be used, in which behaviours of wild conspecifics provide the baseline, and controlled behavioural experiments assess the suitability of specific captive-bred individuals for release (Mathews *et al.* 2005). Some species are flexible, and individuals can acquire appropriate behaviours; in these cases the development of specific pre-release training programmes may increase post-release survival (Beck *et al.* 1991; Biggins *et al.* 1999).

Predation animals naive to a wild environment, is a major source of high post-release mortality (Baker 2002; Beck *et al.* 1991). Griffin *et al.* (2000) proposed that captive-bred animals should experience anti-predator training routinely in a bid to reduce this effect. The ability of primates to 'learn' behaviours by watching the response of other conspecifics has a great advantage in enhancing the success of the pre-release training (Griffin *et al.* 2001). For example, in captivity, wild-born rhesus macaques (*Macaca mulatta*) showed a fear of snakes, whereas

captive-born macaques did not (Mineka *et al.* 1980). However, captive-born individuals socially learned to fear snakes simply by watching a wild-born individual behave fearfully toward a snake (Cook *et al.* 1985; Mineka *et al.* 1980).

1.4.6.2 Welfare

Adhering to internationally accepted standards for animal welfare, alongside complying with the legislation, regulations and policies in both the source and release areas is essential for all translocation programmes. Animals undergoing translocation may experience stress during capture, handling, transportation, release and adaptation to the wild, or adaptation to a new wild location (Aguilar-Cucurachi *et al.* 2010; IUCN/SSC 2013). The stresses experienced may differ for different species and also for captive-born and wild-caught animals of the same species. In addition, animals in the source population and the release site population may suffer stress from social disruption and/or resource reduction. Translocation personnel must make every effort to reduce potential stress and suffering (IUCN/SSC 2013).

1.4.7 Transport and Release

The actual release of individuals is an important stage in any translocation process. If transportation of animals to a release site is applicable, careful planning to minimise the level of stress individuals are subjected to is essential (Baker 2002). Considerations required include qualified staff to accompany the animals in transit to deal with any emergencies, facilities to separate animals during transit to prevent injuries, the best time of day to travel and the provisioning of food and water (Baker 2002). On arrival at the release site the transported animals must be placed in a purpose built pre-release enclosure. This allows a recovery period from the stress of travelling, and for group living species, ensure bonds are re-established prior to release (Baker 2002).

Preparation of the release site, such as mapping and marking trails, testing of radio tracking equipment, erection of pre-release enclosure(s) and feeding stations, must be completed prior to the arrival of the animals, ensuring that stress and disturbance to the animals is kept to a minimum (Baker 2002). Once in the pre-release enclosure, careful monitoring of each animal is required, to ensure ailments or abnormal behaviours have not developed during transit. Food provisioning, at the release site, on the day of release, reduces the chances of the newly released animals immediately dispersing in fear (Farmer *et al.* 2006). For group living species reducing immediate dispersal following release allows the group to remain stable and cohesive, increasing survivorship (Farmer *et al.* 2006). Prolonged food provisioning, to ease the

transition from captive to wild living, is standard in many successful soft releases (Beck *et al.* 1991).

1.4.8 Post-release Requirements

Post-release responses and survival of animals can only be determined through long term monitoring of individually identified animals (Miller *et al.* 1996; Ostermann *et al.* 2001; Saltz and Rubenstein 1995; Stoinski *et al.* 2003). This requires collecting data on behavioural, demographic and ecological factors as well as taking into account social changes, health, reproductive behaviour, mortality and impact on the habitat. In addition, these data sets can assist in the planning of future translocation programmes.

Health monitoring of the released individuals is essential to establish a baseline for when intervention is necessary and to increase survival. Protocols should be developed prior to release to reflect a wide variety of possible circumstances in which intervention may be necessary, e.g. an injured or problem animal. Decision-makers must be clearly identified (Baker 2002; Kierulff *et al.* 2002).

The overall success of a translocation project requires regular evaluation and may result in revision, rescheduling or the discontinuation of the programme (Baker 2002). The dissemination of post-release information to the translocation and scientific community, local communities, and appropriate governmental bodies, ensures that other translocation practitioners will benefit from the results.

1.4.9 Exit Strategy

Even with thorough planning, translocations do not always proceed as expected. There may come a point when further investment can no longer be justified, regardless of all prior actions already undertaken. A clear and fully researched exit strategy is an integral part of any translocation plan and should be agreed upon in the early planning stages of a translocation project. The exit strategy includes indicators of lack of success, along with the tolerable limits of their duration, and contingency plans if undesired and unacceptable consequences occur. An exit strategy must aim to consider and evaluate the survival of the translocated population, their impact upon the release site and/or its inhabitants. Having a strategy in place ensures that all stakeholders are knowledgeable of potential failures, and have agreed a rational and justifiable protocol that may lead to the termination of a translocation.

1.5 Evaluating Translocation Success

The IUCN guidelines state that the aim of translocation is to "establish a self sustaining wild population" (Baker 2002; Beck *et al.* 2007; IUCN/SSC 2013), but do not offer any alternative protocol or standardised method of assessing when, or if a translocation has been successful. When dealing with long-lived animals, it may take a long time to evaluate if a population is viable (Pinter-Wollman *et al.* 2009), and generally requires a longer time investment than funding permits. As a result, quantifying the success of a translocation programme involving long-lived animals is difficult, with each translocation programme, or external assessors, devising individual guidelines with varying parameters as measures of success. In a general review of animal reintroduction, challenges and lessons, Sarrazin and Barbault (1996) only consider reintroduction successful when the first wild-born generation reproduce, or when a third generation breeding population becomes established, with recruitment exceeding adult death rate. Similarly, Griffith *et al.* (1989), who reviewed translocations of native birds and mammals in Australia, Canada, Hawaii, New Zealand and the USA, set their criteria to establish a self-sustaining population or population persistence. While discussing criteria for success in the Golden Lion Tamarin Conservation Program, Kleiman *et al.* (1991) suggest two differing measures of success, depending on the ecology of the species released. For 'K-selected' species, the simple post-release survival of reintroduced individuals can be taken as an indication of success. However, for 'r-selected' species, reintroductions can only be regarded as successful if there is reproductive output and infant survival during the early years. Seddon (1999) argues that regardless of the species, success of a project can only be determined at the time of assessment and that standardised categorisation of reintroduction projects as successful could have negative ramifications were it to define an end-point beyond which further conservation efforts would be deemed unnecessary.

A review of published reintroductions using captive-born animals, defined success as when the wild population attained a size of 500 surviving individuals or when it showed long-term viability in a population viability analysis (PVA) (Beck *et al.* 1994). However, without consideration of the life history traits of the translocated species, habitat quality of the release area or eventual metapopulation structure, this threshold of 500 individuals is relatively arbitrary (Sarrazin and Barbault 1996). According to Beck *et al* (1994) criteria only 11% of reviewed reintroductions were considered successful. In contrast, Soorae (2008) reviewed 62 reintroduction projects of animals and plants and considered 21% highly successful, 33% successful, 43% partially successful and only 3% as failures. Soorae (2008) attributed success to

good rearing techniques, increase in species distribution range and increased socio-political awareness within the local and/or global human community. Projects were considered partially successful or failures if there was no post-release monitoring, slow reproduction rates, poor habitat quality and a failure to establish a viable population. However, evaluating the success of a reintroduction is difficult; goals vary from programme to programme, and are dependent on whether the reintroduction is a conservation translocation or rehabilitation release. Following reintroduction guidelines, evaluation depends on methodology, and objectives are time-dependent (Sarrazin and Barbault 1996; Seddon 1999). While the success of reintroduction programmes has arguably been limited to date, the increasing risk of global extinctions will cause their importance and value to grow in the future (Cowlishaw and Dunbar 2000; Lindburg 1992). Therefore, there is a requirement for more intensive research on reintroduction strategies in order to determine the factors that currently limit effectiveness (Day 2003).

In recent years, a more detailed analysis of behaviour and interactions of newly released animals within their environment, and in comparison to species relevant published data, have offered greater insight into the ability of individuals to adapt and become established within the habitat. Furthermore, measurable results that other releases can learn from are provided (Guy *et al.* 2012; Humle *et al.* 2010; Pinter-Wollman *et al.* 2009; Strum 2005; Wimberger *et al.* 2010b). These measures include details of home range patterns (Cowan 2001; Guy *et al.* 2012; Humle *et al.* 2010; Moehrenschlager and Macdonald 2003; Pinter-Wollman 2009; Wimberger *et al.* 2010b), foraging efficiency (Britt and Iambana 2003; Farmer *et al.* 2006), activity budgets (Farmer *et al.* 2006; Guy *et al.* 2011, 2012; Wimberger *et al.* 2010b), survivorship and reproduction rates (Goossens *et al.* 2005; Guy 2013; Guy *et al.* 2011, 2012; Humle *et al.* 2010; Kleiman *et al.* 1991; Osterberg *et al.* 2015; Wimberger *et al.* 2010b). Despite the recognition of using behavioural measures to indicate success of translocation, few post-release studies compare detailed measures of behavioural and feeding ecology of released groups to data from indigenous control groups, collected in the same time frame as the translocation occurred. Strum (2005) strongly advocates that measures of translocation success must be both verifiable and broadly applicable, with indicators evaluated relative to a detailed performance target or controls groups. Environmental factors within a release location may affect food supply; and close monitoring of the indigenous populations and release groups provides a more detailed understanding of successes and failures (Strum 2005).

1.6 Primate Translocations

Historically, primate translocation programs have not been well documented and have incorporated little pre-release planning and post-release monitoring (Moinde *et al.* 2004; Struhsaker and Siex 1998; Warren and Swan 2002). Such absence of scientific rigor within the framework of translocation programs has likely contributed to a poor overall success rate (Moinde *et al.* 2004), and has generated significant scientific scepticism (Ewen and Armstrong 2007; Sarrazin and Barbault 1996). Inadequate details of pre-release planning, methodology and lack of post-release monitoring made it impossible to define what factors led to success or failure of the translocation and introduction of red colobus (*Procolobus kirkii*) into Zanzibar (Struhsaker and Siex 1998). Similarly, no data exist to quantify the outcome of hundreds of orangutans (*Pongo abelii; P. pygmaeus*) reintroduced into protected areas in Malaysia and Indonesia since the mid 1970s (Warren and Swan 2002). However, in recent years a more stringent approach has become the trend, and reporting on successes and failures is increasing. For example release site selection for gibbons (Cheyne 2006; Wade and Malone 2013), the reintroduction of wild-born orphaned chimpanzees (Ancrenaz 2001; Goossens *et al.* 2005; Hannah and McGrew 1991; Humle *et al.* 2010) and their inability to thrive post-release due to lack of life skills (Hannah and McGrew 1991), dietary adaption of lemurs (Britt and Iambana 2003), rehabilitation release of rehabilitated vervet monkeys (Guy 2013; Guy *et al.* 2011, 2012; Wimberger *et al.* 2010b) and reintroduction of orangutans (Russon 2008), pre-release training (Schwartz *et al.* 2016), behavioural ecology and group cohesion of gorillas (Le Flohic *et al.* 2015), rehabilitation and translocation of slow lorises (Moore *et al.* 2014) and species specific proposed guidelines (Cheyne *et al.* 2012; Guy and Curnoe 2013).

Using the IUCN criteria of a self sustaining population indicating success, there have been some successful primate reintroductions; most notably the golden lion tamarin (*Leontopithecus rosalia*) project (Kierulff *et al.* 2002) and H.E.L.P., a chimpanzee (*Pan troglodytes troglodytes)* reintroduction programme (Ancrenaz 2001; Farmer *et al.* 2006; Goossens *et al.* 2005). These projects are considered two of the few primate reintroduction programmes to be precisely designed, monitored and well documented. The scientific approach taken towards these programmes allowed the reintroductions to be planned and evaluated systematically. The success of the golden lion tamarin project, defined by survival rates of the monkeys and the subsequent rate of reproduction, was attributed to the soft release protocol and the intensive post-release monitoring that facilitated identification of sick and injured individuals needing rescue, and the targeted provision of food and critical

resources such as nest boxes until the individuals were fully adjusted to life in the wild (Kierulff *et al.* 2002).

Translocations, regardless of species, are complex, extensive and expensive, and the success of a programme is never guaranteed (Kleiman 1996). After the first six years of the golden lion tamarin reintroduction project it was estimated that each surviving reintroduced tamarin had cost $220,000 (Kleiman *et al.* 1991), with post-release management costs estimated at $7000 per surviving individual (Kierulff *et al.* 2002). As a project becomes more established, such high costs are likely to decline. However, the expense of intensive pre- and post-release training of captive-bred animals and the isolated nature of the areas where reintroductions occur will always raise the question as to whether such population management is a cost-effective conservation tool (MacKinnon and MacKinnon 1991; Snyder *et al.* 1996).

1.6.1 Wild-born versus Captive-born

In general, the translocation of captive animals refers to animals that have been bred, selected and trained, entirely in a captive environment (Baker 2002; Beck *et al.* 2007; Britt *et al.* 2004; Earnhardt 2010). Individuals are carefully selected to give a good genetic representation of the wild population, without over-harvesting of the captive stock (Earnhardt 2010). Conversely, the translocation of wild-born animals is the deliberate movement of wild animals from one natural habitat to another for the purpose of conservation or management.

There is a cross-over between these two translocation types; the translocation of wild born individuals that have been held captive as a result of human/wildlife interactions. This area is of particular importance when the animals in question represent a threatened species, and the translocation of such animals has a primary conservation benefit, in addition to welfare aims. Therefore adhering to conservation translocation definitions. Rehabilitation releases occur when the welfare of the individual, rather than conservation of the species, is the driving force for releases (IUCN/SSC 2013). Strategies used in these translocation of wild-born captive individuals can be different from those used with captive born individuals (Chivers 1991). Animals born in the wild and with the advantage of prior wild experience have higher survival rates upon release than captive born individuals (Fischer and Lindenmayer 2000; Griffin *et al.* 2001; Kleiman 1996).

1.6.2 Rehabilitation Release

Tutin *et al.* (2003) state that the importance of avoiding extinction is clear, but questions if the release of captive individuals can be justified in situations where the species is not under

immediate threat of extinction in the wild. The majority of translocations occur as a result of two separate problems; the population concerned is under threat, classed as a conservation translocation, or in response to the ethical problem of orphan animals, defined as rehabilitation release (Beck *et al.* 2007; Cowlishaw and Dunbar 2000; Farmer and Courage 2008; Hannah and McGrew 1991). Rehabilitation releases have different goals to those of conservation translocations. Such projects aim to improve the welfare of individual animals, to enable displaced, sick, injured or orphaned wild animals to function normally and live self-sufficiently (Anon 2008), rather than aid the conservation of a species. In many cases animals subject to rehabilitation release have spent some time living in the wild prior to becoming captive, which immediately increases the chances of survival (Fischer and Lindenmayer 2000; Griffith *et al.* 1989). However, the experiences these animals have been subjected to during their time in captivity, mean individuals require a period of rehabilitation and de-habituation to humans (pers. obs.). Due to the difference in the ultimate aim of rehabilitation releases to conservation translocations, the success of such projects can arguably be measured using a different set of criteria (Goossens *et al.* 2005). If a rehabilitation release fails to maintain or actively improve the welfare of previously captive individuals, then the continuation of such programmes should be questioned (Goossens *et al.* 2005).

1.7 Study Species

Vervet monkeys (*Chlorocebus pygerythrus*) are opportunistic omnivorous primates, living a semi-terrestrial, semi-arboreal lifestyle. This flexibility is reflected in their distribution, which covers most of sub-Saharan Africa (Wolfheim 1984), where they predominantly occupy open canopy forest or woodland habitats that have herb/shrub/grass rich ground layers. Typically found in multi-male, multi-female groups of around 20-30 individuals, vervet monkeys occupy stable home ranges of between 0.18km^2 and 6km^2 that may overlap with neighbouring groups (Lee and Hauser 1998).

Variation in population density and group size of vervet monkeys is determined by habitat quality, principally food abundance and water availability (Harrison 1983a; Lee and Hauser 1998; Struhsaker 1967a). The feeding ecology of a population of vervet monkeys in Amboseli, Kenya, indicated consumption of 46 different plant species (Lee and Hauser 1998). The most important food plants were considered to be *Acacia xanthophloea* and its associated woodland species, along with *A. tortilis* (Lee and Hauser 1998; Struhsaker 1967a).

With a relatively small body size, males: 4–8 kg; females: 3–5 kg (Willems and Hill 2009), vervet monkeys are subject to high rates of predation by up to 16 different predators (Struhsaker 1967a), including wild cats (*Panthera sp*. and *Felix sp*.), hyenas (*Hyaena sp.*), jackals (*Canis sp*.) and baboons (*Papio sp*.). In an avoidance response from ground predators, vervet monkeys are known to use tall trees, positioned in woodland, as sleeping and refuge sites (Nakagawa 1999).

1.7.1 Rehabilitation Releases of Vervet Monkeys

Published research detailing the rehabilitation release of vervet monkeys is confined to just four studies, all based in South Africa (Guy 2013; Guy *et al.* 2011, 2012; Wimberger *et al.* 2010b). Wimberger *et al.* (2010) detailed the release of two groups of vervet monkeys in South Africa. Using a soft release strategy, with 11 months post-release monitoring, the progress of the groups was well documented. However, details of the pre-release planning and habitat selection were not provided. Post-release survival was used as the indicator of success, resulting in the release being deemed unsuccessful due to a 20% mortality rate in 10 months, compared to 15% annually for wild groups. Yet, when success indicators in terms of rehabilitation release were analysed, individuals behaved similarly to wild conspecifics, were independent from humans for food and/or companionship and the groups became established in an area. On the basis of these criteria, Wimberger *et al.* (2010) argued that future releases could be successful. The rehabilitation release of a vervet group in KwaZulu-Natal was deemed a partial success (Guy *et al.* 2011). A large number of missing animals with unknown fates (65%) made survival difficult to assess, however the remaining individuals that were monitored displayed a range of wild behaviours. To combat post-release monitoring problems in future releases, Guy *et al* (2011) recommended radio collaring all released individuals. A vervet rehabilitation release into the Ntendeka Wilderness Area of KwaZulu-Natal, South Africa was also considered a partial success (Guy *et al.* 2012). The group experienced a high mortality rate as a result of predation and hunting and post-release monitoring was limited to 6 months due to the lifespan of radio collars used. However, during this time release group members were a wild-living, independent group exhibiting a range of natural behaviours. Finally, the rehabilitation release of a group onto a Game Farm in KwaZulu-Natal, South Africa had a higher survival rate of 62% at six months post-release; conversely the projected one year survivorship was just 28% as a result of illegal hunting. Details of behavioural ecology were not included in the report (Guy 2013). None of these rehabilitation releases would be considered successful following the IUCN criteria for conservation translocations of establishing a self sustaining population.

1.8 Aims

The translocation of primates is a complex process with variable results, and rehabilitation releases of vervet monkeys present a low success rate. The release project presented in this thesis of Hilgert's vervet monkey (*Chlorocebus pygerythrus hilgerti*) meets the criteria of a rehabilitation release. In the absence of specific guidelines for rehabilitation release, this project aimed to follow the IUCN recommendations for a reinforcement translocation. A soft release strategy that included the rehabilitation of wild born primates, which had spent many months or years in captivity as a result of the live animal trade or human/wildlife interactions, was used. This strategy was combined with robust pre-release ecological and behavioural data collection, an 18 month post-release monitoring period of both the release and two wild indigenous control groups, and recording of important environmental variables. The methodology was predominantly guided by the IUCN Guidelines for Non-human Primate Reintroductions (Baker 2002; Beck *et al.* 2007), in conjunction with the IUCN Guidelines for Reintroductions and Other Conservation Translocations (IUCN/SSC 2013). The primary aim of this thesis is to investigate whether the rehabilitation and release of vervet monkeys can be achieved successfully.

1.9 Thesis Outline

This thesis compiles seven chapters. Chapter 2 is the methodology chapter and presents a description of the study site and species, and contains an overview of ecological and behavioural sampling methods that are used in multiple subsequent chapters. Chapter 3 details considerations for release site selection and presents the results of habitat assessments of known vervet monkey habitat in the area of release and of the selected release site. Additional information details the results of a one year phenological study of the research areas and a post-release impact assessment of the habitat. Chapter 4 presents the basic behavioural ecology of two control vervet groups and how the anthropogenic environment in which they live influences this. Chapter 5 is an assessment of changes in the behavioural ecology of a vervet release group for 18 months post-release and a comparison of their behaviour to that of two control groups. Chapter 6 details cohesion of the release group, pre- and post-release with comparisons to group cohesion of two control groups. Chapter 7 integrates all of the previous chapters for general discussion, highlights factors that required careful consideration in the release process and presents interesting preliminary findings that warrant further analysis.

Chapter 2 General Methods

2.1 Study Site

2.1.1 Coastal Forests of Eastern Africa

The Coastal Forests of Eastern Africa (Clarke 2000), formally referred to as the Northern Zanzibar-Inhambane Coastal Forest Mosaic (White 1983), are an area of high endemism. Presently, these coastal forests are listed as one of 25 global biodiversity hotspots (Myers *et al.* 2000) and one of 11 'priority' regions for international conservation investment (Brooks *et al.* 2002). The coastal forest band stretches from small patches of coastal (riverine) forest along the Jubba and Shabelle Rivers in southern Somalia, south through Kenya, where it occurs in a relatively narrow coastal strip of about 40km in width, except along the Tana River where it extends about 120 km inland. The hotspot stretches farther south into Tanzania, where some outlying forest patches occur about 300 km inland, and along nearly the entire coast of Mozambique, ending at the Limpopo River. The hotspot also includes the offshore islands, including Pemba, Zanzibar, Mafia and the Bazarruto Archipelago off Mozambique. (CEPF 2003a; Clarke 2000) (Figure 2.1).

Figure 2.1 Map of the Coastal Forests of Eastern Africa Hotspot (CEPF 2005)

Coastal forests in Kenya cover an area of 660 km² (Burgess *et al.* 2000); the most notable patches are Arabuko-Sokoke (*ca* 370 km²) and the Shimba Hills National Reserve (*ca* 63 km^2) (Younge 2002). In Kenya, the coastal belt has become fragmented and forests are remnants of what was once an extensive coverage of lowland rain forest, swamp forest, scrub forest, and undifferentiated forest types (Clarke 2000). The forest remnants are extremely diverse and include many strictly endemic species, including 400 plant, 10 bird, 34 reptile, 14 amphibian, 75 butterfly and 8 mammal species (Burgess 2000; Schipper and Burgess 2004). International interest in these coastal forests has increased over the last three decades due to the realization of their global biodiversity value, and the threat of anthropogenic modification that has reduced the vegetation of this important eco-region by 90%, mainly due to agriculture and urbanization (CEPF 2003b; Clarke 2000; Schipper and Burgess 2004).

2.1.2 Kwale District

Kwale district in the Coastal Province of Kenya contains 124 coastal forest fragments that range in size from 1ha to 160km^2 (Anderson *et al.* 2007) and cover approximately 8322km^2 (Figure 2.2). The human population in Kwale district stands at approximately 536,381, where 49% of people are below the age of 15 (WWF 2009). The main type of habitat is agriculture; including grasslands, woodlands, swamps, shrublands, forestry plantations, annual and perennial cropland (Burgess *et al.* 1998).

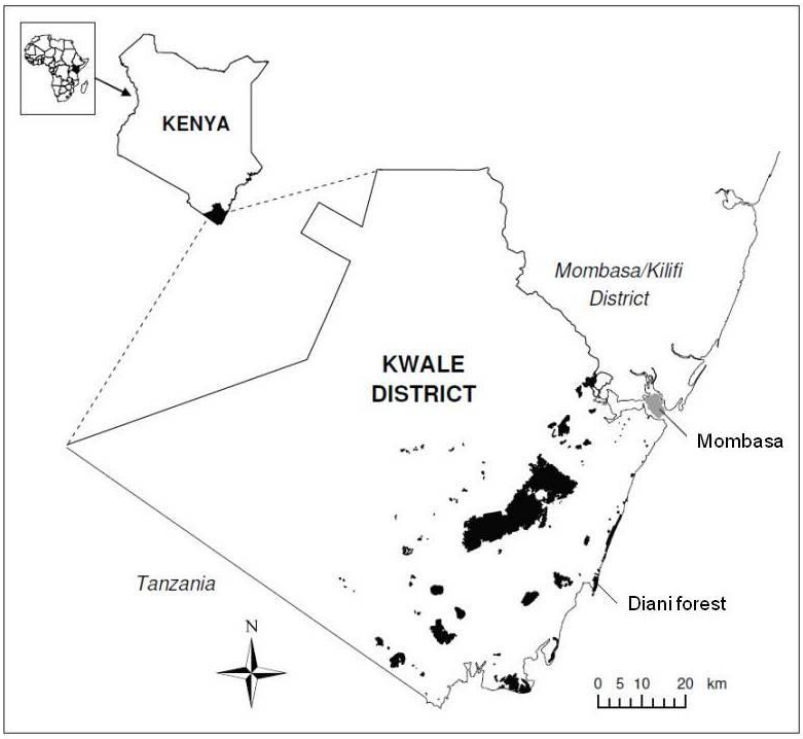


Figure 2.2 The distribution of coastal forest fragments in Kwale County, Kenya (Edited from Anderson *et al*, 2007).

2.1.3 Diani

Covering an area of 455ha (Anderson *et al.* 2007), the forested areas of Diani were scrub forests growing on coastal sedimentary rocks in the form of fossilised coral, covered by a thin layer of soil (Hawthorne 1993). These areas are commonly referred to as Coral Rag Forest. In these forests the canopy reaches a height of 6-10m (Clarke and Robertson 2000) and herbs are usually absent. Tree species present include *Combretum schumannii, Adansonia digitata, Mallotus oppsitifolius, Sideroxylon diospyroides, Tamarindus indica* and a variety of *Ficus* sp. The understory is characterised by *Pemphis acidula, Pycnocoma littoralis* and *Grewia* sp. The coastal forest of Diani was once one of the most diverse areas of forest along the Kenya coast, with a rich coral rag flora (Robertson and Luke 1993).

Within the greater Diani area there are three protected forest areas, Kaya Diani, Kaya Ukunda and Kaya Kinondo (Figure 2.3). The Kayas owe their existence to the beliefs, culture and history of the coastal Mijikenda people (Digo, Duruma and seven groups of Giriama) who historically established fortified villages within these forests (Githitho 1998). Today, the Kayas are jointly protected by the National Museums of Kenya (Coastal Forest Conservation Unit) and the local Mijikenda, with some communities still actively using the Kayas as ceremonial or burial grounds (Robertson and Luke 1993). These forest areas are remnant patches of the lowland forest that once covered the coastal belt of southern Kenya. They have a canopy height of 25-35m (Clarke and Robertson 2000) and are characterised by the presence of *Antiaris toxicaris.*

Due to its location on the Indian Ocean, Diani has benefited financially from commercial tourism, but this has come at the cost of dramatic habitat loss. The majority of the former Diani forest area occurs on unprotected and sub-divided privately owned land, with plots ranging in size from 600m^2 to more than 50 hectares. Once the original forest was bisected in 1971 with the construction of a 10km paved road (Donaldson and Cunneyworth 2015; Moreno-Black and Maples 1977), the formerly continuous forest became increasingly fragmented so that a mosaic of small patches, in various degrees of intactness, now remain. The remaining forest patches are interspersed with sympathetic and unsympathetic developments. Diani is dominated by tourist development with large hotel complexes, small holiday cottages, residential areas and the associated infrastructure. Within these areas many exotic species have been introduced; the most notable are *Azadirachta indica, Bougainvillea* sp*., Delonix regia, Hibiscus* sp*.,* and a large variety of palm species.

2.1.4 Fauna

Despite the fragmentation and degradation of the Diani forest area there remains a variety of terrestrial fauna. Species recorded include elephant shrew (*Rhynclocyox* sp.), mongoose (*Herpesles* sp.), bush pig (*Potumochoreus porcus*), suni (*Nesotraynes mochatus*), genet (*Genetta genetta*), civet (*Civettictis* sp.) monitor lizards (*Varanus* sp.), and a variety of reptiles including snakes and tortoises and birds including Hornbills (*Tockus* sp.).

Six primate species occur in and around Diani; Zanzibar Sykes's monkey (*Cercopithecus mitis albogularis)*, Hilgert's vervet monkey (*Chlorocebus pygerythrus hilgerti),* Ibean yellow baboon (*Papio cynocephalus ibeanus)*, Peter's Angolan colobus (*Colobus angolensis palliatus)*, white-tailed small-eared galago (*Otolemur garnettii lasiotis)*, and Kenya coast galago (*Galagoides cocos)*, and their densities are high (De Jong and Butynski, 2009). Species often seen feeding alongside vervet monkeys without agonistic interactions were Sykes and colobus monkeys, monitor lizards and hornbills. Natural vervet predators in Diani were restricted to baboons and snakes. During the study period a handful of vervet monkeys in the wider Diani area died as the result of snake bites (Colobus Conservation, unpublished). No baboon attacks were recorded for vervet monkeys, but two Sykes monkeys were killed in a baboon attack (pers. obs.). Historically, both lion (*Panthera leo*) and leopard (*Panthera pardus*) were present and active predators within the Diani area. Due to the anthropogenic habitat of Diani, the vervet monkeys face additional unconventional predators and dangers, these include domestic and stray dogs, humans, moving vehicles and uninsulated electricity cables. Death of all primate species in Diani was recorded by one or more of these anthropogenic dangers during the study period (Colobus Conservation, unpublished).

2.1.5 Climate

The coastal forest belt climate is classified as tropical humid and the climate is mainly influenced by the large-scale pressure systems of the Western Indian Ocean and monsoon winds (De Jong and Butynski 2009b). During December through March the winds blow from the northeast, and during May through October they blow southeast. In between there are 1-2 month transition periods with variable and lower winds (Kairo and Bosire 2007). The mean annual temperature is 26.3°C, with a mean annual maximum of 30.3°C and a mean annual minimum of 22.4°C. The rainfall pattern of coastal Kenya is bimodal, with long rains between April and July, and short rains from October until December, with annual rainfall of 900-1500mm (Jaetzold and Schmidt 1983).

2.1.6 Colobus Conservation

Colobus Conservation (CC) was the conservation organisation and primate welfare facility from which the rehabilitated vervet monkeys were released. Established in 1997 as a not-for-profit organisation, Colobus Conservation's aim is to promote conservation of the colobus monkey along with other endemic primate species, and address the threats to their survival. Primate species that fall within the remit of Colobus Conservation include Zanzibar Sykes's monkey (*Cercopithecus mitis albogularis)*, Hilgert's vervet monkey (*Chlorocebus pygerythrus hilgerti),* Ibean yellow baboon (*Papio cynocephalus ibeanus)*, Peter's Angolan colobus (*Colobus angolensis palliatus)*, white-tailed small-eared galago (*Otolemur garnettii lasiotis)*, and Kenya coast galago (*Galagoides cocos)*. The organization works in partnership with local communities to promote the conservation of primates and the unique coastal forest habitat on which they depend.

Colobus Conservation programmes focus on habitat conservation and community linkages as well as human/primate interaction mitigation, animal welfare, education and research. Their objectives are met by projects working on three levels. Firstly, individual care which focus' on primate welfare rescue, with short and long term medical care, orphan hand rearing, captive care, rehabilitation and release. Secondly, population management of the primates which seeks to mitigate issues relating to primates living in an anthropogenic environment and includes reducing wildlife vehicle collisions, electrocutions and primate pest behaviour, while ultimately promoting coexistence. Finally, meta-population dynamics, which promote environmental community support, forest development and environmental education in the wider Kwale district. Their area of operation is highlighted in Figure 2.3. Their work is recognised and supported nationally by Kenyan Wildlife Service (KWS) and internationally by American Zoological Association (AZA) Colobus Species Survival Plan (SSP), with accreditation from Pan African Sanctuary Alliance (PASA) and Global Federation of Animal Sanctuaries (GFAS).

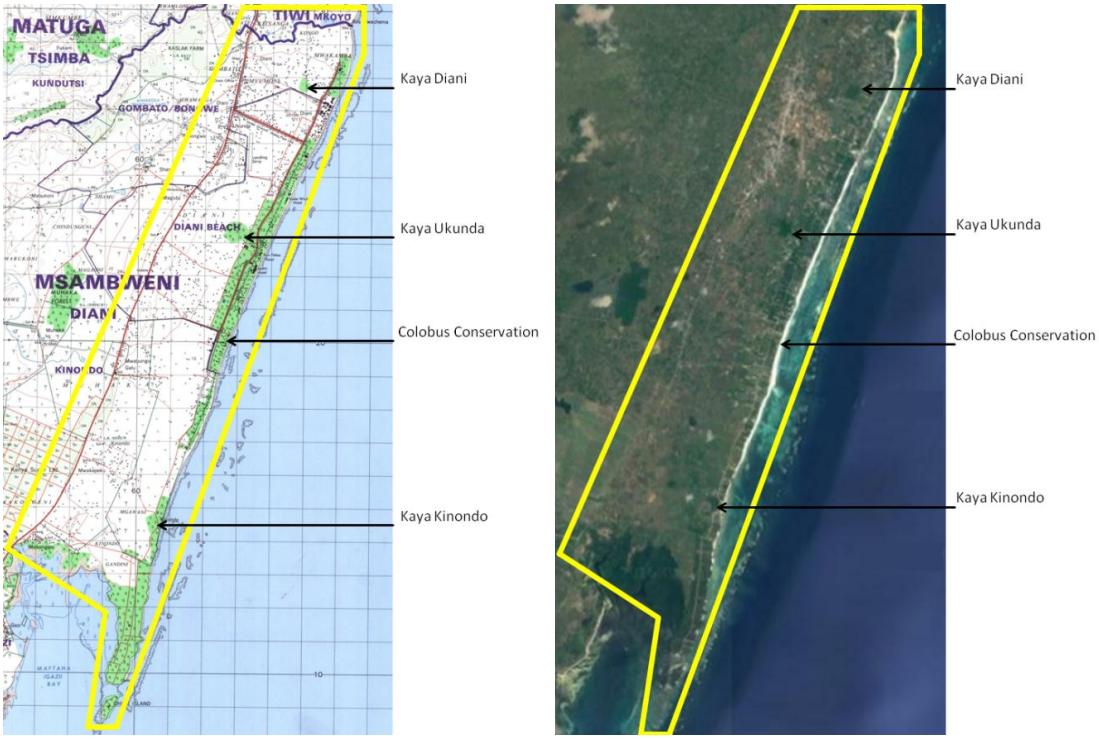


Figure 2.3 A Land map and an aerial photograph of the greater Diani area. Area outlined in yellow shows Colobus Conservation area of operation. Protected forests (Kayas) and Colobus Conservation Centre are labelled. Land map image 2006 CNES/Astrium Data SIO, NOAA, U.S. Navy, NGA, GEBCO. Aerial photograph ©2016 DigitalGlobe ©2016 GeoEye Earthstar Geographics SIO ©Microsoft Corporation.

2.2 Study Species

2.2.1 Taxonomy

Vervet monkeys have been involved in several taxonomic debates. The most recent review of the classification of vervet monkeys has resulted in moving all of the vervet species from the guenon genus *Cercopithecus* to a new genus, *Chlorocebus* (Groves 2001). Within this new genus six species of *Chlorocebus* are currently recognised, *Ch. aethiops, Ch. cynosuros, Ch. djamdjamensis, Ch. pygerythrus, Ch. sabaeus* and *Ch. tantalus* and eight sub-species (Table 2.1). The taxonomic names used are the most recent and widely accepted taxonomy for the African primates (Groves 1993, 2001), together with recent findings of Primates: Eastern Africa Primates Diversity and Conservation Programme (Butynski and De Jong 2010).

Table 2.1 The six species of *Chlorocebus* as recognised by IUCN (Butynski *et al.* 2008; Kingdon and Butynski 2008; Kingdon and Gippoliti 2008a, 2008b)

Species	Synonym	Sub-species	Common Name	Conservation Status
Ch. aethiops **(Linnaeus, 1758)**	*Cercopithecus aethiops*		Grivet monkey	Least Concern
Ch. cynosuros **(Scopoli, 1786)**	*Cercopithecus cynosurus*		Malbrouck monkey	Least Concern
Ch. djamdjamensis **(Neumann, 1902)**	*Cercopithecus aethiops djamdjamensis, Cercopithecus djamdjamensis*		Bale monkey, Bale Mountains Grivet, Djam-djam	Vulnerable
Ch. pygerythrus **(F. Cuvier, 1821)**	*Cercopithecus pygerythrus*	*C. p. rufoviridis*, *C. p. nesiotes*, *C. p. hilgerti*, *C. p. excubitor*; *C. p. pygerythrus*	Vervet monkey	Least Concern
Ch. sabaeus **(Linnaeus, 1766)**	*Cercopithecus sabaeus*		Green monkey	Least Concern
Ch. tantalus **(Ogilby, 1841)**	*Cercopithecus tantalus*	*C. t. tantalus*, *C. t. budgetti*, *C. t. marrensis*	Tantalus monkey	Least Concern

2.2.2 Distribution

Vervet monkeys are one of the most widely spread African monkey species, occurring through most of sub-Saharan Africa (Wolfheim 1984). They are distributed broadly across the continent from Senegal to Ethiopia, northerly from Egypt and Eritrea, and southwards into South Africa as well as on the Islands of Zanzibar, Pemba and Mafia. Vervet monkeys are largely absent from the forests of the Congo Basin in west-central Africa, though some species inhabit the edges of these forests (Wolfheim 1984). The species are separated geographically, but some areas of hybridization exist (Groves 2001).

Ch. pygerythrus ranges from the Ethiopian Rift Valley in central Ethiopia eastward into Somalia, and southward into Kenya, northern Tanzania and eastern Uganda. To the north, *Ch. aethiops* is found in Sudan, east of the White Nile River, Ethiopia, Eritrea, and probably into south-eastern Egypt. In the south-eastern part of its range, *Ch. aethiops* hybridizes with *Ch.*

pygerythrus as well as with *Ch. p. hilgerti* at the Omo River in Ethiopia. Another species of vervet found in Ethiopia is *Ch. djamdjamensis*, restricted to the Bale Mountains region and surrounding highland areas east of the central Rift Valley. *Ch. tantalus* is found in Sudan, Uganda, and north-western Kenya around Lake Turkana and its range stretches west into Togo, Benin, Nigeria, Niger, Chad, Cameroon, Equatorial Guinea, Central African Republic, Congo, and into Ghana where it is restricted by the Volta River. It hybridizes with *Ch. p. rufoviridis* in Uganda along the northern and western shores of Lake Victoria. The westernmost species of vervet is *Ch. sabaeus*, found from Senegal to the west bank of the Volta River in Ghana and ranging in Mauritania, Mali, Gambia, Guinea-Bissau, Guinea, Sierra Leone, Liberia, Côte d'Ivoire and Burkina Faso. *Ch. cynosuros* is found in northern Namibia, Angola, southern Democratic Republic of Congo, Botswana, and in Zambia. *Chlorocebus* is also found in Rwanda, Burundi, South Africa, Lesotho, Zimbabwe, Swaziland, Malawi, and Mozambique (Groves 2001).

2.2.3 Description

Monkeys of the genus *Chlorocebus are* commonly known as vervet, grivet or green monkeys (throughout this thesis they will be referred to as vervet monkeys or vervets). They are a medium sized monkey with a body size of 3-8kg; males: 4–8 kg; females 3–5 kg (Willems and Hill 2009). Their colouration is geographically variable from silvery grey to olive, yellow or reddish green, under-parts are white to yellowish, black face with a white ruff and brow band, eyelids pale pink, pale blue skin under fur-covered areas with the skin on their hands, feet and tail tip black (Estes 1990). Adult males have a pale blue scrotum, red penis and white perineal skin that are used in displays of dominance between males of the same group (Struhsaker 1967b). Natal coats are dark and silky with pink face skin that gradually turns black through the first three months. Vervets have an average life span of around 31 years in the wild (Harvey *et al.* 1987). Females reach sexual maturity at around 48 months, and usually give birth for the first time at around 60 months (Cheney *et al.* 1981), with a gestation period of 165 days (Rowell 1970). Weaning generally occurs around 3 months, but infants have been recorded suckling into their second year of life if their mother has not reproduced (Lee 1984). Female inter-birth interval varies between 12 - 24 months. Males reach sexual maturity at approximately 60 months, but do not achieve full adult weight until 72 months (Eley *et al.* 1986). They are rated as 'Least Concern' by the IUCN as they are widespread, abundant and with no major threats (Kingdon and Butynski 2008). However, vervet monkeys are classed as vermin in parts of their range and are actively persecuted by landowners in areas where they raid crops or interact with humans (De Jong and Butynski 2009a).

2.2.4 Behavioural Ecology

Vervet monkeys are opportunistic omnivorous primates, often consuming what is most abundant and available (Struhsaker 1967a). Herbs, grasses and insects are less important than tree foods and are mainly eaten during the rainy season (Gartlan and Brain 1968). They live a semi-terrestrial, semi-arboreal lifestyle and are adapted to all wooded habitats outside of the equatorial rain forest, but predominantly occupy open canopy forest or woodland habitats that have herb/shrub/grass rich ground layers. The feeding ecology of a population of vervet monkeys in Amboseli, Kenya, indicated consumption of 46 different plant species (Lee and Hauser 1998). The most important food plants were considered to be *Acacia xanthophloea* and its associated woodland species, along with *A. tortilis* (Lee and Hauser 1998; Struhsaker 1967a).

Typically found in multi-male, multi-female groups of around 20-30 individuals, there is a linear dominance hierarchy among males, and a kinship relationship among females. Males emigrate as they near maturity, while females stay in the family group and take their place in the female bonded society wherein the mother's rank predetermines the daughter. Vervet monkeys occupy home ranges of between 12 - 178ha (Willems and Hill 2009), that may overlap with neighbouring groups (Lee and Hauser 1998). Variation in home range size, population density and group size of vervet monkeys is determined by habitat quality, principal food abundance, sleeping sites and water availability (Lee and Hauser 1998; Struhsaker 1967a). They are often found in association with baboons (Struhsaker 1967a), with whom they share many feeding and sleeping trees and watering holes and also associate and compete with Sykes monkeys generally at the forest edge (Struhsaker 1967a). Due to their small size and terrestrial nature vervet monkeys are subject to higher rates of predation than any other African primate by at least 16 different predators (Struhsaker 1967a), including wild cats (*Panthera* sp. and *Felix* sp.), hyenas (*Hyaena* sp.), jackals (*Canis* sp.), birds of prey (e.g. *Stephanoaetus coronatus)* and baboons (*Papio* sp.). In an avoidance response from ground predators, vervets are known to use tall trees, positioned in woodland, as sleeping and refuge sites (Nakagawa 1999).

2.3 Study Groups

2.3.1 Control Groups

From accumulated annual primate census surveys conducted by Colobus Conservation, there were 18 locations in Diani where vervet monkey groups were recorded (Figure 2.4). From these 18 locations two groups were selected as wild, indigenous control groups for data

collection. Selection was based on four variables. Firstly, did the group show signs of habituation to humans? Due to the anthropogenic habitat of the Diani environment some groups of vervet monkeys were already partially habituated to humans. This would speed up the habituation process of the group, allowing data collection to begin more quickly. However, those groups that were not habituated to humans may inhabit an area with higher levels of human persecution and I did not want to habituate monkeys in this situation. Secondly, was the area safe from human conflict for staff members and volunteers to roam freely throughout the day, especially at dawn and dusk?. Thirdly, could access permission to each land parcel that the vervet group moved through be granted for the research teams? Finally, were the habitats between the two groups different in their anthropogenic use, plant species composition and level of modification? This final point was important because the data gathered from the control groups had a dual purpose. In the first instant, and before the release of the rehabilitated vervet group, the data was to be used to inform on release site selection. Secondly, and after the release, the data from the control groups was used as baseline data comparisons, forming meaningful measures of success against which the release could be quantified. As such, having data from different habitats provided a range of indicators for release site selection and a range of measures that would quantify release success.

The two control groups of vervet monkeys were habituated to 5–30 m proximity of observers, and all individuals were identified by their natural markings (e.g. sizes, coat colour, and facial features) and physical abnormalities (e.g. scars, damaged limbs, digits and tails). Both groups occupied areas under considerable human disturbance in the form of private residences, hotels with their associated grounds and staff housing, and both areas were adjacent to relatively large and undisturbed patches of forest. Specifically, Hotel group inhabited an area that consisted of two large hotel complexes, a number of holiday cottages and a few private residences. Green areas largely consisted of manicured lawns and open tropical gardens mixed with remnant forest trees. University group inhabited an area that was centred around the Nairobi University field station, neighbouring a smaller Hotel complex with staff quarters and a few private residences. Numerous remnant forest trees interspersed with exotic species formed a thin, but largely continuous canopy. During the research period, group sizes and composition fluctuated (Table 2.2).

Figure 2.4 Map of 18 known locations of vervet monkey groups in Diani. The yellow line delineates the census survey area. The red circle indicates Hotel group, blue circle indicates University group, and yellow circles indicate all other recorded vervet groups. Scale 1:100,000, ©2016 DigitalGlobe ©2016 GeoEye Earthstar Geographics SIO ©Microsoft Corporation.

Table 2.2 Size and composition changes of the two research groups at the beginning, mid-point and end of the study period

Group	Date	Adult male	Adult female	Sub-adult male	Sub-adult female	Juvenile	Infant	Total
Hotel	December 2011	3	5	1	2	5	3	19
	December 2012	2	7	2	0	10	3	24
	November 2013	1	5	4	2	8	6	27
University	December 2011	5	4	3	3	8	0	23
	December 2012	3	5	5	4	4	4	25
	November 2013	4	7	5	1	2	1	20

2.3.2 Release Group

Release group consisted of 12 individuals that had spent 3 - 39 months in captivity at Colobus Conservation prior to release and had arrived as a result of various human/wildlife interactions (Table 2.3). Upon admission to the rescue facility all individuals were given a full health check, treated medically as required and quarantined either individually, in human care or as part of a small group, for a minimum period of 30 days. Once medically healthy, individuals less than a year old began rehabilitation in orphan care and the nursery enclosure, before being transferred to the pre-release enclosure, while older individuals were integrated directly in the pre-release enclosure. All Release group individuals were fitted with radio-collars (Advanced Telemetry Systems, USA), and tagged with individually coloured ear tags at least one week prior to release to aid identification and post-release monitoring.

2.3.2.1 Release Group Composition

Release groups that are representative of wild groups in their composition have a better chance of survival than groups that are not representative (Baker 2002; Beck *et al.* 2007). Using data collected during the 2011 annual Diani census by Colobus Conservation, 14 vervet groups were recorded with a mean average of 12.2 (6-33) individuals. The mean average of adults per group was 6.11 (3-19), sub-adults was 3.67 (1-9), juveniles was 2.22 (0-6) and infants 0.39 (0-2). Using these data, the composition of Release group was selected to fall within 1 standard deviation of the wild group mean composition (Figure 2.5).

2.4 Data Collection

Data collection methods that are relevant to two or more chapters are detailed in the following section. Any data collection methods that are specific to only one chapter are detailed within that chapter's methodology section.

2.4.1 Hardware and Software

All data sets were collected using paper field sheets and entered on an electronic spreadsheet using Microsoft Office Excel 2007. GPS data were collected utilizing four units, two Garmin eTrex Vista HCx and two Garmin eTrex 20. All GPS data were downloaded onto a laptop using Garmin MapSource (Version 6.13.7 Garmin Ltd) and converted to GIS compatible files. GIS work was completed using QGIS (Version 2.8.1).

Table 2.3 Details of individual vervet monkeys in Release group. * Approximated time frames based on estimated age on arrival and known circumstances of the individual prior to arrival, WVC - Wildlife vehicle collision

ID (code)	Sex	Arrival date at CC	Age on arrival	Time in the wild prior to rehabilitation*	Time in pre-release group (months)	Age at release	Background
Handy Joe (HJ)	M	Unknown	Unknown	> 2 years	3	Adult	Individual released by CC in 2009 who had lived on-site as a lone male for at least 2 years. Original reason for admission to CC was unknown
Kinky Tail (KT)	F	29/09/2009	Juvenile	Unknown	31	Adult	Pet
Face (FA)	F	05/09/2010	Sub-adult	Unknown	19	Adult	Pet, who was released by her owner, but crop raided nearby farm land. Brought to CC for rehabilitation after failed solo release
Broken Arm (BA)	M	05/02/2009	Infant	10 weeks	35	Sub-adult	Orphan - hand reared at CC
Eye (EY)	M	05/02/2009	Infant	8 weeks	35	Sub-adult	Pet - hand reared at CC
Short Tail (ST)	M	08/02/2009	Infant	6 weeks	35	Sub-adult	Captured by poachers, Mother likely killed for food - hand reared at CC
Diego (DI)	F	05/06/2010	Infant	6 months	22	Sub-adult	Captured by poachers
Emily (EM)	F	30/03/2010	Infant	2 weeks	22	Juvenile	Orphan, Mother electrocuted – hand reared at CC
Houdini (HO)	F	01/08/2011	Juvenile	1 year	9	Juvenile	Suspected infanticide victim
Rafiki (RA)	F	16/08/2011	Juvenile	1 year	8	Juvenile	Head injury in HWI
Malindi (ML)	F	23/09/2011	Infant	8 weeks	6	Juvenile	Pet, confiscated by KWS and sent to CC for rehabilitation – hand reared at CC
Mambi (MM)	M	24/09/2011	Infant	4 weeks	6	Infant	Orphan – hand reared at CC

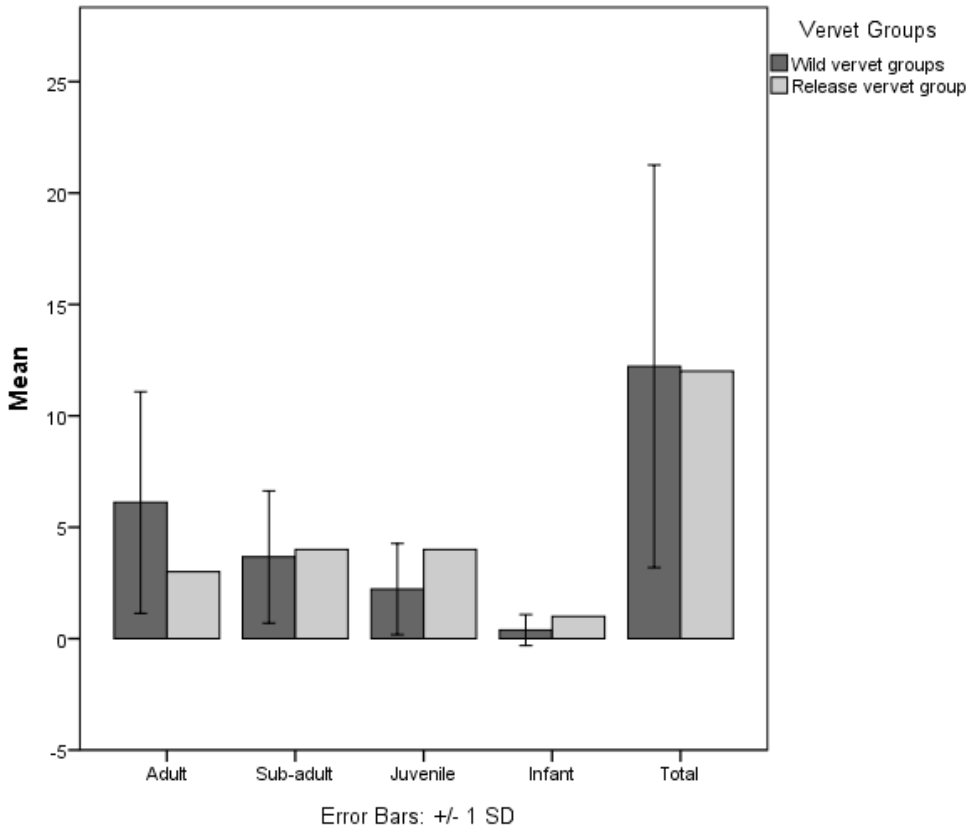


Figure 2.5 Mean group composition of wild vervet monkeys (n=14) in Diani in 2011, with one standard deviation illustrated, compared to the vervet release group composition.

2.4.2 Climatic Monitoring

Rainfall data were collected daily at the Colobus Conservation facility (S4° 20' 39.9" E39° 33' 53.8"), approximately 1km south of the Hotel study site and 2.5km south of University study site. Rainfall was collected using a basic rain gauge, measured in millimetres and recorded daily at 8am. The rainfall pattern was bimodal, with long rains beginning in March-April, and short rains starting in October, with a peak in rainfall in May of both years. Temperatures were collected at a nearby weather station at Moi International Airport, Mombasa (S4° 02' 24" E39° 35' 24") approximately 33km north of the study sites. Mean monthly temperature fluctuated by approximately 5 degrees (23.9° - 29.1°), throughout the whole study period, with the coolest period occurring May to October, while December to March were the warmest months (Figure 2.6). Wet and dry periods were calculated based on the plant productivity index P2T, where wet months are month in which the rainfall (mm) was more than double the average monthly temperature (^{O}C). (le Houe´rou 1984). P2T is used as a measure of growing season in tropical habitats, as it yields a very strong correlation with primary productivity (le Houe´rou 1984). Previous primate studies have used this method to determine seasonality (Beck *et al.*

1994; Hill and Dunbar 2002; Lehmann *et al.* 2006; van Woerden *et al.* 2010)Temperature variation, monthly rainfall and wet/dry months for the duration of this study are shown in figure 2.6.

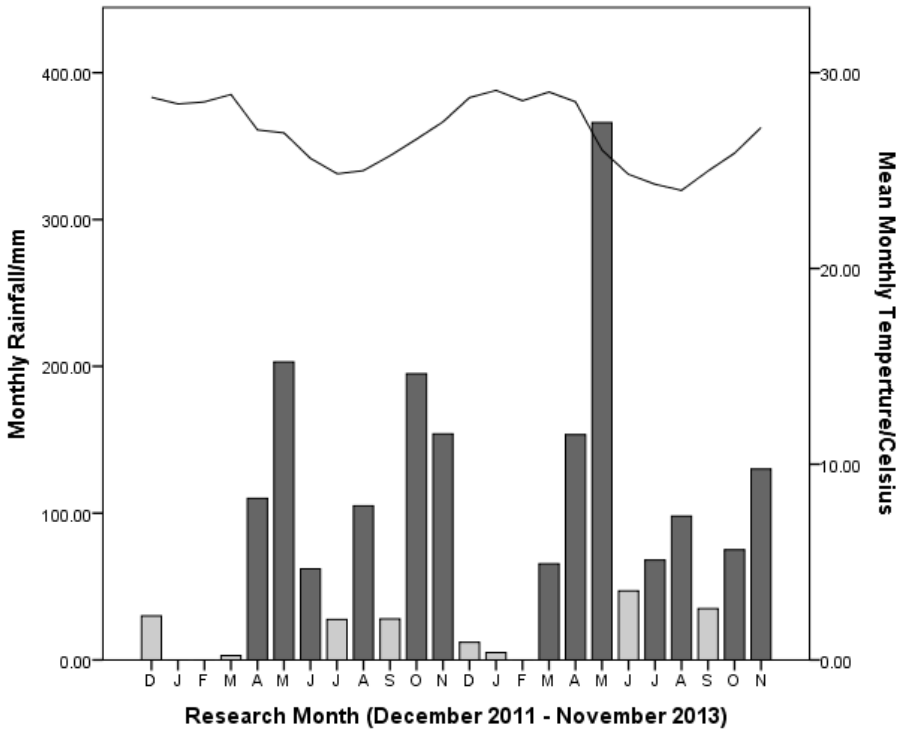


Figure 2.6 Weather patterns for research period December 2011 - November 2013. Rainfall recorded at Colobus Conservation, Diani and temperature recorded at Moi International Airport, Mombasa. Bar colour indicates wet months (dark grey) and dry months (light grey) according to P2T calculations.

2.4.3 Behavioural Sampling

Data collection was conducted by three research teams, one per location. All teams were selected, trained and overseen by the author with regular site visits. Each team was led by one person who was present daily for the entirety of the study. Hotel team was lead by Opere Paul Otieno, University team was led by Wesley Koech and the Release team was led by the author. Each team was assisted by multiple local, national and international volunteer research assistants throughout the data collection period. No more than two researchers were with any group at any time, except during new research assistant training and handover periods. The teams met on a weekly basis to discuss and resolve issues at each research location. Inter observer reliability tests were performed on a monthly basis.

Control Groups

The two control groups were observed over a 24-month period, December 2011 - November 2013. Data collection consisted of three consecutive research periods, per week, per group (Day 1: midday - dusk; Day 2: dawn – dusk; Day 3: dawn – midday). This totalled 106 half day and 83 full day research periods for Hotel group and 145 half day and 86 full day research periods for University group. The aim was to maintain full visual contact for the duration of these periods. However, movement of the monkeys between individually walled properties and occasional issues with access permission meant this aim was met with varying levels of success.

Release Group

Release group was observed over a 20-month period, March 2012 - November 2013. The release group was monitored in their pre-release enclosure from March - May 2012. The 27th May 2012 marked the day of release and the group was then monitored for 18 months post-release. Data relating to life history continued to be collected for four years post-release. Prior to release, data were collected on the group in their in-situ pre-release enclosure for a two month period and consisted of five research periods per week, alternating between dawn - midday and midday - dusk. Data collection was actively avoided during cleaning periods as the group was generally divided into smaller enclosure sections during this time. Post-release the intensity of data collection gradually decreased. For the first 3-month period immediately post-release the group was monitored daily from dawn till dusk; over time this intensity reduced in half-day increments until by 15 months post-release the group was being monitored on average only one full day per week until 18 months post-release. This totalled 40 half day research periods pre-release and 133 half day and 180 full day research periods post-release.

It should be noted that while this behavioural sampling is the basis for analysis in Chapter 4, Chapter 5 and Chapter 6, different data collection periods or time frames are assessed as detailed within the methodology of each chapter.

During these follow days a variety of different behavioural sampling methods were employed. Sampling methods were identical for all three groups.

Daily Census

A census of each group was taken at the beginning and/or end of each research period as the group descended from or ascended to their sleeping site. Each known group member was recorded as present or absent. Infants born to group females where immediately classed as

group members, immigrating individuals were classed as group members after a consistent presence of two weeks, emigrating individuals were recorded as such only if seen alive, either alone or with another group, after a two-week absence from the group. Individuals were recorded as dead only when their death was witnessed or an identifiable body discovered. Individuals absent from the group, but with no confirmed outcome were classed as missing.

Instantaneous Focal Sampling

Instantaneous focal sampling (Altmann 1974) was used to gain detailed information on specific classes of individuals. Focal individuals were selected using random sampling; rotating according to a fixed, randomly selected schedule, through all individuals (Altmann 1974). This method prevented prominent individuals from being studied more frequently than non-prominent individuals and ensured that different age and sex classes of monkeys were studied at different times of the day, reducing bias in possible time associated behaviours such as feeding behaviour.

Focal follows occurred continuously throughout each research period. Each individual focal was 20 minutes in length with instantaneous sampling occurring every minute, followed by a ten minute period to collect and order any plant samples for later identification. Up to twelve focal sessions were completed during each morning and afternoon study period, with a different focal animal being sampled in each 20-minute session.

Behaviours were classified as one of 25 categories (Table 2.4). For behaviours where individuals other than the focal individual were involved, the ID of the additional individuals was recorded. Finally, details of food items consumed were recorded detailing food type (fruit, flower, seed, leaf, grass, animal matter, human and other) and the species. Unidentified species were collected for later taxonomic identification at the Kwale County Herbarium, WWF and the National Museum of Kenya. Due to the anthropogenic environment, the groups were able to access human food. Human food items ranged from fresh produce, cooked goods, garbage and with very rare occurrence crop raiding. Human food was located both within and outside of buildings. All food items accessed from a human source were recorded as human food, including fruits that grow naturally in the wild environment i.e. mango (*Mangifera indica*) and coconut (*Cocos nucifera*). When human food was recorded as being consumed, additional information on how it was accessed was also recorded (Table 2.5). Additionally, Release group had supplementary food which was supplied as part of the soft release protocol (see Appendix 1 for Release Protocol).

Table 2.4 Behaviour categories detailing behaviour type, behaviour description and any additional information required.

Behaviour	Description	Additional recording
Aggression +	Acting aggressively towards another individual	ID of individual(s) involved
Aggression -	The recipient of an aggressive encounter	ID of individual(s) involved
Contact	Two or more individuals touching when the behaviour does not require contact	ID of individual(s) involved
Clinging	Infant clinging to another individual	ID of individual involved
Feeding	The act of eating a food item i.e. biting, chewing and storing in cheek pouch	Record food type and species
Foraging	The act of preparing a food item to be ingested i.e. locating, picking, smelling and rolling.	Record species and type of food involved
Grooming +	Being the recipient of grooming	ID of individual(s) involved
Grooming -	Grooming another individual	ID of individual(s) involved
Locomotion	Any distance travelled, vertical, horizontal, on the ground, in the trees or on buildings	
Mating	Copulation	ID of individual involved
Mounting +	One individual mounting another without copulation	ID of individual involved
Mounting -	One individual being mounted by another without copulation	ID of individual involved
Nursing	Mother breast feeding infant	ID of individual involved
Other	Any behaviour that does not fall within the other descriptions	Describe the behaviour and ID of individual involved
Out of Sight	When individual cannot be clearly seen and behaviour accurately described	
Play	Playing	ID of individual(s) involved
Predator Avoidance	Actively avoiding predators or alarm calling	Complete wildlife interaction data sheet
Presenting +	Being presented to by another individual	ID of individual involved
Presenting -	Presenting itself to another individual	ID of individual involved
Resting	Sitting or lying with eyes closed	
Scratching	Scratching own body	
Self Grooming	Grooming own body	
Suckling	Infants or juveniles breast feeding from mother	ID of individual involved
Vigilance	Eyes open, aware of environment. Can be standing, seated or lying	
Yawning	Yawning	

Table 2.5 Human food categories and codes

Code	Description	Code	Description
1	Garbage pile/scattered waste food	9	Taken directly from a person
2	Rubbish bin	10	Given directly from a person
3	Hotel/guest room	11	Crop raiding
4	Hotel dining table	12	Fruit or vegetable from monkey enclosure
5	Buffet table	13	Other animal food (poultry, cat, dog)
6	Bag (shopping, backpack, handbag)	14	Wild leaves from monkey enclosure
7	Kitchen	15	Roadside shop
8	House dining area		

Ranging Data

At the start of each focal follow at approximately 30-minute intervals, the geographical location of the focal individual was recorded via a handheld Garmin GPS unit. All GPS data were downloaded onto a laptop using Garmin MapSource (Version 6.13.7 Garmin Ltd) and used to calculate day journey length and home range for each group.

Proximity Data Collection

Proximity data was collected using scan sampling (Altmann 1974) of adult, sub-adult and juvenile individuals. Scan sampling was conducted at 10 minute intervals in conjunction with the focal follow. At minutes 0, 10 and 20 of the focal follow a scan sample recorded all group members that were in contact, $\leq$1 meter, >1$\leq$3m, >3$\leq$5 m and >5 meters from the focal subject.

2.5 Data analysis and processing

Data analysis and processing methods that are relevant to two or more chapters are detailed in the following section. Any data analysis and processing methods that are specific to only one chapter are detailed within that chapter methodology section.

2.5.1 Software

Data analyses were completed using a combination of SPSS (Version 20, an IBM Company Statistical package), R (Version 3.2.0, The R Foundation for Statistical Computing) and Microsoft Excel (2010 Version, Microsoft, Redmond, Washington).

2.5.2 Home Range

Local Convex Hulls (T-LoCoH) analysis was used for the calculation of total and core home range size (Getz *et al.* 2007; Lyons *et al.* 2013). T-LoCoH analysis uses a nonparametric kernel density estimation which constructs convex hulls around each data point and uses these to determine utilisation distribution (Getz *et al.* 2007; Lyons *et al.* 2013). Getz *et al* (2007) showed that T-LoCoH has superior convergence properties and can define hard boundaries such as cliffs and rivers better than traditional minimum convex polygons. The package is also able to better cope with clumping and/or repeat data points than kernel density estimation (Getz *et al.* 2007). The calculations for the analysis were achieved using R, and then the shape files were uploaded to QGIS for further manipulation and presentation.

2.5.3 Day Journey Length

Using GPS locations recorded during full-day follows, beginning between 0600-0700h and ending around 1800h depending on access permissions, day journey length was determined for each group based on the shortest point-to-point movements of the group between consecutive GPS locations. Full day follows that lacked GPS locations for one or more consecutive hours were not included in this analysis. GPS points were entered in to MapSource and day journey length was calculated using the measuring tool in the routes application.

2.5.4 Statistical Analysis

To test for normality, Shapiro-Wilk test were performed on all monthly data. Sharpiro-Wilk was selected as it is the recommended test when n=<2,000 (Park 2008). Where Shapiro-Wilk tests revealed that data were not normally distributed Log10 transformations were conducted and normality reassessed to enable parametric analysis. In the cases where Log10 transformation did not result in normally distributed data, non-parametric testing was conducted on the un-logged variables or the variables were removed from analysis.

To account for familywise errors arising from multiple comparisons, I applied a false discovery rate (FDR) control (Benjamini and Hochberg 1995; Storey 2002), which calculates the expected proportion of 'false positives' among all the discoveries (i.e., rejected null hypotheses). FDR is calculated by putting the individual *P* values in order, from smallest to largest. The smallest *P* value has a rank of i=1, then next smallest has i=2, etc. Next, each individual *P* value was compared to its Benjamini-Hochberg critical value, $(i/m)Q$, where i is the rank, m is the total number of tests, and Q is the false discovery rate chosen. The largest *P* value that has $P<(i/m)Q$ is significant, and all of the *P* values smaller than it are also significant, even the ones that are not less than their Benjamini-Hochberg critical value (McDonald 2014). The false

discovery rate was applied to all *P* values using an online calculated FDR excel spreadsheet downloaded from www.biostathandbook.com/benjaminihochberg.xls and the Benjamini-Hochberg critical value for a false discovery rate was set at 0.05 (Hopper *et al.* 2014). Within the text I will highlight all significant p values as follows *p<0.05, **p<0.01, ***p<0.001. In cases where FDR control has been applied, and the p value is no longer significant the * will not be included.

Additional statistical analysis and models are described within the relevant data chapter.

Chapter 3 Habitat Quality Assessment and Considerations for Release Site Selection and Post-Release Impact

Abstract

The selection of an appropriate release site is essential when planning a translocation and inadequate or poor habitat quality is likely to be the main reason for success or failure in many translocation projects. Detailed guidelines for selecting an appropriate release site do not exist, however. This chapter presents methods for conducting habitat assessments using modified Whittaker plots to inform release site selection. Assessments of the habitat in the known home ranges of two vervet control groups living in the anthropogenically modified landscape of Diani, Kenya, were used to advise on the selection of a suitable release site. This assessment was followed by phenological monitoring and analysis to calculate a food availability index of favoured plant species across the three research sites, to verify the reliability of habitat assessments in selection of release site. Two years post-release, the plots were re-surveyed to analyse the impact of Release group upon the habitat at the release site. Results from modified Whittaker plots indicated that Release site was suitable as a release location in terms of stem density and biomass. However, one year of phenological monitoring indicated a period of extremely low food availability from October 2012 to January 2013 as a result of a lower percentage of indigenous trees than recorded at the control sites. The impact assessment showed that the biomass of Release site increased (+7%), more than the control sites (Hotel, +5.2% and University, +4.6%) suggesting that Release group did not have a negative impact upon the habitat. Exploring the relationship between biomass calculations and a 20 month phenological studied highlighted that biomass calculations alone are not a good indicator of release site viability. Habitat assessments are complex and multi-tiered, and this research shows that a minimum of one year monitoring of the habitat prior to release is essential in order to understand seasonal fluctuations in food availability.

3.1 Introduction

Methods for quantifying the success of a translocation remains an area of debate (section 1.5). However, it is widely recognised that success rates for translocation of birds, mammals and fish are generally <50% (Beck *et al.* 1994; Fischer and Lindenmayer 2000; Griffith *et al.* 1989; Haring *et al.* 2000), with habitat quality of the release site, cited as one of the main factors

influencing success (Griffith *et al.* 1989; Wolf *et al.* 1998). In fact, Osborne and Seddon (2012) state that habitat quality is likely to be the main reason for success or failure in many translocation projects, but acknowledge that hard data to justify the statement are difficult to come by. Historically, many translocations have lacked the detailed monitoring required to assess the impact of habitat selection up on translocation success or failure (Haring *et al.* 2000; Osborne and Seddon 2012). There is therefore a necessity for quantitative assessment of specific ecological factors that contribute to the success or failure of translocations (Haring *et al.* 2000). Given this understanding, improvements to the way habitats are assessed prior to translocation are urgently required (Osborne and Seddon 2012).

Translocation success requires habitat of sufficient quality to meet the life history requirements of the species (Williams 1988), and of sufficient area to support a self-sustaining population despite demographic and environmental stochasticity (Moyle and Sato 1991). While these broad requirements outline the ultimate needs for a suitable release site, they do not provide specific information for selecting a suitable release site with a high probability of success. Factors defining sufficient habitat are specific to particular taxa. Therefore, research on the minimum habitat requirements of a species is necessary to identify suitable release sites prior to translocation, particularly if factors contributing to translocation failure for the species are unknown (Hodder and Bullock, 1997).

The IUCN guidelines for Reintroduction and other Conservation Translocations highlight that the selection of an appropriate release site is key when planning a translocation, and detail considerations that must be met in the selection process (IUCN/SSC 2013). In brief, a release site should, meet all biotic and abiotic requirements of the species to be translocated, be protected and have threats controlled or managed, be adequate for all seasonal habitat needs, and be large enough, or have suitable connectivity to support a viable population (or metapopulation management strategy is in place). However, it is not necessarily clear how these assessments should be conducted or quantified. The more recent, species specific IUCN guidelines for the rehabilitation and translocation of gibbons (Campbell *et al.* 2015) offer a more prescriptive account regarding how habitat suitability should be assessed, and what constitutes an adequate test of suitability. These guidelines detail two key aspects in release site selection; population assessment of the release site for existing resident populations and habitat assessment to determine whether sufficient resources are available.

Population Assessment

A detailed population survey and assessment of a proposed release site must be conducted prior to any translocation. The assessment must determine whether any population of the species to be released persists in the area, and if so details of population status and biology must be recorded. In addition, an assessment of other species that may be directly or indirectly impacted by the proposed translocation must be made. Release sites with resident populations of the species to be translocated require different considerations to those without resident populations. For example, if population reinforcement is not required for long-term viability of the resident population, translocation should not occur in the area as the potential risks outweigh the potential benefits. In addition, both sites with and without existing populations, require assessments to determine whether translocations can establish/maintain a viable population into the long-term. Locating suitable release sites without an existing resident population can be achieved by matching distribution data with data from habitat surveys (see Habitat Assessment below). Finally, an assessment of potential carrying capacity must be conducted. This will require data on both habitat availability and species home range requirements, ideally from an assessment at the release site or by using data from wild conspecifics or closely related heterospecifics in similar habitats (e.g. similar latitude, altitude, forest structure, floristic composition etc.).

Habitat Assessment

The aim of habitat assessments is to determine whether sufficient resources are available to support the translocated population. It is essential that the release habitat resembles the natural habitat for the species as closely as possible. In cases where the site has an existing population, or one that has only recently become locally extinct, a comprehensive assessment is still required to ensure that there have been no significant changes in habitat quality. Long-term habitat assessment, both before and after release, can help increase the probable success of a translocation programme (Cheyne 2006; Cheyne *et al.* 2012). The structure and composition of the habitat in the potential release site requires assessment, with areas of existing and potential fragmentation identified. The availability of suitable food, water and adequate sleeping and refuge sites from predators are all essential requirements for assessment (Abbott 2000; Britt *et al.* 2004; Cheyne *et al.* 2006; Cheyne *et al.* 2013; Isbell 1990; Nakagawa 1999). Finally, in areas with significant seasonal food availability, surveys should be conducted over a period of time that allows a complete cyclical/annual assessment of food availability. This should be assessed in parallel with existing knowledge of the ecology of the species to be translocated.

Other detailed approaches to habitat assessments have been reported. For example a two phase approach was applied in the selection of reintroduction sites for the Iberian lynx (*Lynx pardinus*) (Gil-Sánchez *et al.* 2011). Initially, potential reintroduction areas were highlighted within a large scale landscape. The areas were identified based on five criteria; 1) suitable habitat structure, based on known habitat selection by resident radio-tagged Iberian lynxes applied to a Geographic Information System (GIS) and a regional map, 2) optimal food resources, based on surveys of the staple prey, 3) area size, 4) existing legal protection and 5) possibilities of contributing to a meta-population system, linking with existing populations through dispersing individuals. In the second phase, the pre-selected large scale areas were examined and evaluated in more detail, comparing fourteen variables related to four key-factors; human-induced mortality, micro-habitat structure, carrying capacity and possibilities of natural expansion. Of the five potential areas selected during the first, large-scale phase, two were deemed adequate for reintroduction sites after the detailed assessment.

In summary, translocation can only be contemplated if a suitable release site is available that satisfies the taxon's habitat requirements, and which is likely to be sustained for the foreseeable future (Baker 2002; Beck *et al.* 2007; IUCN/SSC 2013). Ideally the proposed site should fall within the historical range of the species, and there must be sufficient capacity for the site to sustain the diet of the translocated species. In addition, scientific estimations of carrying capacity must be determined to ensure there are adequate resources and food availability across the seasons to prevent competition for resources and guard against the local extinction of fauna and flora already inhabiting the area (Armstrong and Seddon 2007; Baker 2002; Beck *et al.* 2007; IUCN/SSC 2013; Moinde *et al.* 2004). However, it is recognised that translocation is likely to disrupt established species to some degree (Beck *et al.* 2007). An assessment of the potential threats in and around the release site is also required (Page *et al.* 2015). Availability of food, water, sleeping and refuge sites from predators are among the most important habitat features for primates and must be available throughout the year (Abbott 2000; Britt *et al.* 2004; Cheyne *et al.* 2006; Cheyne *et al.* 2013; Isbell 1990; Nakagawa 1999). To achieve all of this, detailed knowledge of habitat use by the taxon of interest is required (Baker 2002; Beck *et al.* 2007; Soorae 2008). Finally, it is essential that release site selection is informed by an assessment of habitat quality and the selected release site continues to be monitored after the release of animals, using established scientific methods (Cheyne 2006) to ensure that they are not imposing a negative impact upon the habitat.

The purpose of this chapter is to highlight the requirement to thoroughly assess habitat suitability and quality before any release takes place, and to stress the need for ongoing monitoring of habitat quality post-release Here, I present small scale, detailed habitat assessment data from three locations; Hotel site, University site and Release site. The habitat assessments of Hotel site and University site were focused on the known home ranges of two wild control groups of vervet monkeys (Hotel and University), and therefore provide a baseline requirement of habitat structure that Release site must be representative of. The habitat assessment of Release site focuses on the anticipated home range at the selected release site. Analysis of the habitat assessments compared Hotel and University site to Release site to ensure that the proposed release area was capable of supporting a vervet monkey group. Habitat monitoring continued throughout the post-release monitoring phase and phenology data of favoured natural food items was recorded. Using this data food availability was calculated for each of the three locations over an eighteen month period. Finally the habitat assessments were repeated two years post-release to assess the impact of Release group upon their habitat. Knowledge of resident vervet populations was provided via Colobus Conservations annual census data and has been detailed in section 2.3.1 and Figure 2.4.

Hypothesis 1: The habitat composition of Release site will be different to the habitat composition recorded at Hotel and University site, and Hotel site and University site will have difference in habitat composition. This difference will be the result of the variation in anthropogenic pressures at the three research sites. However, due to the closer proximity and neighbouring of Release site to Hotel Site, I predict that Release site and Hotel site will have a more similar habitat composition than Release site to University site or Hotel site to University site.

Hypothesis 2: Food availability at the three sites will be predicted by habitat composition. I predict that the site with the largest biomass per hectare will produce the highest food availability. Secondly, I predict that food availability will vary seasonally in relation to environmental variables, such as rainfall and temperature, at all three sites. Finally, I predict that there will be a difference in food availability of indigenous and exotic plants in all three research sites.

Hypothesis 3: The Release group will have an impact up on the release site. I predict that because vervet monkeys have been present for many years in Hotel and University site there

will be little recorded difference in the habitat impact assessment between the two years. However, because Release site has not previously had a permanent population of vervet monkeys, there will be a noticeable impact of their presence, in terms of a reduction in plant biomass, in the post-release habitat assessment.

3.2 Methods

3.2.1 Hypothesis 1: Habitat Composition

Modified Whittaker plots for multi scale vegetation sampling were used to describe and quantify the overall vegetation of each study area and identify differences in habitat composition between the home ranges of the control groups and Release site (Strohlgren and Chong 1997). As modified Whittaker plots require measurements of all stratum within a habitat, coupled with identification of all species recorded, this method of habitat assessment was considered best suited to describe the anthropogenically modified habitats within the study site including remnant forests, bush and lawn areas and also to record indigenous and exotic species. Nested subplots of different sizes within a larger plot allow for the development of species-areas curves and estimation of the number species in a larger unsampled area (Ganzhorn 2003; Strohlgren and Chong 1997).

Within each modified Whittaker plot four levels of the habitat were surveyed:

- A: one 50m x 20m (1000m^2) plot detailed all trees $\geq$ 30cm diameter at breast height (DBH) recording species, percentage of canopy cover, crown width, tree height, DBH and bole height.

Within plot A, a further twelve rectangular plots with side ratios of 1:2 were surveyed at varying sizes reflecting different vegetation stratums of the habitat.

- B: Two plots of 7.07m x 14.14m (100m^2) were surveyed and all trees <30cm $\geq$ 10cm DBH recorded, noting species, percentage of canopy cover, crown width, tree height, DBH and bole height.
- C: Four plots of 2.24m x 4.47m (10m^2) were surveyed and record all bushes, shrubs and trees $\leq$10cm DBH, noting species, percentage of canopy cover for the trees or percentage of ground cover for the shrubs and bushes, tree height and DBH.
- D: Six plots of 0.71m x 1.41m (2m^2) were surveyed and record the herbaceous vegetation, noting species and percentage of ground cover (Figure 3.1).

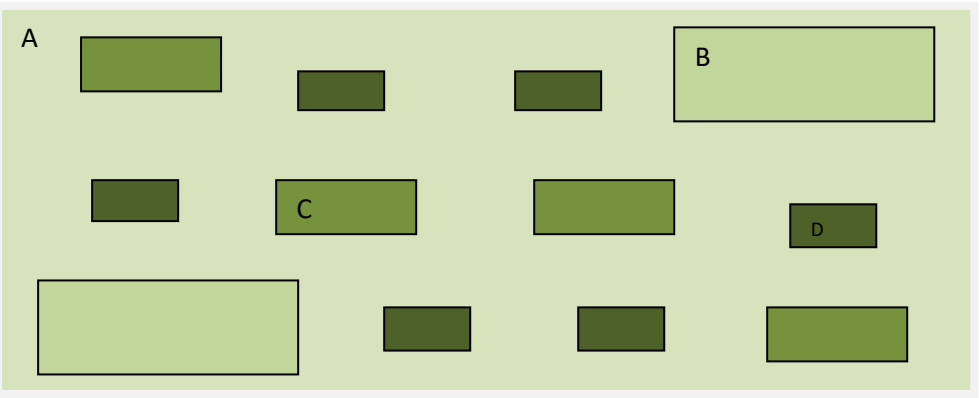


Figure 3.1 Modified Whittaker Plots, consisting of nested subplots (Strohlgren and Chong 1997). A, B, C, D and associated colour coding indicate subplots of different size as detailed in the text.

In April and May 2012 26 modified Whittaker plots were sampled across the three research sites, 9 at Hotel site, 9 at University site and 8 at Release site (Figure 3.2). The location of each plot was selected at random within the limits of the groups' home range or anticipated home range in the case of Release site. Data collected from the modified Whittaker plots was used to calculate stem density, biomass, overlap, diversity and equitability of each site.

Stem Density

Stem density was calculated for trees $\geq$ 30cm DBH and trees <30cm $\geq$ 10cm DBH by counting the number of each recorded species in a particular groups home range in A plots and B plots and extrapolating the count up to 1ha to allow for comparisons between research sites. Total stem density was achieved by combining the extrapolated figures for A plots and B plots. Stem density measures the number of trees in a given area, highlighting the density of larger mature trees recorded in A plots against younger or smaller growth trees in B plots. This division allowed for insights in to the availability of sleeping sites in larger mature trees and the potential future communities of the site with the quantity of younger, established trees.

Figure 3.2 Locations of modified Whittaker plots at Hotel site, University site and Release site.

Biomass

The basal area (BA) for each individual tree $\geq$ 30cm DBH and <30cm $\geq$ 10cm DBH was calculated using the formula:

$$BA = (0.5XDBH)^2 \times \pi$$

The BA of each species present in A plots and B plots were summed and a BA per species per hectare calculated; this figure was used as an estimator of each tree species biomass, per hectare, at each research site (Fashing 2001; Kool 1989). Tree species biomass acts as a valuable index for comparing potential food productivity between sites (Fashing 2001), aiding predictions for the suitability of a release site.

A method to estimate the biomass of grass species was devised following the same principles as those used for tree species, where percentage ground cover measurements from the D plots of the modified Whittaker plots were converted in to cm^2/ha and the resulting figure used as an indication of grass biomass.

Diversity and Equitability

The diversity and equitability of tree biomass was calculated using the Shannon-Weaver index (H) and equitability (E_H). These measures how diverse and evenly represented the plant community was at a given site. The Shannon-Weaver index measures species diversity using the formula:

$$H=-\sum pi(\ln(pi))$$

where pi is the proportion of a species in a given sample. Values range from 0 to 5.0, with a value near 0 indicating that every species in the sample is the same. A score of ≥2.0 indicates a rich and diverse plant community (Cheyne 2006).

Shannon-Weaver equitability measures how evenly different plant species were represented in the community, using the formula:

$$E_H=H/\ln S$$

where S is the total number of species in the community. Values range between 0-1, with 1 being complete evenness.

Habitat Overlap

The proportional overlap of the trees at each location were measured using Schoener's overlap index.

$$P_{hur}=[\sum_{i=1}^{n}(\text{minimum } p_{ih}, p_{iu}, p_{ir})]$$

Where p_{ih}, p_{iu}, p_{ir} are the proportions of tree species i found in the habitat of each location (based on percentage of biomass). The index ranges from 0 (no overlap) to 1 (all items in equal proportions), with values above 0.6 usually considered to be indicative of significant overlap (Wallace 1981).

3.2.2 Hypothesis 2: Habitat Phenology and Food Availability

To produce a quantitative measure of natural food availability, 62 plant species across the three research sites were selected for phenological monitoring. Ten mature individuals of each species were selected for monitoring and their GPS coordinates recorded. If ten mature specimens were not available for a specific species, phenological monitoring was conducted on all known individuals recorded within the appropriate groups' home range. A species qualified for phenological monitoring when one or more of its plant parts contributed >5% to any months dietary consumption in any of the three research groups. New species were added to the list for the entirety of the study.

Phenological assessment of the selected plant species was completed on the first Sunday of each month and was conducted from April 2012 - November 2013. The relative abundance of five phenophases (young leaves, mature leaves, flowers, whole fruits and seeds) was determined. Unripe and ripe fruits were combined as distinguishing between these two categories created difficulty (Fashing 2001). Each phenophase was assessed separately and given a score between 0 (none present) to 10 (full canopy) at intervals of 1, with each interval representing 10% of the canopy. For analysis these intervals were converted to phenological scores on a 0 - 3 scale as follows; 0 (0%), 1 (1-10%), 2 (11-30%) or 3 (31-100%) (Agostini *et al.* 2010). The phenological scores of individual trees of each species were averaged to obtain a Phenological Index for the Species (PISp) for each monthly sample and for each phenophase (Agostini *et al.* 2010). Food availability index (FAI) for trees was calculated using the PISp and tree species biomass values at each research site (Agostini *et al.* 2010; Dasilva 1994; Fashing 2001) using the following formula:

FAI (Tree) = Phenological Index for the Species x basal area for species *i*

FAI (Tree) calculations were formulated for all tree species that featured in the top 15 plant species from which fruit or seeds were consumed by any research group and for which a minimum 12 months of phenology data was available. Initial calculations revealed that young and mature leaves were the most abundant item in the ranges of all groups and were available

in large quantities throughout the year. Due to these large FAI quantities, and the relatively small contribution leaves made to the diets of any vervet group (Chapter 4 and 5), they were removed from the FAI scores. Flowers were removed for the same reason. Therefore, FAI (Tree) calculations indicate only fruit and seed availability. *Cocos nucifera* met the criteria to be included in the FAI analysis, but the fruit of this species (coconut) has an extremely hard outer shell that the vervet monkeys are unable to open. The only occasions any vervet group were recorded consuming this wild fruit was as they ate morsels left behind by baboon groups in the area. Therefore the fruit of this species were not considered an accessible food resource for the vervet groups and not included in FAI (Tree) calculations. Based on these criteria a total of 58 trees at Hotel site, 56 trees at University site and 53 at Release site of 11 species were analysed (Table 3.1 and Figure 3.3). From these 11 tree species, 9 were recorded for a minimum of 20 months (April 2012 - November 2013), while *Lannea welwitschii* and *Ficus sycomorus* were recorded for 18 (June 2012 - November 2013) and 16 (August 2012 - November 2013) months respectively. Due to habitat difference not all species were equally represented in all research sites.

Grass was an important food item in the diets of all three research groups (Chapter 4 and Chapter 5) and the phenological assessment of this food item was conducted using the same measures as those applied to trees. Ten 1m x 1m quadrats were recorded on a monthly basis within each research area. FAI for grass species was calculated using a variation of the FAI (Tree) calculation where basal area is substituted for cover and all PISp measures were combined to produce one figure per month, per research site.

FAI (Grass) = Phenological Index for the Species x cover for species *i*

Due to the anthropogenic nature of all three sites some large areas of grass were cut on a regular rotation and a variety of salt-resistant grass species were sown to create lawn areas. This resulted in identification of different grass species in the field being very difficult and as such all species (even those that were identifiable) were recorded as grass. Grass species know to grow in the research area included *Hyparrhenia sp., Digitaria sp*., and *Heteropagan contortus*.

Statistical differences in FAI (Tree) and FAI (Grass) where analysed using one-way ANOVA with post-hoc Tukey tests.

Table 3.1 List of the 11 tree species selected for phenological monitoring, including number of individuals monitored in each home range

Species	Status	Number of individuals monitored		
		Hotel site	University site	Release site
Azadirachta indica	Exotic	10	10	10
Delonix regia	Exotic	10	7	10
Dictyospermum album	Exotic	4	3	8
Ficus benjamina	Exotic	5	2	3
Ficus lingua	Indigenous	4	2	2
Ficus sycomorus	Indigenous	3	4	2
Lecaniodiscus fraxinifolius	Indigenous	9	9	1
Lannea weltswischi	Indigenous	3	2	10
Mangifera indica	Exotic	2	5	3
Sideroxylon inerme	Indigenous	5	5	3
Tamarindus indica	Indigenous	3	7	3

3.2.3 Hypothesis 3: Post-release Habitat Impact Assessment

The habitat assessment methods detailed in 3.2.1 were repeated, using the same modified Whittaker plot locations, in May 2014. It was important to ensure the habitat assessments were repeated during the same month to control for seasonal variation. Repeating the habitat assessments allowed for any changes in habitat composition, stem density and/or biomass to be measured within the locations of Hotel site and University site and to compare these changes to those measured in Release site. Using these data, a comparison to assess if the release process had resulted in a negative impact on the release habitat was preformed.

3.2.4 Indigenous and Exotic

Due to the anthropogenic habitat of Diani, all research sites had some level of human modification. Exotic plants have been introduced to the area for various reasons ranging from income generating in the form of fruit production and building poles, medicinal purposes, shade giving properties to simply ornamental. Exotic plant species range in size and diversity from grasses and herbs to large mature tree species. Some exotic species have thrived in this humid tropical environment, were self germinating, fast growing and able to out compete the indigenous plant flora and as such have very high stem densities.

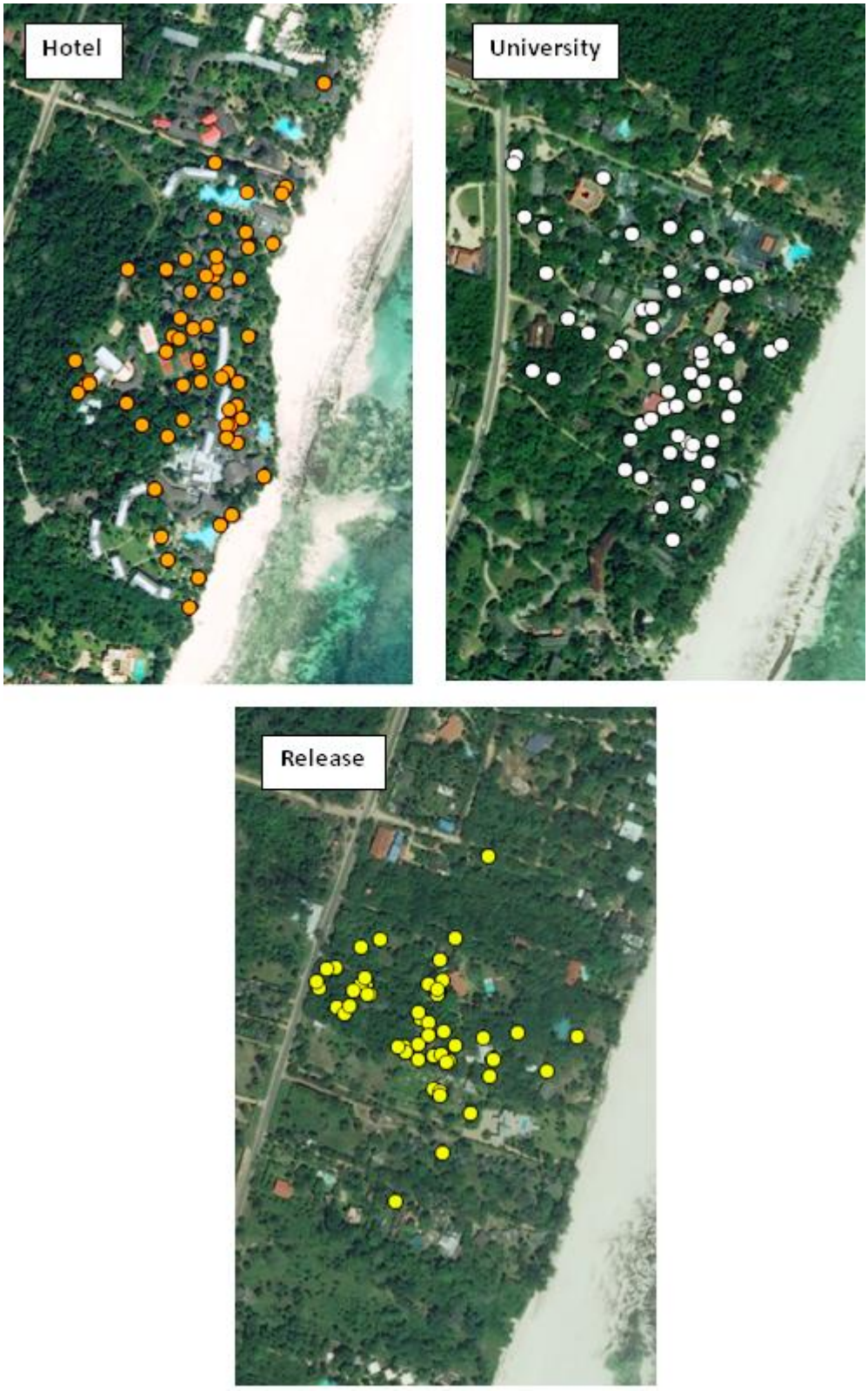


Figure 3.3 Locations of phenology trees at Hotel site, University site and Release site. ©2016 DigitalGlobe ©2016 GeoEye Earthstar Geographics SIO ©Microsoft Corporation

3.2.5 Climate

Rainfall data was collected daily at the Colobus Conservation facility (S4° 20' 39.9" E39° 33' 53.8"), approximately 1km south of Hotel groups study site and 2.5km south of University groups study site. Rainfall was collected using a basic rain gauge, measured in millimetres and recorded daily at 8am. The rainfall pattern is bimodal, with long rains between April and August, and short rains in October to December, with a peak in rainfall in May of both years. Temperatures were collected at a nearby weather station at Moi International Airport, Mombasa (S4° 02' 24" E39° 35' 24") approximately 33km north of the study sites. Mean monthly temperature fluctuated by approximately 5 degrees (23.9° - 29.1°), throughout the whole study period, with the coolest period occurring May to October, while December to March were the warmest months (Figure 2.6).

3.3 Results

All habitat sites were heavily anthropogenically modified and were largely focused on a strip of land, approximately 300-500m wide, between the beach and the main road. The historical methods used to clear the original coastal forest at the time of modification and the current daily management of each research site were different, as detailed below.

Hotel Site

The anthropogenically modified environment within the Hotel site was largely limited to a beach-fronted, clear cut strip to create hotel structures and open lawn tropical gardens, and only a small number of historic forest trees remained uncut. An area of remnant forest further from the beach was retained untouched for wildlife. Residential plots in this area covered a small section of the groups range and were generally composed of large historic forest trees, mixed with exotic trees and ornamental plants, lawns and property. The area mainly used by Hotel vervet group was maintained on a daily basis with grasses and shrubs being regularly cut and watered. While the Hotel vervet group had access to the remnant forest area, which was uninhabited by other vervet groups, they limited their range almost exclusively to the manicured hotel grounds and nearby residential plots. This area was also inhabited by two groups of Ibean yellow baboon (*Papio cynocephalus ibeanus*) with group sizes of 23 and 60 individuals, at least five groups of Zanzibar Sykes's monkey (*Cercopithecus mitis albogularis*) with group sizes ranging from 12 - 27 individuals, and at least four groups of Peter's Angolan colobus (*Colobus angolensis palliatus*) with group sizes ranging from 7-8 individuals. Vervet

groups were recorded directly north of this area, but not to the west or south, and no other group was ever observed within the research area (Figure 3.4).

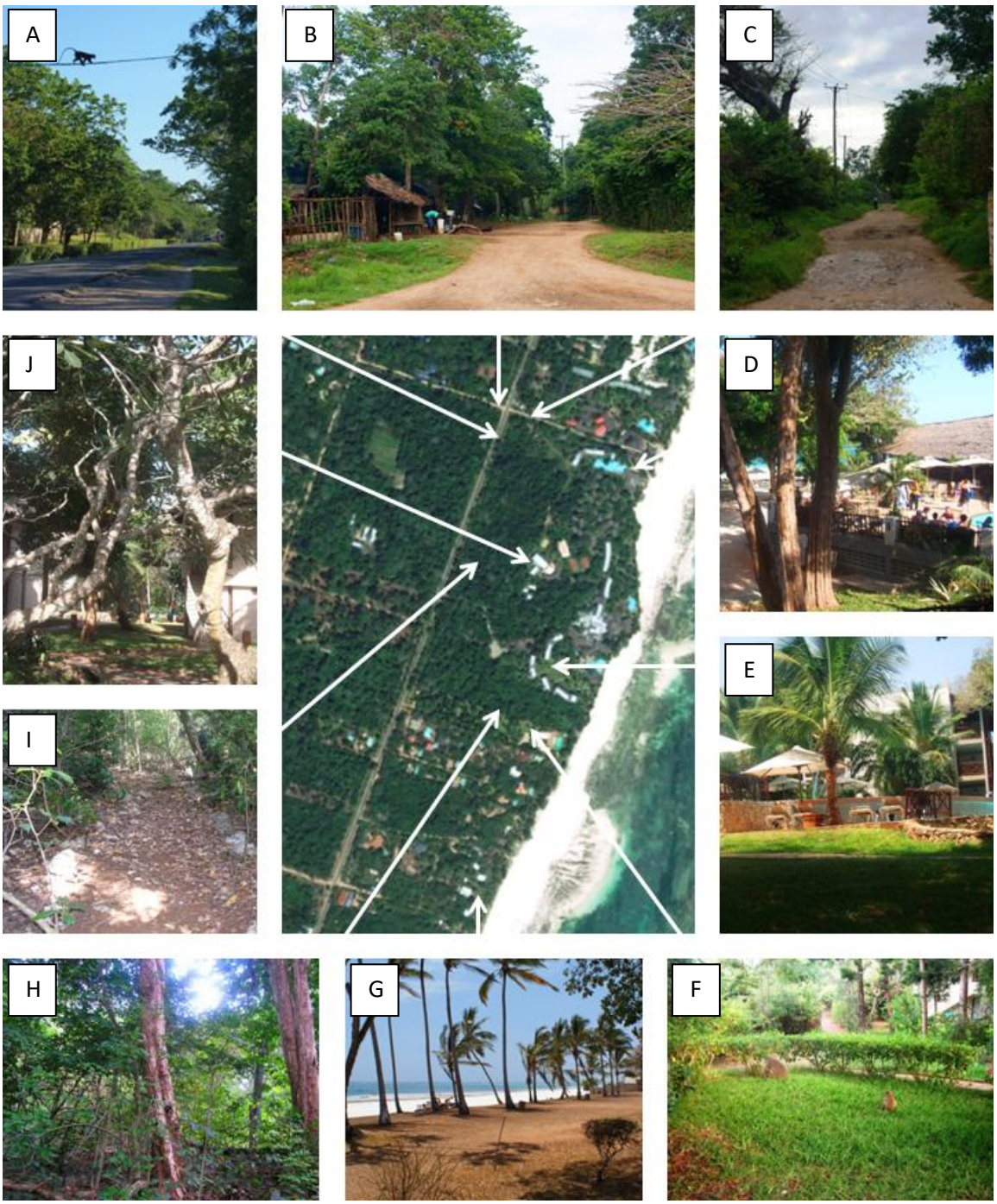


Figure 3.4 Some of the landscape characteristics of the habitat matrix within and surrounding Hotel site. Images A, B, C, G, H and I are authors own, images D, E, F and J are used with the permission of Laura Dalgetty, central map ©2016 DigitalGlobe ©2016 GeoEye Earthstar Geographics SIO ©Microsoft Corporation

University Site

The majority of the habitat at University site was clear cut at the under-storey level, removing shrubs and bushes, with the upper canopy being extensively 'thinned' but a canopy cover remained in most areas. Residential structures, along with ornamental plants and lawns were constructed under and around the remaining forest trees. Only a relatively small area of top canopy trees were clear cut in the area surrounding a hotel. Some parts of the range were maintained on a daily basis, but relatively large sections were allowed to develop naturally producing area with tall grasses. This type of management resulted in a more integrated landscape in the habitat of University site than the hard contrast in habitat types of Hotel site. This area was also inhabited by a group of Ibean yellow baboon with a group size of 36 individuals, at least four groups of Zanzibar Sykes's monkey with group sizes ranging from 20 - 40 individuals and at least three groups of Peter's Angolan colobus with group sizes ranging from 9 - 11 individuals. Vervet groups were recorded directly north, south and west of this area. No other vervet group was ever observed within the area, but occasional territory disputes were recorded at boundaries (Figure 3.5).

Release Site

The selected Release site, while heavily human-modified, contained substantially less daily human activity than the home ranges of the control groups. There were no hotels and a comparatively small number of residential plots, with the largest hub of activity the area used by Colobus Conservation as their operations base. Historically, sections of habitat had been entirely clear cut for residential buildings. Some areas had the under-storey removed and in a few areas remnant forest remained creating a mosaic landscape. In recent years the private residents in this location had focused a lot of attention on replanting indigenous forest trees in a bid to restore the forest area and with this an increase in resident primate groups had been seen. The area was inhabited by a group of Ibean yellow baboons with group size of 23 individuals, at least two groups of Zanzibar Sykes's monkey with group sizes ranging from 18 - 24 individuals and at least three groups of Peter's Angolan colobus with group sizes ranging from 7-11 individuals. One vervet group was recorded north of this location, this was the group inhabiting the Hotel location and their core area was approximately 1km from Release site. In previous years the Hotel vervet group were recorded visiting the release location on only a few occasions during March, the last month of the long dry season. No other vervet group were recorded to the south or west of this location (Figure 3.6).

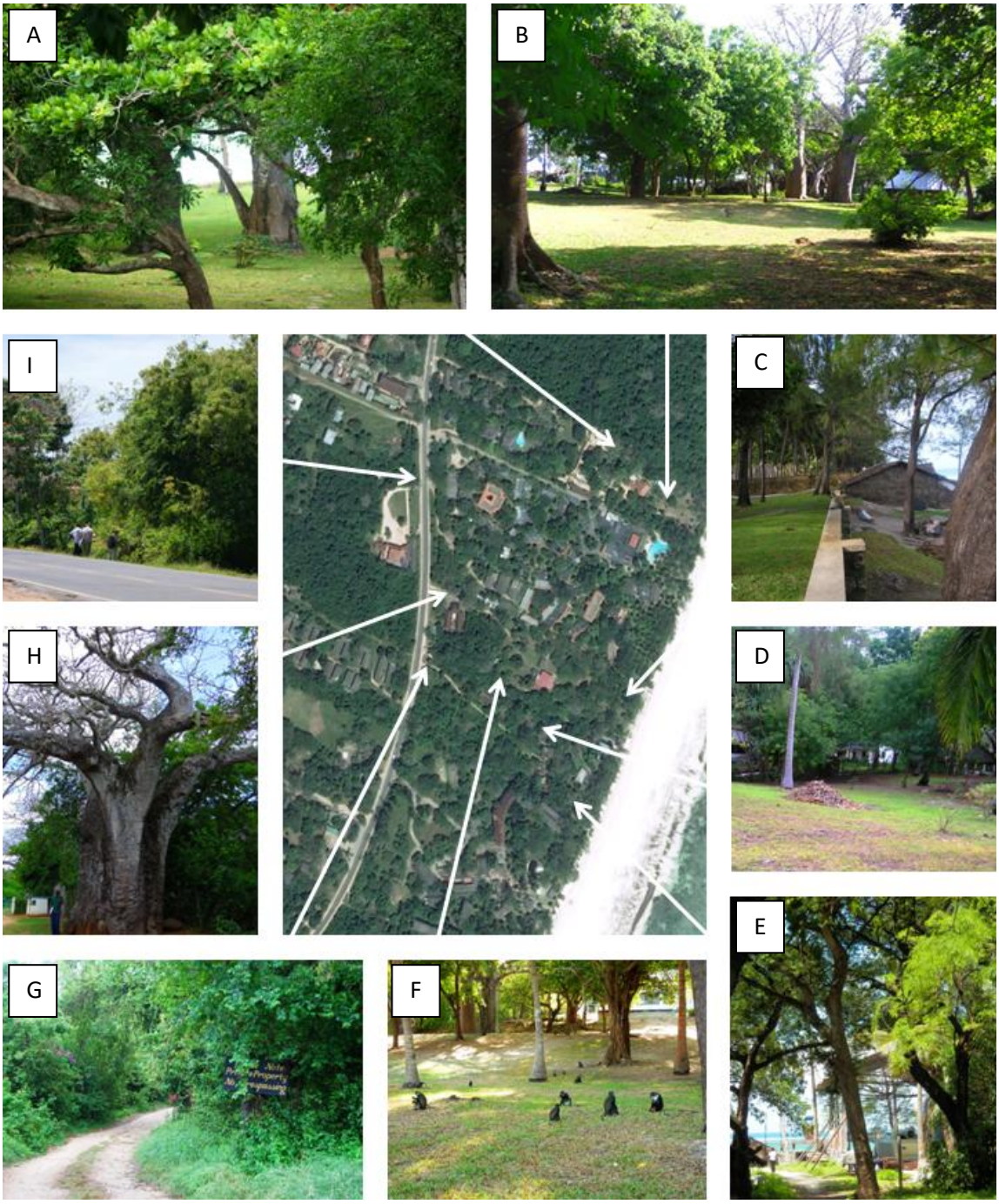


Figure 3.5 Some of the landscape characteristics of the habitat matrix within and surrounding University site. Images A, C, D, G and I are authors own, images B and H are used with the permission of Kate Lees, images E and F are used with the permission of Nika Bellchambers, central map ©2016 DigitalGlobe ©2016 GeoEye Earthstar Geographics SIO ©Microsoft Corporation

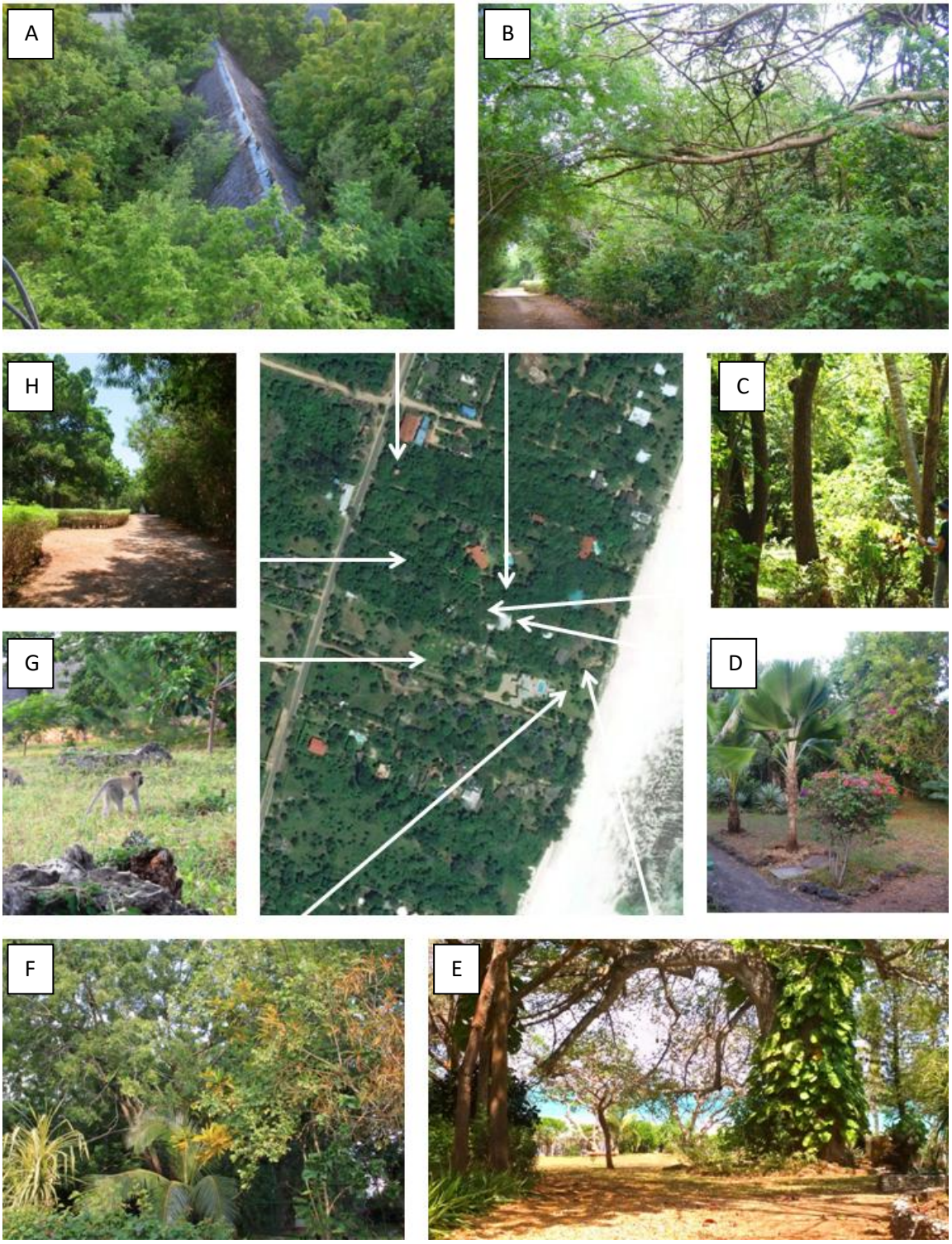


Figure 3.6 Some of the landscape characteristics of the habitat matrix within and surrounding release site. Images A to F are authors own, image H is used with the permission of Laura Dalgetty, image G is used with the permission of Marta Ramos, central map ©2016 DigitalGlobe ©2016 GeoEye Earthstar Geographics SIO ©Microsoft Corporation.

Other notable wildlife inhabiting all three locations included white-tailed small-eared galago (*Otolemur garnettii lasiotis*), Kenya coast galago (*Galagoides cocos*) and hornbills, but exact numbers were unavailable. There were no natural large carnivorous predators remaining within Diani, but dogs (pet and feral), snakes and baboons were all recorded injuring or killing monkeys during the study period.

3.3.1 Hypothesis 1: Habitat Composition

Species present

A total of 39 tree species were recorded within all modified Whittaker plots. Hotel and University sites both had 26.4 tree species per hectare, while Release site had 25 tree species per hectare. Due to the anthropogenically modified nature of Diani, exotic plant species were prevalent throughout the all locations. Of the 39 tree species recorded across all sites, 33% were exotics. All sites had a larger variety of indigenous species than exotic species. Hotel site had a higher percentage of exotic species than University or Release site (Table 3.2).

Table 3.2 Number of tree species present, per hectare in Hotel, University and Release site.

All trees ≥ 10cm DBH	**Hotel group/1ha**		**University group/1ha**		**Release group/1ha**	
	Count	Percentage	Count	Percentage	Count	Percentage
All species	26.4	100	26.4	100	25	100
Indigenous species	14.6	54.2	19	70.8	17.5	70
Exotic species	12.3	45.8	7.8	29.2	7.5	30

Stem Density

The overall stem density for Hotel and University sites was closely matched (Table 3.3). Release site had a larger overall stem density, due to a considerably higher number of smaller trees (DBH <30cm ≥ 10cm). Calculating stem density of indigenous and exotic tree species revealed that the habitat of all locations had a higher stem density of exotic species than indigenous species and the levels recorded at Release site were within an expected range (Table 3.4).

Table 3.3 Stem density per hectare, of trees within the Hotel, University and Release sites.

Study Site	Trees per ha		
	≥30cm	<30cm ≥ 10cm	Total
Hotel	72.80	94.52	167.32
University	70.56	72.82	142.84
Release	56.25	137.50	193.75

Table 3.4 Stem density per hectare, of all trees ≥ 10cm DBH divided into indigenous and exotic species within the Hotel, University and Release study sites.

All trees ≥ 10cm DBH	Hotel		University		Release	
	Count	Percentage	Count	Percentage	Count	Percentage
Stem density	167.32	100	142.84	100	193.75	100
Indigenous stem density	50.24	30.03	59.20	41.44	62.50	32.26
Exotic stem density	117.08	69.97	83.64	58.56	131.25	67.74

Three species were among the 10 highest ranking tree species in terms of stem density, in all three study sites (Table 3.5). A further six species were shared by two of the sites. Overall, 7 of the top 10 highest ranking tree species in terms of stem density at Release site were also among the top 10 most commonly occurring tree species at one or more of the control sites.

Biomass

Hotel site had a total biomass of 231,628cm^2 per ha, University's biomass was substantially higher at 422,166cm^2 per ha and Release site had the smallest biomass of just 143,116cm^2. Four species were among the 10 highest ranking trees in terms of biomass within the three study sites (Table 3.6). A further three were present in two of the sites. Overall 7 of the top 10 biomass species at Release site were also in the top 10 of one or both control sites.

Diversity and Equitability

Based on biomass figures, Hotel site had the highest tree diversity with a Shannon-Weaver H-value with 2.54, followed by Release site with 2.23 and finally University site with 2.03. Equitability values were 0.21, 0.19 and 0.16 for Hotel, Release and University sites respectively.

Table 3.5 The 10 highest ranking tree species in terms of stem density per hectare (SD/ha) from modified Whittaker Plots within Hotel, University and Release site. * - species present in top 10 at all three sites, † - species present in top 10 at two sites, I - indigenous, E - exotic.

	Hotel site				University site				Release site			
Rank	**Species**	**Status**	**SD/ ha**	**% total SD**	**Species**	**Status**	**SD/ ha**	**% total SD**	**Species**	**Status**	**SD/ ha**	**% total SD**
1	*Azadirachta indica**	E	33.4	20.0	*Azadirachta indica**	E	24.5	17.2	*Azadirachta indica**	E	72.5	37.4
2	*Cocos nucifera**	E	22.4	13.4	*Casurina equisetifolia†*	E	17.8	12.5	*Delonix regia†*	E	17.5	9.0
3	*Delonix regia†*	E	20.1	12.0	*Cocos nucifera**	E	13.4	9.4	*Mangifera indica †* ·	E	13.8	7.1
4	*Plumeria rubra** ·	E	16.7	10.0	*Lecaniodiscus fraxinifolius*	I	11.2	7.8	*Fernandoa magnifica*	I	12.5	6.5
5	*Pycnocoma litoralis†*	I	11.1	6.7	*Dictyospermum album†*	E	11.1	7.8	*Pycnocoma litoralis†*	I	12.5	6.5
6	*Sideroxylon inerme†*	I	8.9	5.3	*Carpodiptera africana*	I	7.8	5.5	*Plumeria rubra** ·	E	12.5	6.5
7	*Dictyospermum album†*	E	7.8	4.7	*Mangifera indica†* ·	E	5.6	3.9	*Cocos nucifera**	E	8.8	4.5
8	*Lannea welwitschii*	I	5.6	3.4	*Markhamia zanzibarica*	I	5.6	3.9	*Ficus sycamorus*	I	7.5	3.9
9	*Casurina equisetifolia†*	E	5.6	3.3	*Pandanus kirkii*	I	5.6	3.9	*Ficus benjamina*	E	6.3	3.2
10	*Ficus elastica*	E	5.6	3.3	*Plumeria rubra** ·	E	5.6	3.9	*Sideroxylon inerme†*	I	6.3	3.2

Table 3.6 The 10 highest ranking tree species in terms of biomass per hectare from modified Whittaker Plots within Hotel, University and Release site.

* - species present in top 10 at all three sites, † - species present in top 10 at two sites, I - indigenous, E - exotic.

	Hotel site				University site				Release site			
Rank	**Species**	**Status**	**Biomass cm^2/ha**	**% total biomass**	**Species**	**Status**	**Biomass cm^2/ha**	**% total biomass**	**Species**	**Status**	**Biomass cm^2/ha**	**% total biomass**
1	*Adansonia digitata**	I	53688	23.2	*Adansonia digitata**	I	223131	52.6	*Azadirachta indica**	E	54492.9	38.08
2	*Delonix regia**	E	31293	13.5	*Azadirachta indica**	E	29089	6.9	*Delonix regia**	E	19772.7	13.82
3	*Sideroxylon inerme†*	I	27702	12.0	*Casurina equisetifolia*	E	24099	5.7	*Adansonia digitata**	I	15243.8	10.65
4	*Azadirachta indica**	E	24796	10.7	*Delonix regia**	E	15691	3.7	*Mangifera indica†*	E	7546.8	5.27
5	*Cocos nucifera**	E	19650	8.5	*Cordia goetzei*	I	13977	3.3	*Cocos nucifera**	E	7349.2	5.14
6	*Lannea welwitschii*	I	10212	4.4	*Sideroxylon inerme†*	I	13879	3.3	*Ficus sycamorus*	I	6739.7	4.71
7	*Tamarindus indica*	I	8322	3.6	*Mangifera indica†*	E	12700	3.0	*Lannea schweinfurthianum*	I	4557.7	3.18
8	*Ficus bubu*	I	7200	3.1	*Lecaniodiscus fraxinifolius†*	I	11701	2.8	*Carpodiptera africana†*	I	3889.7	2.72
9	*Lepisanthes senegalensis*	E	6793	2.9	*Cocos nucifera**	E	10620	2.5	*Fernandoa magnifica*	I	3571.9	2.50
10	*Ficus benjamina*	E	5890	2.5	*Carpodiptera africana†*	I	7905	1.9	*Lecaniodiscus fraxinifolius†*	I	3351.6	2.34
	Hotel Total		**231,628**		**University Total**		**422,166**		**Release Total**		**143,116**	

Habitat Overlap

Schoener's index revealed a low (0.3) habitat overlap between the three groups (Figure 3.7). When the sites were compared as pairs the habitat overlap increased (Figure 3.7). However, no pair of sites had an overlap of significant value (>0.6). The greatest habitat overlap occurred between Hotel and Release site, while the smallest overlap was between University and Release site. Ten tree species were common to all three sites. Hotel and University site shared a further 12 species, Hotel and Release site shared 3 species and University and Release site shared 3 species. Eight species featured in Hotel site only, 8 species were unique to University group and 4 species to Release group. *Delonix regia* was the primary overlapping species between Hotel and Release sites while *Adansonia digitata* was the primary overlapping species for the remaining three group combinations.

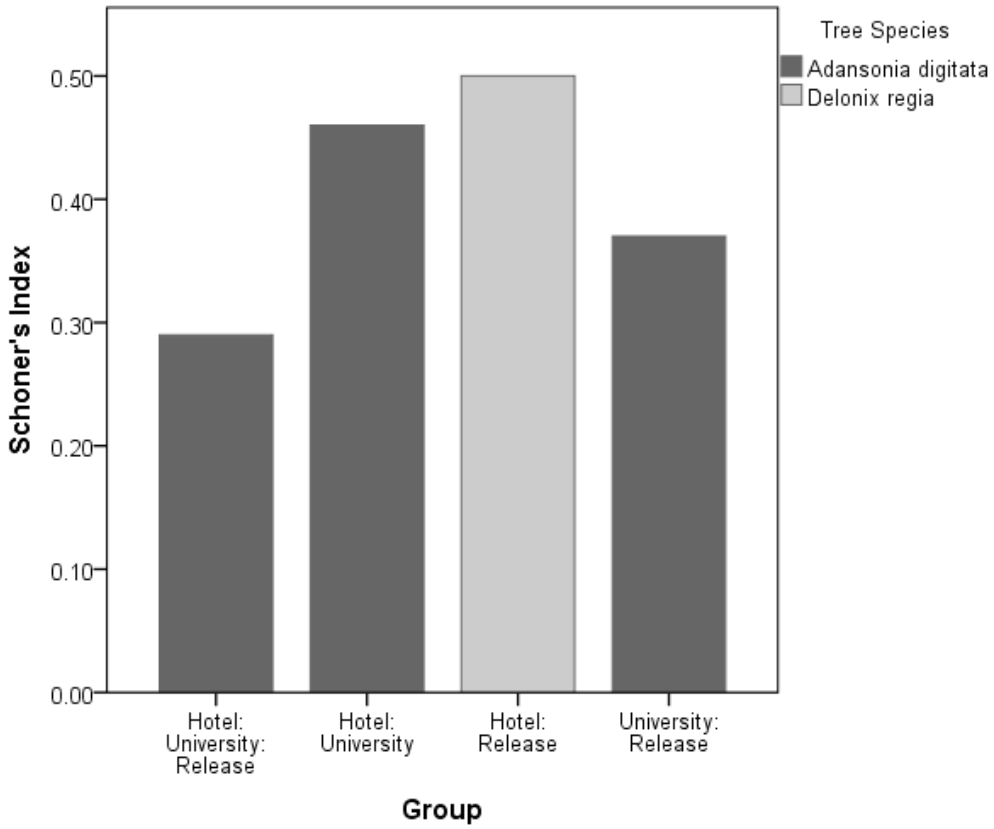


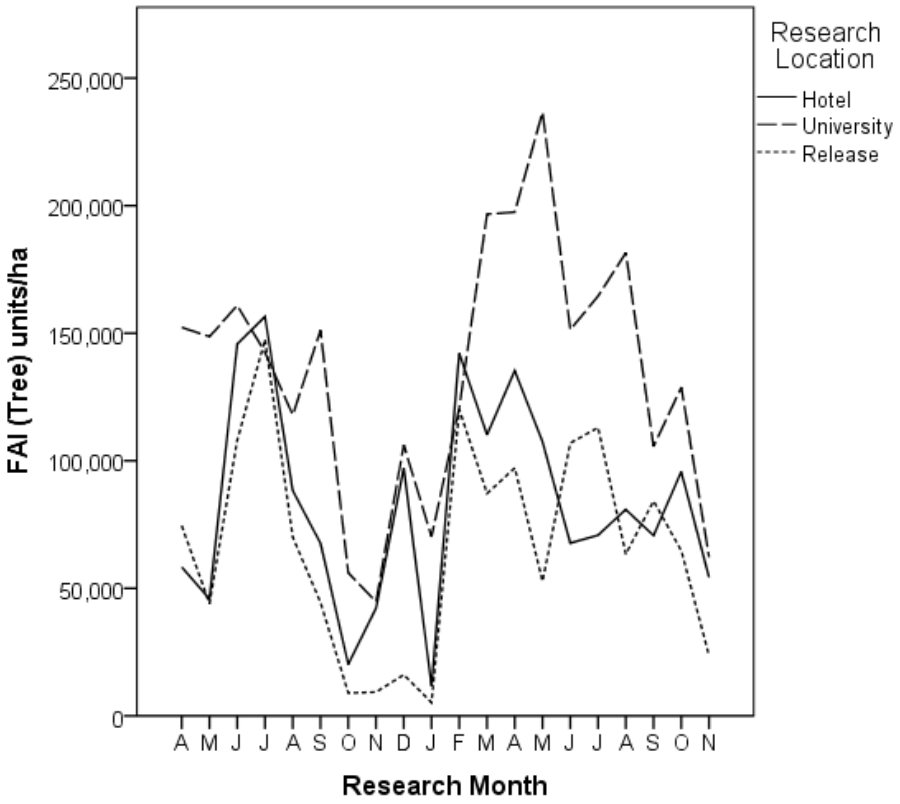
Figure 3.7 Habitat overlap of Hotel, University and Release site displayed as a group of three and subsequently in pairs. Bar colour indicates the tree species that was the highest overlapping species between the groups.

3.3.2 Hypothesis 2: Habitat Phenology and Food Availability

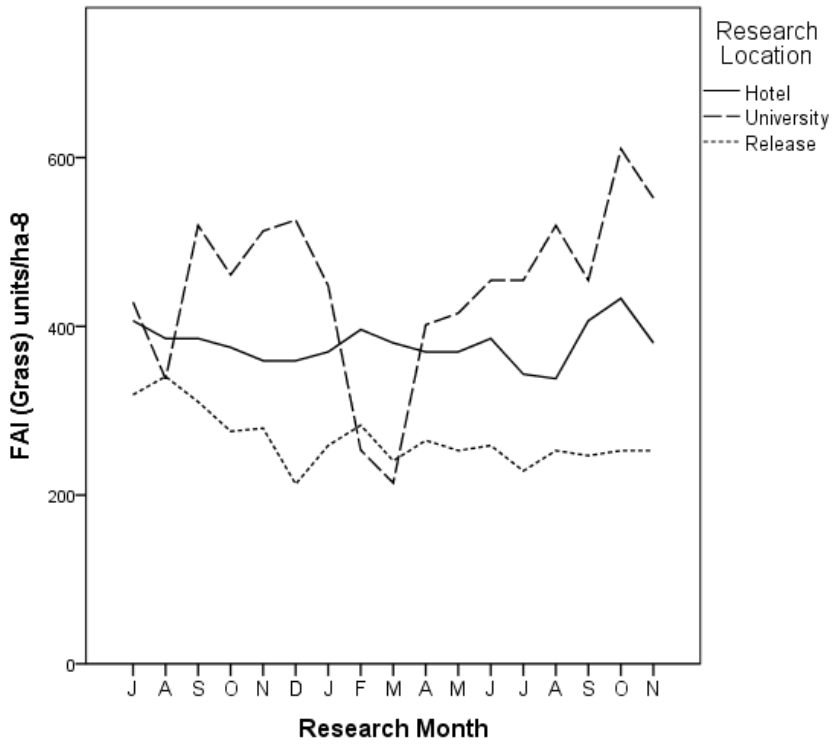
Two important food items in the natural diet of all study groups, fruits (including fruit and seeds) and grass, (Chapters 4 and 5) varied considerably in FAI from month to month across the three sites (Figure 3.8 a and b). The FAI (Tree) per hectare at Hotel and Release study site were fairly well matched throughout the study period. However, University had a higher FAI (Tree) per hectare than Hotel or Release for 16 out of 20 months, , this was most notable throughout 2013. All locations showed peaks and troughs in FAI (Tree), with all locations recording the lowest FAI (Tree) in October 2012 and January 2013, and peaks occurring in June and July of both years and February - April 2013. A significant difference was found in FAI (Tree) values between the three sites (one-way ANOVA: FAI (Trees): $F_{(2,57)}$= 12.596, p=<0.001***). Tukey tests indicated that FAI (Trees) values were significantly different at the University site, while there was no difference between the Hotel and Release site (University/Hotel, p=<0.02*; University/Release, p=<0.001***; Hotel/Release, p=0.481).

Monthly FAI (Grass) varied considerably between the three areas, with Hotel and Release sites having a relatively constant grass FAI, while University site was highly variable across the research period exhibiting peaks during cooler and wetter months and troughs during hot and extremely dry periods. A significant difference was found in the FAI (Grass) values between the three study sites, (one-way ANOVA FAI (Grass): $F_{(2,48)}$= 34.639, p=<0.001). Tukey tests indicated that FAI (Grass) values were significantly different between all sites (University/Hotel, p=<0.001***; University/Release, p=<0.001***; Hotel/Release, p=<0.001***).

No correlation was found in any site between FAI (Tree) or FAI (Grass) with either mean monthly rainfall or temperature (Table 3.7).



a)



b)

Figure 3.8 Monthly variation in FAI within Hotel, University and Release site, a) FAI (Tree) from April 2012 - November 2013, b) FAI (Grass) from July 2012 - November 2013.

Table 3.7 Results from correlation coefficient analysis for FAI (Tree), FAI (Grass)and environmental variables data. Significant relationships are highlighted with * p=<0.05 or ** p=<0.01, r = correlation coefficient. FAI (Tree): n=20, FAI (Grass) n=17.

Group	Variable	r/p	Rainfall Spearman's Rank	Mean Temperature Pearson's
Hotel	FAI (Tree)	r	-0.296	-0.056
		p	0.205	0.814
	FAI (Grass)	r	-0.327	-0.043
		p	0.200	0.869
University	FAI (Tree)	r	0.140	-0.215
		p	0.556	0.362
	FAI (Grass)	r	0.100	-0.320
		p	0.701	0.210
Release	FAI (Tree)	r	-0.331	-0.376
		p	0.154	0.102
	FAI (Grass)	r	-0.023	-0.244
		p	0.929	0.345

Indigenous and Exotic Trees

All study sites had a higher total FAI of exotic trees compared to indigenous trees over the course of the research period. FAI of exotic trees dramatically reduced in all study sites between October 2012 and January 2013 (Figure 3.9). During this same period the FAI of indigenous trees increased to its highest peak at Hotel and University sites. There was only a small increase in FAI of indigenous trees at Release site during this time. The FAI of exotic trees compared to indigenous trees were different throughout the study period and in general when exotic tree FAI was lower, indigenous tree FAI was higher and vice versa. This difference was statistically significant for all research sites (Table 3.8).

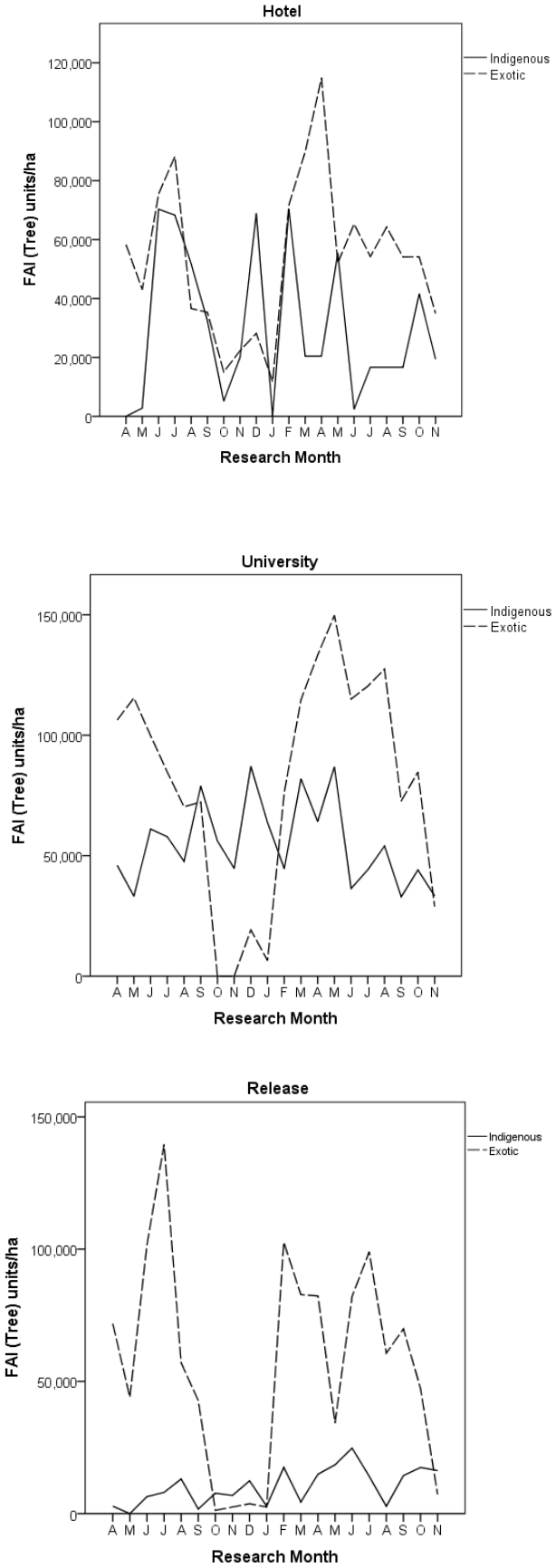


Figure 3.9 Monthly variation of FAI (Tree) of indigenous and exotic species from April 2012 - November 2013 in the Hotel, University and Release study sites.

Table 3.8 Results for FAI (Tree) comparisons between indigenous and exotic species within the Hotel, University and Release study sites. Significant relationships are highlighted with * p=<0.05, ** p=<0.01 or *** p=<0.001

Group	FAI (Trees)		Wilcoxon signed rank test		
	Indigenous trees	Exotic trees	z	n	Significance
Hotel group	599,414	1,069,504	-2.875	20	0.004**
			Paired t-test		
			t	df	p
University group	1,098,803	1,597,680	-2.287	19	0.034*
Release group	206,721	1,134,909	-5.238	19	<0.001***

3.3.3 Hypothesis 3: Post-release Habitat Impact Assessment

Species Present and Stem Density

Repeated habitat assessments conducted exactly two years after the initial assessments revealed no change to the species present or the stem density at any of the three study sites (Table 3.9). This lack of change in stem density indicates that no trees had died or been removed, neither had any smaller saplings grown sufficiently to increase their DBH to ≥ 30cm or ≥ 10cm, within the repeated modified Whittaker plots at any site.

Table 3.9 Stem density per hectare of trees within Hotel, University and Release sites in 2012 and 2014.

Trees per hectare	Study Site					
	Hotel		University		Release	
	2012	2014	2012	2014	2012	2014
≥30cm	72.80	72.80	70.56	70.56	56.25	56.25
<30cm ≥ 10cm	94.52	94.52	72.82	72.82	137.50	137.50
Total	167.32	167.32	142.84	142.84	193.75	193.75

Biomass

Overall biomass across the three study sites had increased between the 2012 and 2014 surveys. The largest biomass increase was recorded at Release site (+7.0%), followed by Hotel site (+5.2%) with University site displaying the smallest increase (+4.6%) (Table 3.10). Only two

species *Cocos nucifera* and *Ficus bubu* at Release site did not register any increase in biomass over the two years. Biomass increase at species level ranged from 0.2% - 24.2%.

3.4 Discussion

All habitats are multi-layered and complex (Ganzhorn 2003) but those of the Diani environment had additional levels to be considered in terms of anthropogenic modification, resulting in a mixture of indigenous and exotic plants, alongside human management which produced unpredictable changes. A detailed understanding of habitat composition, the presence of adequate food species, sleeping and refuge sites is an essential component of release site selection (Baker 2002; Beck *et al.* 2007; Cheyne 2006; Soorae 2008). Therefore, gaining an understanding of the impact the anthropogenic modification had on the environment in terms of plant species present, tree cutting and pruning rotations and watering of grounds was vital.

3.4.1 Hypothesis 1: Habitat Composition

As predicted, the three habitats displayed numerous differences in their habitat composition. Release site had a slightly smaller variety of tree species than either of the two control sites. Despite this it was representative of the control sites when only indigenous species were counted. Release site had a much higher overall stem density than Hotel or University sites. This appears to be due to a high number of younger *A. indica* trees, an exotic species prevalent throughout much of the Diani environment. Preliminary behavioural data collection on Hotel and University groups revealed that *A. indica* was the most consumed plant species during the dry season, contributing 30% to the control groups combined diet, making this tree an important fallback species. Additionally, this species was in the top five consumed plant species, and preferentially selected as a food item by both Hotel and University group throughout the duration of a two year behavioural study (Chapter 4). As such, the high concentration of *A. indica* was considered to be a positive attribute of Release site. Exotic species accounted for more the 50% of the stem density in all three sites, with Release site falling between the percentages for Hotel and University sites. Comparisons of the 10 highest ranking tree species in terms of stem density showed considerable overlap, with Release site sharing 7 species with one or both control sites.

Table 3.10 The 10 highest ranking tree species in terms of biomass per hectare from modified Whittaker Plots in Hotel, University and Release site in 2014. Percentage increases from the 2012 survey are indicated in brackets. * - species present in top 10 at all three sites, † - species present in top 10 at two sites, I - indigenous, E - exotic.

	Hotel group				University group				Release group			
Rank	**Species**	**Status**	**Biomass cm^2/ha**	**% total biomass**	**Species**	**Status**	**Biomass cm^2/ha**	**% total biomass**	**Species**	**Status**	**Biomass cm^2/ha**	**% total biomass**
1	*Adansonia digitata**	I	54207 (+1.0%)	22.25	*Adansonia digitata**	I	226597 (+1.6%)	51.33	*Azadirachta indica**	E	60256 (+10.6%)	39.33
2	*Delonix regia**	E	33327 (+6.5%)	13.68	*Azadirachta indica**	E	31159 (+7.1%)	7.06	*Delonix regia**	E	21199 (+7.2%)	13.84
3	*Sideroxylon inerme†*	I	28587 (+3.2%)	11.73	*Casurina equisetifolia*	E	25717 (+6.7%)	5.83	*Adansonia digitata**	I	15557 (+2.1%)	10.16
4	*Azadirachta indica**	E	26602 (+7.3%)	10.92	*Delonix regia**	E	16648 (+6.1%)	3.77	*Mangifera indica†*	E	7562 (+0.2%)	4.94
5	*Cocos nucifera**	E	20875 (+6.2%)	8.57	*Cordia goetzei*	I	14995 (+7.3%)	3.40	*Cocos nucifera**	E	7349 (0.0%)	4.80
6	*Lannea welwitschii*	I	11076 (+8.5%)	4.55	*Mangifera indica†*	E	14542 (+14.5%)	3.29	*Ficus sycamorus*	I	7025 (+4.2%)	4.59
7	*Tamarindus indica*	I	8595 (+3.3%)	3.53	*Sideroxylon inerme†*	I	14489 (+4.4%)	3.28	*Lannea schweinfurthianum*	I	4773 (+4.7%)	3.12
8	*Lepisanthes senegalensis*	E	7399 (+8.9%)	3.04	*Lecaniodiscus fraxinifolius†*	I	13044 (+11.5%)	2.95	*Carpodiptera africana†*	I	4025 (+3.5%)	2.63
9	*Ficus bubu*	I	7341 (+2.0%)	3.01	*Cocos nucifera**	E	11476 (+8.1%)	2.60	*Fernandoa magnifica*	I	3946 (+10.5%)	2.58
10	*Ficus benjamina*	E	6028 (+2.3%)	2.47	*Carpodiptera africana†*	I	8802 (+11.3%)	1.99	*Lecaniodiscus fraxinifolius†*	I	3435 (+2.5%)	2.24
	Hotel Total		**243,642 (+5.2%)**		**University Total**		**441,483 (+4.6%)**		**Release Total**		**153,191 (+7.0%)**	

University site had a substantially higher biomass than both Hotel site and Release site, with Release site recording the lowest biomass. The difference in biomass between the three sites was accounted for by several extremely large *Adansonia digitata* trees being present in University site which contributed 52.63% to the areas biomass. No one species contributed so heavily to the biomass of Hotel or Release site (Table 3.6). *A. digitata* is a tree considered to be sacred and believed to be associated with the spirit of the departed within coastal Digo tradition (Davidson and Gitlitz 2002). Development in the area of University site has been sympathetic to this. Like *C. nucifera*, the fruit of *A. digitata* is extremely hard and vervet monkeys are unable to access the edible centre without the fruit firstly being cracked by baboons. While the leaves and flowers of both of these species were recorded being eating by one or more of the groups the contribution to the overall diet was small despite being so prominent in the habitat. Calculating the biomass of all three sites excluding *A. digitata* and *C. nucifera*, revealed that the remaining biomass of University was still greater than Hotel and Release site, but the difference was reduced (Table 3.11).

Table 3.11 Total biomass per hectare of the all trees from modified Whittaker Plots within Hotel, University and Release, including and excluding *A. digitata* and *C. nucifera*.

Species	**Indigenous and Exotic Biomass**	**Hotel group**		**University group**		**Release group**	
		Biomass cm^2/ha	% total biomass	Biomass cm^2/ha	% total biomass	Biomass cm^2/ha	% total biomass
Including	Total biomass	231628	100	422166	100	143116	100
A. digitata ***C. nucifera***	Indigenous biomass	127701	55.1	317735	75.3	55172	38.6
	Exotic biomass	103926	44.9	104431	24.7	87943	61.4
Excluding	Total biomass	158290	100	188416	100	115996	100
A. digitata ***C. nucifera***	Indigenous biomass	74014	46.8	94604	50.2	35400	30.5
	Exotic biomass	84276	53.2	93812	49.8	80594	69.5

Based on the dietary calculations of Hotel and University groups presented in Chapter 4, 65.1% of the tree biomass at Release site was comprised from the top 10 vervet tree food species (Table 3.12). This percentage is higher than that found at Hotel or University site for the same species. Even with the removal of *A. indica* which dominated the biomass at Release site, the percentage remains higher than that recorded at University site. When the biomass of favoured food tree species alone are considered the biomass per hectare at Release site was

higher than at either of the control sites and indicated that sufficient food items where available at Release site for a vervet group.

Diversity and equitability results for Release site show that the area hosts a rich tree community that falls within the expectations of the environment and are representative of habitats already hosting stable vervet populations. As predicted, habitat overlap between the sites was not significant but, Release site had a more similar habitat composition to Hotel site, than Release site had to University site, or University site had to Hotel site. This further highlights the potential impact of human modification up on the environment and as such is not a useful tool to inform release site selection in this location.

3.4.1.1 Carrying Capacity

By extrapolating data from the control groups on known group sizes, home range size (Chapter 4) and biomass of the home range an estimation of the required home range size at Release site, based on the known biomass and starting group size, can be calculated.

Using the equation

$$\text{Biomass requirements per monkey} = \frac{\text{Home range size x Biomass per Hectare}}{\text{Average group size}}$$

the biomass requirement per vervet monkey in Hotel is 222,404cm^2/ha while in University it is 211,083cm^2/ha. Reconfiguring the above equation to estimate the required home range size based on the known requirements per monkey, group size and biomass per cm^2/ha figure, indicates that Release group required a home range of 17.7 - 18.6ha at Release site. An area of approximately 30ha surrounding Release site was subsequently deemed as appropriate vervet habitat in terms of available food sources and a lack of vervet groups (Figure 2.4). Additionally, baboons did not use this more southerly area, thus further reducing potential food competition. With an area of up to 30ha of vacant, vervet appropriate habitat to utilise the Release group would have the potential to almost double in size before reaching carrying capacity. This method does have limitations; the extrapolation only deals with data on vervet densities based on the biomass of trees in the home range and does not account for densities of other fauna, just their presences or absence. However, this limitation was applicable to all sites and as all three sites had similar presences of animal numbers the calculation remained useful as an indicator.

Table 3.12 Percentage of biomass per study site that was comprised of the top 10 tree food species. The top 10 list is calculated from the combined diet of natural food items of Hotel and University vervet control groups as presented in Chapter 4.* - Grass and *Bougainvillea spectabilis* are included in this list as the only non-tree species to contribute a significant amount to the vervet plant diet, but do not feature in the biomass calculations. NB - species is present in the study site, but was not recorded in the habitat assessments and therefore does not have a biomass figure.

Rank	Species	Percentage of Diet	Hotel Biomass	University Biomass	Release Biomass
1	*Grass**	36.9	-	-	-
2	*Azadrachtica indica*	13.3	10.7	6.9	38.1
3	*Tamarindus indica*	10.2	3.6	1.5	NB
4	*Bougainvillea spectabilis**	4.2	-	-	-
5	*Ficus benjamina*	3.2	2.5	NB	0.9
6	*Mangifera indica*	3.0	NB	3.0	5.3
7	*Delonix regia*	2.7	13.5	3.7	13.8
8	*Lecaniodiscus fraxinifolius*	2.6	1.2	2.8	2.3
9	*Terminalia catappa*	2.4	NB	NB	NB
10	*Dictyospermum album*	2.3	2.3	0.8	NB
11	*Diospyros consolatae*	2.2	NB	NB	NB
12	*Ficus sycamorus*	2.1	NB	NB	4.7
Total percentage of biomass comprised from most consumed tree species			33.8	18.7	65.1
Biomass per hectare			78,290	84,433	94,600

3.4.1.2 Release Site Justification

Based on the preliminary data, the habitat of Release site was deemed suitable to be used for a vervet release site. While species variety was lower at Release site when compared to the control sites, the range of indigenous species was representative of the control sites. The reduced exotic species diversity is likely related to Release site not having a large hotel development in the area. Release site displayed a higher stem density than the control sites and this was discovered to be predominantly related to one exotic species. This species however, was considered an important fall back species. Biomass of Release site was greatly reduced compared to University site, but this was seen to be the result of one very large tree

species, *A. digitata*, which did not contribute significantly to the natural diets of the control groups. Once this species was removed from the biomass equations the figures were more closely matched. A basic calculation to predict home range size based on group number and known biomass showed an area of up to 18.6ha would be required to support a vervet group at the selected Release site and with no limiting factor to the south of the Release site, group growth was also possible. There was no obvious limit to the potential southerly range from Release site; Sykes and colobus monkeys both utilised this area and further habitat surveys revealed there were suitable habitats in this extension. A habitat restoration programme targeting the replanting of indigenous forest tree species had been in place within the suggested release area since 2006 and was to continue in the future. Additional issues considered related to releasing monkeys into areas with wild conspecifics, which raised questions about disease transmission, social disruption and introduction of alien genes to wild populations (Baker 2002; Beck *et al.* 2007; Soorae 2008). The individuals scheduled for release all originated from this wild population, they were subject to extensive veterinary screening and treated for all diseases and parasites of concern as listed by IUCN. As such the introduction of alien genes and disease transmission was minimal. To minimise social disruption, Release site was 1km away from the nearest vervet core territory (Wimberger *et al.* 2010b) and while this group (Hotel) had been recorded previously visiting Release site they were monitored for eight months pre-release and for the duration of the release, to ensure any disruption was recorded and dealt with accordingly. The proximity of a main tarmac single carriageway road was a concern of Release site selection. The same road was present at the western edge of the home ranges of both control groups. Within these areas canopy bridges, known locally as colobridges, had been installed at suitable locations to facilitate safer road passage by the Diani primate groups. Unfortunately, the habitat either side of the road at the release site was not suitable to support the installation of a canopy bridge and alternatively a speed bump was installed as a traffic calming measure. With all this information and the aforementioned measures put in place, it was deemed suitable to proceed with this area as the release site.

3.4.2 Hypothesis 2: Habitat Phenology and Food Availability

In line with predictions, biomass was predictive of FAI of the three sites, with University displaying the highest biomass and generally the highest FAI for trees and grass. Against predictions there was no correlation between FAI (Tree) or FAI (Grass) and seasonality at any of the study sites. In tropical environments rainfall influences the fruiting of trees and the growth of grass (Brienen *et al.* 2016; Hutley and Setterfield 2009). Therefore, to find no relationship between these environmental factors and food availability is very unusual and is

likely linked to three factors, all human induced. Firstly, the presence of exotic trees; exotic trees appear to have different fruiting cycles to indigenous trees, resulting in some fruit being available all through the year (Figure 3.3). Secondly, human management of the sites; some areas of all study sites were watered throughout the dry season, meaning that the plant life did not experience a true dry period thereby reducing seasonality. Finally, cutting of grass; the human management of grass was different between the three research sites, but the availability of seed and flower heads as a food source was reduced in all locations as a result. While all sites had areas of manicured grass that was regularly cut, a large section of open grassland in University site was permitted to develop naturally, only being cut if sightings of snakes increased.

As predicted, indigenous and exotic trees provide variation in FAI throughout the research period. Most consistently across all three sites the FAI of exotic trees was low between October - January and during the same period an increase in FAI of indigenous tree was recorded. However, due to low indigenous biomass at Release site the increase was very small, leaving this area with low, overall FAI from October 2012 - January 2013, and may have an impacted on the diet of Release group and their survivability. This highlights that habitat composition, and its influence on exotic and indigenous biomass, need more careful consideration in the selection of release sites with a heterogeneous mix of native and non-native tree species. Ideally, longer term data on food availability through the same period in other years would have been beneficial to inform if this was a particularly sparse year at Release site or if this was the anticipated norm. However, further data on food availability in this area does not exist.

3.4.3 Hypothesis 3: Post-release Habitat Impact Assessment

Contrary to predictions, all sites recorded an increase in biomass between 2012 and 2014, with Release site displaying the largest biomass increase. Furthermore, all three sites also had an increase in Sykes numbers (for those groups monitored), and the colobus population at Release site also increased. The baboon population at both Release and Hotel site decreased while the numbers recorded at University site increased (Colobus Conservation, unpublished). The decrease of baboons in the Hotel and Release area was most likely the result of garbage management within the area, leading to baboon numbers increasing to the north of the area, also explaining the dramatic increase in baboon numbers in the University area. These measures suggest that the release of the vervet group at the Release site did not pose a negative impact upon the environment, nor the wildlife.

3.5 Conclusion

In the IUCN/SSC reintroduction and translocation guidelines state that translocations should only take place when the taxon's habitat requirements are satisfied and likely to be sustainable for the foreseeable future. If the taxon's basic habitat and ecological requirements cannot be determined, the animals should not be released (Baker 2002; Beck *et al.* 2007; IUCN/SSC 2013). The only way to meet these requirements is to conduct in-depth habitat analysis of the release site, both pre- and post-release. Here I have shown that the release site within the grounds of Colobus Conservation and surrounding area has the capacity to support a release group of 12 individuals, with a larger expanse of unoccupied habitat to the south of the site permitting an increase in group size. However, additional planting of appropriate indigenous tree species is required to ensure this population are self-sustaining for the long term. The accurate analysis of the release area is essential if the released animals are going to survive in the future and for them to become nutritionally representative of the wild population as soon as possible post-release.

Releasing animals into close proximity of human habitation is not a practice that is endorsed by IUCN. However, the primates being released in this programme were all wild born individuals previously living within their groups within Diani or closely surrounding area. Therefore it was considered that these individuals were being returned back to their environment rather than introduced to a new location. Vervet monkeys live throughout Diani, alongside humans and their numbers have remained stable over the last 12 years (169 - 282 individuals, n=9) (Colobus Conservation, unpublished). The density of humans was a major consideration of the release site selection and was as important to understand and manage as the habitat composition. The site needed to be lower in human density than the control group sites, and have permanent residents' rather high volumes of visiting tourists. This restriction enabled long term education to be conducted with the residence on how to behaviour around the monkeys, respond to interactions, and who to contact should an issue arise. Relationships were built with all community members and when needed mitigation techniques were implemented to reduce negative behaviour developing. The soft release monitoring that was adhered to post-release (Appendix 1), meant that at least one researcher was with Release group for all daylight hours for four months post-release and any conflict with the human population was addressed immediately. After this four month period, research hours were reduced in half day periods meaning that the monkeys, and their interactions within the human environment were managed as the post-release monitoring reduced. For all of these

reasons, and as habitat assessments had shown the area was able to support a vervet group, a release site within the grounds of Colobus Conservation offices was considered a good location. Full access to all land parcels was obtainable, the research team had almost instance back up in case of any problems from Colobus Conservation staff members, a 24/7 presence of knowledgeable personnel meant any issue was dealt with quickly and effectively and importantly the human community had a contact point.

This study can be used as a template for future releases to more effectively address and assess the issues of habitat suitability at release sites and the impact released animals have upon their environment. A topic for which there is currently very limited literature (Osborne and Seddon 2012). This study looked at the important aspect of the relationship between biomass, how that translated to food availability and the estimated vervet group size and home range area it would support. This highlights that habitat composition and biomass alone are not adequate indicators of release site viability. While it may act as a route to highlight areas that warrant further consideration, release site selection should not be based largely on this information. Considerations of site specific variations, in habitat composition, such as the heterogeneous mix of indigenous and exotic species recorded in this study, need to be taken in to account. Habitat assessments are complex and multi-tiered, and this research shows that a minimum of one year monitoring of the habitat prior to release is essential in order to understand seasonal fluctuations in food availability.

Chapter 4 Behaviour and Ecology of Vervet Monkeys (*Chlorocebus pygerythrus hilgerti*) in an Anthropogenically Modified Habitat

Abstract

Vervet monkeys are characterised by their wide distribution and ability to adapt to a variety of habitats, with their group sizes and behavioural ecology affected by habitat type, weather and food availability. Habitat loss from anthropogenic habitat modification has become a severe threat to natural areas, and species continuing to live in these fragmented landscapes must adapt to changes in vegetation type and high levels of anthropogenic disturbances. Diani is an international tourist destination located on the south coast of Kenya, and the formerly continuous forest has become increasingly fragmented so that a mosaic of small patches, in various degrees of intactness, now remains. This chapter evaluates how the behaviour, feeding and ranging activities of vervet monkeys (*Chlorocebus pygerythrus hilgerti*) respond to the anthropogenic habitat of Diani. Home ranges of Diani vervet monkeys were smaller than those reported for populations inhabiting more natural environments, with feeding activity influenced by human-derived food which constituted 16.2-24.1% of their diet. This high energy food source resulted in reduced feeding and increased resting activity budgets compared to vervet monkey populations that inhabit more natural areas. Nevertheless, wild foods remained an important food source, although selection ratios highlighted a preference towards human introduced exotic species. These findings recommend further management of vervet monkeys' access to human food sources with the aim of reducing conflict and ensuring preferred tree species are retained within the tourist developments in Diani.

4.1 Introduction

Anthropogenic habitat modification degrades and alters natural ecosystems and is generally a threat to biodiversity worldwide (Lee *et al.* 2013; Lowry *et al.* 2013; Murray and St. Clair 2015; Widdows and Downs 2016). Natural habitats are replaced with infrastructure, causing fragmented landscapes and food sources that are artificial and/or spatially concentrated (Sol *et al.* 2013). Resources are decreased or their availability altered (Lee *et al.* 2013; Lowry *et al.* 2013; Maibeche *et al.* 2015), requiring wild animal populations to be flexible and adaptable in resource exploitation (Hoffman and O'Riain 2012b). Species that are dietary and habitat specialists are vulnerable to habitat modification and are unable to inhabit altered

environments (Devictor *et al.* 2008; Harris and Baker 2007; Onderdonk and Chapman 2000). However, generalist species can adapt to altered habitats, seizing the opportunity to exploit different resources and use anthropogenic food (Harris and Baker 2007; Nowak *et al.* 2016; Sol *et al.* 2013; Widdows and Downs 2015). Persecution by humans, conflict with domestic pets, collisions with motor vehicles and electrocutions from power lines are other risks faced by wild animals inhabiting anthropogenically modified habitats (Donaldson and Cunneyworth 2015; Kanga and Heidi 1999; Merkle *et al.* 2013). Despite these challenges, anthropogenically modified landscapes often offer widespread, high energy food sources that are more reliable and less likely to exhibit seasonal variation than naturally occurring resources (Lowry *et al.* 2013; Merkle *et al.* 2013). High energy food resources include human refuse, crops, road kill, domestic pets, pet food and deliberate feeding or provisioning by humans (Bateman and Fleming 2012). In addition, human occupied areas also afford prey species a lower risk of predation as large natural predators are displaced by disturbances (Isbell and Young 1993a; Nowak *et al.* 2014) and human presence (Berger 1999).

Animal behaviour, life history, movement patterns and habitat selection are influenced by anthropogenic activities (Cozzi *et al.* 2016; Sol *et al.* 2013; Widdows and Downs 2016). Several authors have reported differences in behaviour, morphology and physiology in a range of species, inhabiting environments with varying levels of anthropogenic disturbance; house sparrows (*Passer domesticus*) (Meillere *et al.* 2015), white storks (*Ciconia ciconia*) (Massemin-Challet *et al.* 2006), black bears (*Ursus americanus*) (Merkle *et al.* 2013), brown bears (*Ursus arctos*) (Cozzi *et al.* 2016), true lemurs (*Eulmur* clade) (Donati *et al.* 2015), blue-eyed black lemur (*Eulemur flavifrons*) (Schwitzer *et al.* 2010), chacma baboons (*Papio ursinus*) (Hoffman and O'Riain 2012b), Barbary macaque (*Macaca sylvanus*) (El Alami *et al.* 2012). Studies of changes in feeding habits, activity budgets, movement patterns and habitat selection provide an interesting insight into a species sensitivity and adaptation to anthropogenic activities and alteration of the landscape. These data are critical to understanding a species ability to adapt to a novel or rapidly changing environment, and to contribute to political management and conservation planning (Maibeche *et al.* 2015).

As forest loss and degradation continues, the human-dominated landscape outside protected areas becomes increasingly relevant to primate conservation (Bracebridge *et al.* 2013). Human-dominated landscapes are, by necessity, increasingly being considered in species conservation management efforts (Chazdon *et al.* 2009). Greater demands on natural

resources brought about by an expanding human population, suggest that many primates' survival will depend on their ability to use anthropogenic landscapes surrounding the forest (Chaves *et al.* 2012; Wieczkowski 2010). Almost half of all primate species are classified as Vulnerable, Endangered or Critically Endangered due to habitat degradation (Mittermeier *et al.* 2009; WWF 2016). Tropical forests are disappearing faster than any other biome (Myers 1991) with land use change in these regions occurring at approximately 64,000 km^2 per year (Wright 2010). By reducing forest size and quality, habitat destruction leads to the reduction of food sources for forest-dwelling primates and in some cases threatens them with local extinction (Lee and Hauser 1998; Muoria *et al.* 2003). Due to this there is an increasing interest in primates' responses to anthropogenic habitat alteration (Chapman *et al.* 2016; Hoffman and O'Riain 2012b; Nowak *et al.* 2016; Saj 1998). Many primate species include populations that take advantage of their proximity to humans (Estrada *et al.* 2012) to supplement their diets with abundant and accessible food items (Hoffman and O'Riain 2012b; LaFleur and Gould 2009; Sengupta *et al.* 2015; Strum 2010; Warren *et al.* 2011). In particular, primates living in urban areas may eat ornamental garden plants and/or be deliberately fed by city dwellers or tourists (Brennan *et al.* 1985; Moreno-Black and Maples 1977; Nowak *et al.* 2016; Saj 1998; Sengupta *et al.* 2015). Primates inhabiting anthropogenically modified landscapes exhibit behavioural adjustments (Sol *et al.* 2013) and groups have been observed to decrease their consumption of natural plant parts, their mean daily journey length and home ranges, spending more time resting and less time feeding and foraging (Brennan *et al.* 1985; Saj 1998). The importance of food resources as drivers of animal ecology and behaviour is indisputable, and it has been recognized that provisioning may indirectly alter ecosystem functioning through changes in behaviour and abundance of animals (Muruthi *et al.* 1991; Sengupta *et al.* 2015). Understanding primates adaptive responses and potential use of anthropogenically modified habitat, could inform a wider landscape approach to primate conservation (Bracebridge *et al.* 2013) and such research areas should be a priority for conservation biologists because of the high contemporary extinction rates reported for most vertebrate groups.

As generalists, vervet monkeys are able to adapt to disturbed and marginal habitats such as secondary forests, farming and urban areas (Brennan *et al.* 1985; Saj *et al.* 1999; Wallace and Hill 2012). Vervet home ranges differ dramatically across different study locations, and habitat types, ranging from 8-178ha (Willems and Hill 2009). Groups living in anthropogenically modified habitats, or those with largely leaf based diets, tend to have smaller home ranges

(Brennan *et al.* 1985; Chapman *et al.* 2016; Saj *et al.* 1999). As opportunistic omnivores (Struhsaker 1967a), the diet of East African vervets, in descending order of prevalence, includes fruit (50%), invertebrates, flowers, seeds, leaves, grass and vertebrate prey (Dunbar and Dunbar 1974a; Fedigan and Fedigan 1988; Kavanagh 1978). However, in agricultural areas, tourist locations or places of human habitation, human food can provide a substantial proportion of their diet (Brennan *et al.* 1985; Saj *et al.* 1999). Generally, vervet monkey activity patterns are related to resource availability, which fluctuates seasonally (Baldellou and Adan 1997; Isbell and Young 1993b; McFarland *et al.* 2014b). Seasonal fluctuations in plant food resources, which comprise the largest portion of the vervet monkeys' diet across both the wet and the dry season, are strongly related to ambient temperatures and changes in rainfall (Adeyemo 1997; Harrison 1985).

Numerous authors have reported on a range of people-primate interactions with vervet monkeys including crop-raiding (Wallace and Hill 2012) and living in urban environments (Healy and Nijman 2014). Despite this, few studies have been conducted on the behavioural and feeding ecology of vervet groups living in anthropogenically modified habitats. Saj *et al* (1999) investigated the influence of human food consumption on the time budget of vervet monkeys living in Entebbe, Uganda and concluded that human food had a pervasive influence on vervet activity budget. Group time budgets revealed high proportion of time resting and lower proportions of time feeding compared to groups in non-anthropogenically modified habitats. In addition average daily range and home range sizes were smaller. Chapman *et al* (2016) investigated how vervet monkeys survive and prosper in an extensively anthropogenically modified landscape at Lake Nabugabo Field Stations, Uganda. They concluded that while the group suffered death from various unconventional sources, they prospered by consuming a diverse diet heavily reliant on fruiting trees, crops while occupying small home ranges with intense use of specific areas. Moreno-Black and Maples (1977) studied the four diurnal primate species in Diani, including a vervet group inhabiting the same range as one of the study groups in this thesis. In 1977, Diani was already subject to anthropogenic modifications with the first hotel erected c. 1960 and associated infrastructure in the form of water mains, power lines and a 10km paved road installed between 1969-1972 (Moreno-Black and Maples 1977). The vervet group were reported to rely heavily on secondary forests, ornamental/cultigen trees and sporadic 'food hand-outs' from tourists, but unlike the baboon populations, they were not recorded actively crop-raiding or foraging on garbage piles.

Habitat assessments conducted as part of this thesis (Chapter 3) revealed that the natural habitat of Diani is a heterogeneous mix of indigenous and exotic plants, whose fruiting cycles have no significant relationship with environmental factors such as rainfall and temperature, resulting in very limited seasonality in terms of natural food availability. However, as a tourist destination Diani is subject to annual tourist seasons, which influence the availability of human food, i.e. during peak tourist season more human food is available for the primate population to exploit.

The aim of this chapter was to investigate the variation in ranging behaviour, activity budgets and diet of vervet monkeys living in an anthropogenically modified habitat. Observational data of two wild groups of vervet monkeys, inhabiting anthropogenically modified habitats that varied in the type and extent of modification were analysed. Based on habitat assessments presented and discussed in Chapter 3, Hotel group inhabited an area with lower natural biomass and food availability, but higher plant diversity and equitability than University group. Both areas had a higher availability of indigenous species than exotic species in terms of biomass and the area inhabited by University group had a higher proportion of indigenous species than the area occupied by Hotel group. However, food availability of exotic species was generally higher than indigenous species in both habitats throughout the study. The area used by University group was considered more natural than the area used by Hotel group. The key hypotheses addressed and predictions made are

Hypothesis 1: Ranging patterns of the vervet monkey groups will be different. I predict that University group will have a smaller home range and day journey length than Hotel group due to greater natural food availability. Secondly, I predict that day journey length of University group will be more influenced by environmental factors such as rainfall and temperature.

Hypothesis 2: Activity budgets of the vervet monkey groups will be different. I predict that University group will spend less time in feeding behaviours and more time in resting behaviours than Hotel group due to greater natural food availability. Secondly, I predict that the activity budget of University group will be more influenced by environmental factors such as rainfall.

Hypothesis 3: Feeding ecology of the vervet monkey groups will be different in response to habitat diversity and food availability. Firstly I predict that University group will consume more

fruit than Hotel group due to greater fruit food availability. Secondly, I predict that Hotel group will consume a larger variety of plant species and have a more diverse diet than University group due to a greater diversity of plant species. Finally, I predict that both groups with consume a higher proportion of exotic species than indigenous species due to greater availability of exotic species than indigenous species in their habitat.

Hypothesis 4: Human food consumption will vary in response to its availability throughout the study period. Firstly, I predict that Hotel group will consume more human food than University group due to the larger hotel complexes and reduced natural food availability in their home range. Secondly, I predict that human food consumption will increase with an increase in human food availability for both vervet groups.

This chapter presents a detailed investigation into the impact anthropogenic habitat modification had upon the behavioural ecology of a population of vervet monkeys living in coastal Kenya. This will provide interesting insights in to how a population adapts behaviourally to survive in an environment that is becoming increasingly relevant to primate conservation and ensure improved conservation and management strategies.

4.2 Methods

4.2.1 Study Site

The study site was the Diani Beach area (4°15'30", 4°35'30"S and 39°35'00", 39°34'30"E) of Kwale County, South Coast, Kenya. The local climate is classified as tropical humid, with long rains from April – July and short rains October – December and an annual rainfall of 900-1500mm (Jaetzold and Schmidt 1983). This area is part of the Coastal Forests of East Africa global biodiversity hotspot and was once one of the most diverse areas of forest along the Kenya coast with a rich coral rag flora (Robertson and Luke 1993). However, as an unprotected forest area that occurs on sub-divided privately owned land, the formerly continuous forest has been cleared and fragmented, so that a mosaic of small patches, in various degrees of intactness, now remains. The study area lies at 0-150m asl and is located on fossilised coral covered in a thin layer of soil. For a more comprehensive description of the study site see section 2.3 and 3.3. In 2011 an estimated 14 vervet groups inhabited Diani (Colobus Conservation, unpublished). I focused on two groups living in areas with different types and levels of anthropogenic modification and human presence (Chapter 3).

4.2.2 Data Collection

Two habituated groups of vervet monkeys were observed over a 24 month period, December 2011 - November 2013. Both groups occupied areas with considerable human disturbance in the form of private residences, hotels with their associated grounds and staff housing and both areas were adjacent to relatively large and undisturbed patches of forest. Group sizes and composition fluctuated over the study period (Table 4.1). Both groups were habituated to 5–30 m proximity of observers and all individuals were identified by their natural markings (e.g. sizes, coat colour, and facial features) and physical abnormalities (e.g. scars, damaged limbs, digits and tails).

Table 4.1 Size and composition changes of the two research groups at the beginning, mid-point and end of the study period

Group	Date	Adult male	Adult female	Sub-adult male	Sub-adult female	Juvenile	Infant	Total
Hotel	December 2011	3	5	1	2	5	3	19
	December 2012	2	7	2	0	10	3	24
	November 2013	1	5	4	2	8	6	27
University	December 2011	5	4	3	3	8	0	23
	December 2012	3	5	5	4	4	4	25
	November 2013	4	7	5	1	2	1	20

Data collection consisted of three consecutive research periods per week per group (Day 1: midday - dusk; Day 2: dawn – dusk; Day 3: dawn – midday). This totalled 106 half days and 83 full days for Hotel group and 145 half days and 86 full days for University group. The aim was to maintain full visual contact during these periods, but movement of the monkeys between individually walled properties and occasional issues with access permission meant this aim was met with varying levels of success. The behavioural and dietary data in this chapter was collected using instantaneous focal sampling (Altmann 1974) of adult individuals, while ranging behaviour was collected for all age classes. Instantaneous sampling was conducted at one minute intervals for a 20 minute period, with two 20 minute samples conducted per hour during each research period. For a more comprehensive description of the methods used see Section 2.4.3.

4.2.3 Hypothesis 1: Ranging Behaviour

Home Range Size

The geographical location of the focal individual was recorded at the start of each focal period, which was approximately every thirty minutes during the research period, using a handheld Garmin GPS eTrex unit. This data was recorded even if activity data were not obtainable for the full focal period provided the focal individual's location could be confirmed at the start of the focal period.

Home range and use distributions were calculated using adaptive Local Convex Hulls (T-LoCoH) analysis as a package in R (Lyons *et al.* 2013) for the entire research period and for wet and dry seasons separately. For a detailed description of the T-LoCoH method see Section 2.5.2. T-LoCoH variables selected to calculate home ranges were different for each group (Table 4.2). In both groups k values were selected that minimised the appearance of 'holes' within the home range map (Getz *et al.* 2007; Lyons *et al.* 2013). Holes were permitted if they correlated with areas that the vervet monkeys could not possibly use, i.e. large swimming pools, with no overlapping canopy.

Table 4.2 Variable details for fixed number of points: T-LoCoH.

T-LoCoH variables	Hotel Group	University Group
Data points entire home range	1528	2939
Data points wet season home range	696	1595
Data points dry season home range	832	1344
Value of s	0.00045	0.0007
Value of k	15	15

Day Journey Length

Using GPS locations recorded during full-day follows, beginning between 0600-0700h and ending around 1800h depending on access permissions, day journey length was determined for each group based on the shortest point-to-point movements of the group between consecutive GPS locations. Full day follows that lacked GPS locations for one or more consecutive hours were not included in this analysis.

Paired t-tests were performed to assess difference in day journey length between Hotel and University group. Spearman rank correlation analysis was used to test whether there were any significant relationships between day journey length and environment variables.

4.2.4 Hypothesis 2: Activity Budgets

Behavioural activities were separated into five categories: feeding, moving, resting, social (including aggressive and copulation-related interactions) and other. Using adult instantaneous focal sampling, mean monthly proportion of time spent in each activity category was calculated for each group. From these data overall means were calculated for the entirety of the study period.

Monthly activity budgets of the five behavioural categories for Hotel and University groups were compared using Paired t-tests or Wilcoxon signed tank test to assess differences in activity budget. Spearman rank correlation analyses were used to test whether there were any significant relationship between activity budgets and environmental variables.

4.2.5 Hypothesis 3: Diet

Dietary Composition

Dietary data were separated into seven categories: fruit (including fruits, seeds and seed pods), flowers, leaves, grass, animal matter, human food and other. Using data collected on feeding behaviour from adult instantaneous focal sampling, mean monthly proportion of diet composition was calculated. Total diet composition was calculated using these mean monthly calculations.

Monthly differences in dietary consumption of the seven food categories between Hotel and University group were assessed using Wilcoxon signed rank test. Pearson's linear correlation and Spearman rank correlation analysis were used to test whether there were any significant relationship between the main components of dietary composition and activity budget.

Natural Diet

Dietary Diversity, Equitability and Preference

The diversity and equitability of each groups diet was calculated using the Shannon-Weaver index (H) and equitability (E_H). This measures how diverse and evenly represented different plant species were within the diet of both groups. The Shannon-Weaver index measures dietary diversity using the formula:

$$H=-\sum pi(\ln(pi))$$

where pi is the proportion of a given species in a group's diet. Values range from 0 to 5.0, with higher values indicating greater levels of dietary diversity (Krebs 2014).

Shannon-Weaver equitability measures how evenly different plant species were represented in the diet of each group, using the formula:

$$E_H=H/\ln S$$

where S is the total number of species consumed. Values range between 0-1, with 1 indicating that an equal number of feeding records exist for each species in the diet (Krebs 2014).

Selection ratios were used as a relative dietary preference measure for all plant species by dividing the overall percentage of time spent feeding on species *i* by the percentage biomass species *i* contributes to total biomass in the study group's home range (Fashing 2001; Mekonnen *et al.* 2010). A result of 1 indicates that the species' presence in the diet is proportional to its presence in the home range of the study group. A result >1 indicates that a species is selected more often than chance expectation based on its prevalence in the home range and is therefore a preferred food species. Finally, a figure <1 indicates that the species is selected less than expected based on its prevalence in the home range.

Indigenous or Exotics

Analysis of consumption of indigenous and exotic species was conducted on all plants that were indentified to species level. Grass was excluded from this analysis due to difficulties in species identification and a known mixture of indigenous and exotic grass species present in the Diani environment.

Wilcoxon signed rank tests were used to assess differences in indigenous and exotic plant consumption in both groups. Selection ratios were calculated to test if either group exhibited a preference for indigenous or exotic species.

4.2.6 Hypothesis 4: Human Food

Human food items ranged from fresh produce, cooked goods and garbage, with very rare occurrences of crop raiding. Human food was located both within and outside of buildings. All food items accessed from a human source were recorded as human food, including fruits that grow naturally in the wild environment i.e. mango (*Mangifera indica*) and coconut (*Cocos nucifera*).

A direct measurement of human food availability was not recorded due to complexities in developing an accurate method that could be used across all sources and comparable between research sites. As a tourist destination the human population of Diani is unstable, with dramatic seasonal variation due to tourist numbers and the associated personnel. Under the assumption that an increase in the localised population would create an increase in human food availability, visitor numbers from Colobus Conservation were used as a proxy for human food availability at both locations. Colobus Conservation operates a visitor centre which encourages residents and tourists to participant in eco-tours. As a visitor attraction the assumption was made that the number of monthly eco-tours conducted was a representation of the fluctuating human population within Diani and by proxy human food availability. The relationship between human food availability and each group's dietary consumption, natural food availability (Chapter 3) and environmental variables were analysed using Pearson's linear correlation and Spearman rank correlation analysis.

4.3 Results

4.3.1 Hypothesis 1: Ranging Behaviour

Home Range Size

The home range for Hotel group was 21.7ha and was almost double the size of University group's 10.9ha home range (Figure 4.1). Hotel group's core (50%) home range was also larger than University group's (Table 4.3). Both groups used larger home range and core range areas during wet periods compared to dry periods (Table 4.3).

Table 4.3 Home range (95%) and core home range (50%) totals for the whole research period, wet seasons and dry seasons for Hotel and University group.

Period	Hotel group		University group	
	Home Range (95%)	Core Home Range (50%)	Home Range (95%)	Core Home Range (50%)
Total	21.7ha	2.7ha	10.9ha	1.7ha
Wet months	20.8ha	3.9ha	10.4ha	2.4ha
Dry months	16.4ha	1.9ha	9.6ha	1.2ha

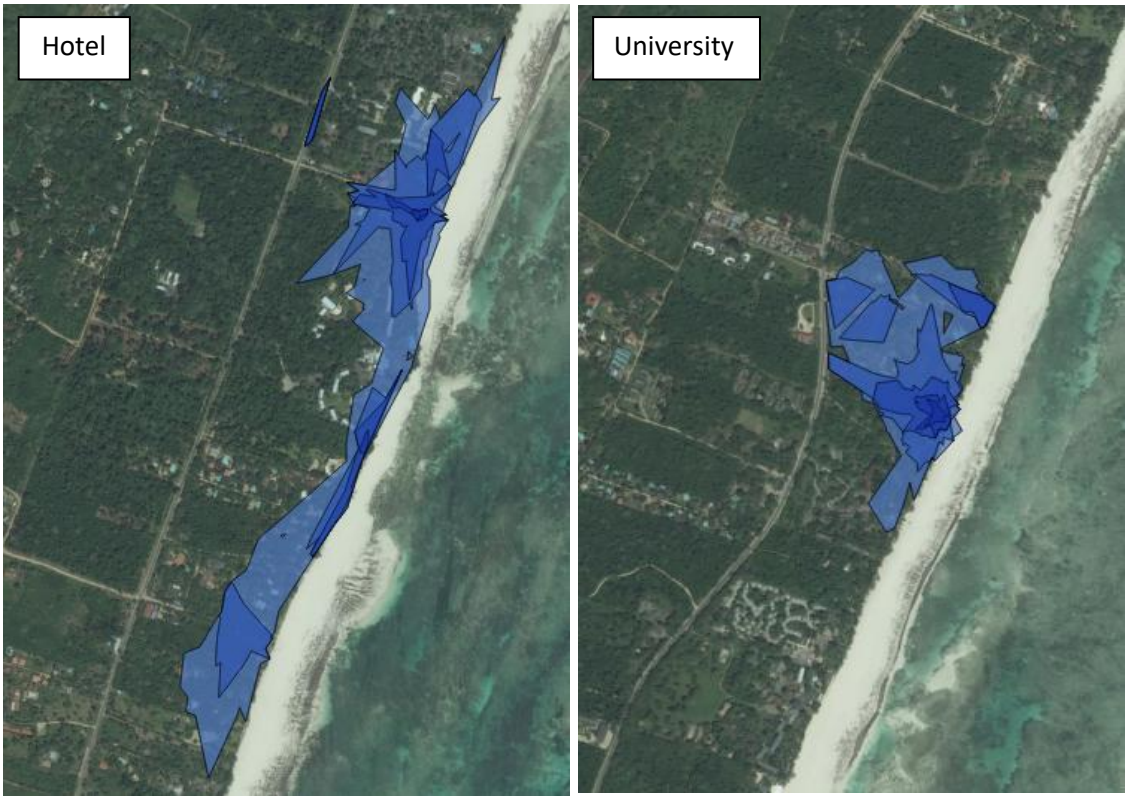


Figure 4.1 LoCoH utilisation distribution for total home range of Hotel group, 21.7 ha, and University group, 10.9 ha. Blue shading indicates level of use by each group, light and transparent areas represent lower levels and darker and opaque areas higher levels of use. Scale 1:13,000 ©2016 DigitalGlobe ©2016 GeoEye Earthstar Geographics SIO ©Microsoft Corporation

Day Journey Length

There was no significant difference in mean day journey length between University group (1104.7m, range 577m - 1525m) and Hotel Group (979.4m, range 409m - 1400m) (paired t-test; n=16, t=-1.184, df=15, p=0.255). Day journey length was correlated with mean monthly temperature for University group, but not Hotel group (Spearman's rank correlation; Hotel, n=16, r=0.082, p=0.761; University, n=24, r=-0.719, p=<0.001***). Day journey length was not significantly correlated with mean monthly rainfall for either group (Spearman's rank correlation ; Hotel, n=16, r=0.179, p=0.508; University, n=24, r=0.362, p=0.082)

4.3.2 Hypothesis 2: Activity Budgets

Both groups spent most of their time resting and the least amount of time in social activities (Table 4.4). Hotel group spent significantly more time moving and resting than University group, while University group spent significantly more time feeding than Hotel group. There was no significant difference in social activity. Time spent in feeding behaviours was correlated

with monthly rainfall for both groups (Spearman's rank correlation ; Hotel, n=24, r=0.650, p=0.001**; University, n=24, r=0.455, p=0.025*).

Table 4.4 Activity budgets of Hotel and University group in terms of percentage of total activity samples. Significant differences between groups are highlighted with *p=<0.05, **p=<0.01 or ***p=<0.001.

Activity	Hotel	University	Paired t-test		
	n=24 months	n=24 months	T	df	p
Feeding	15.6	26.8	-6.441	23	<0.001***
Moving	24.1	19.0	2.686	23	0.013*
			Wilcoxon signed rank test		
			Z	n	p
Resting	52.1	43.5	-2.829	24	0.005*
Social	3.3	4.5	-1.914	24	0.056

4.3.3 Hypothesis 3: Diet

Dietary Composition

Fruit, grass and human food made the largest contribution to both groups' diet, with relatively low levels of animal matter, flowers and leaves (Figure 4.2). University group consumed significantly more grass and leaves than Hotel group (Table 4.5).

Table 4.5 Food item consumption of Hotel and University group in terms of percentage of food consumed. Significant relationships are highlighted with * p=<0.05 or ** p=<0.01.

Food Item	Hotel	University	Wilcoxon signed rank test		
	n=24	n=24	z	n	p
Fruit	37.3	27.6	--1.457	24	0.145
Grass	20.7	29.9	-2.400	24	0.016*
Human food	16.2	24.1	-1.800	24	0.072
Flowers	8.4	3.7	-0.943	24	0.346
Leaves	3.7	7.3	-3.133	24	0.002**
Animal	7.3	5.9	0.000	24	1.000
Other	6.4	1.6	-1.677	24	0.094

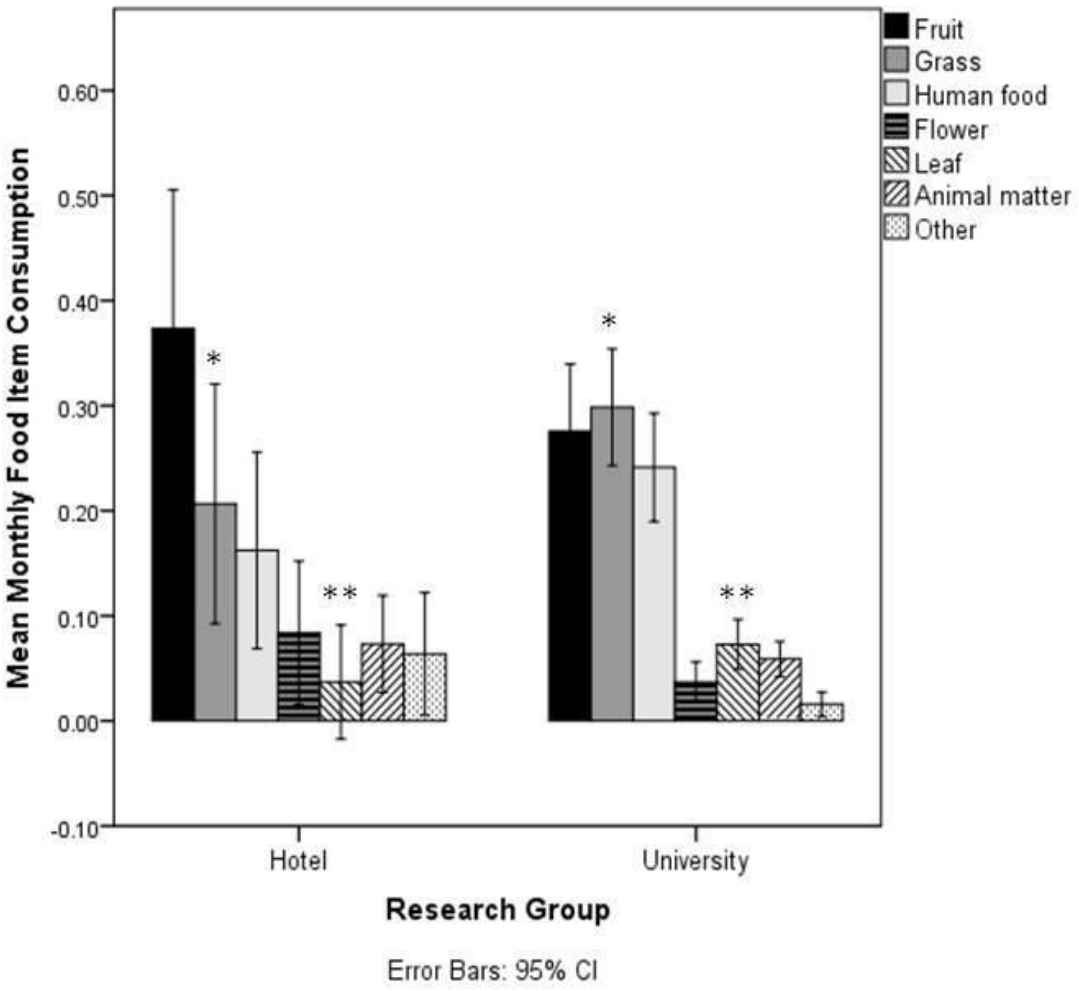


Figure 4.2 Food item consumption for Hotel and University group in terms of percentage of food consumed. Hotel group: n=24 months; University group n=24 months. Significant relationships are highlighted with * p=<0.05 or ** p=<0.01.

Food Consumption and Food Availability

Fruit and grass consumption did not have a significant relationship with the availability (FAI) of either resource, for either group. Hotel group: Spearman's rank correlation coefficient, fruit consumption and FAI (Trees), r=-0.338, n=20, p=0.145; grass consumption and FAI (Grass), r=0.094, n=17, p=0.719. University group: Pearson's correlation coefficient, fruit consumption and FAI (Trees), r=--0.004, n=20, p=0.988; grass consumption and FAI (Grass), r=0.040, n=17, p=0.877.

Natural Diet

Plant matter contributed the largest proportion to each groups' diet, Hotel group 70.2% and 68.4% for University group. University group had a comparatively higher level of variety in

plant species eaten, consuming 53 different species while Hotel group consumed just 25 plant species (see appendix 2 for a full list of species eaten). Only five species contributed to more than 5% of Hotel group's entire natural food diet and only four species to more than 5% University group's diet (Table 4.6).

Table 4.6 Top five consumed plant species throughout the entire study period, as a percentage of the plant diet.

Group	Species	Type	Status	Primary food item	% in diet
Hotel	*Azadrachtica indica*	Tree	Exotic	Fruit	28.1
	Grass	Grass	Mixed	Grass	18.2
	Lecaniodiscus fraxinifolius	Tree	Indigenous	Fruit	7.0
	Dictyospermum album	Palm	Exotic	Fruit	6.4
	Ficus lingua	Tree	Indigenous	Fruit	5.2
University	Grass	Grass	Mixed	Grass	43.1
	Tamarindus indica	Tree	Indigenous	Seed	12.8
	Azadrachtica indica	Tree	Exotic	Fruit	8.5
	Bougainvillea sp.	Shrub	Exotic	Young leaves	5.1
	Ficus benjamina	Tree	Exotic	Fruit	3.1

Diversity and Equitability

For Hotel group the mean monthly Shannon-Weaver index (H') for food species diversity was 0.80 (range 0.00-1.58). Mean monthly dietary equitability index, (E_H) was 0.22 (range 0.00-0.54). For University group the mean monthly Shannon-Wiener index (H') for food species diversity was 1.6 (range 0.8-2.4). Mean monthly dietary equitability index, (E_H), was 0.3 (range 0.16-0.48). University group had a more diverse diet, with species equally represented than Hotel. Dietary diversity and equitability were significantly different between Hotel and University groups mean monthly diet (paired t-test; Dietary diversity, n=23, t=-5.849, df=22 p=<0.001***; Dietary equitability, n=23, t=-3.452, df=22 p=0.002**).

Selection Ratio

Hotel group selected four tree species and University six tree species at rates higher than expected from biomass calculations (Table 4.7). Only two species *A. indica* and *D. album* were preferentially selected by both groups. Only 9 of the 24 tree species recorded in the modified

Whittaker plots of Hotel group's home range were consumed by the group, but University group consumed 20 of the 24 tree species recorded in their habitat assessment.

Indigenous and Exotics

Dividing the groups' plant species consumption into indigenous and exotic species revealed that both Hotel and University group had a slightly, higher percentage of exotic food items in their diets than indigenous, but the difference was not significant (Wilcoxon signed rank test; Hotel, n=24, z=-0.434, p=0.664; University, n=24, z=-0.857, p=0.391).

Selection ratios based on percentage of indigenous and exotic species consumed by each group compared to percentage contribution to biomass of each groups home range indicate that both groups preferentially select exotic species in their diets (Table 4.8).

Table 4.7 Natural food selection ratios for indigenous and exotic species of Hotel and University group based on biomass for tree species consumed.

Hotel Group				University Group			
Species	Plant Diet (%)	Biomass (%)	Selection ratio	Species	Plant Diet (%)	Biomass (%)	Selection ratio
Indigenous	46.9	55.1	0.85	Indigenous	48.6	75.3	0.65
Exotic	53.1	44.9	1.18	Exotic	51.4	24.7	2.08

Table 4.8 Natural food selection ratios of Hotel and University group based on biomass for tree species consumed. Table is ordered in descending order of selection ratio (S/R).

	Hotel Group					University Group				
Rank	Species	Status	Diet (%)	Biomass (%)	S/R	Species	Status	Diet (%)	Biomass (%)	S/R
1	*Lecaniodiscus fraxinifolius*	I	7.0	1.18	5.93	*Tamarindus indica*	I	12.8	1.45	8.83
2	*Dictyospermum album*	E	6.4	2.27	2.82	*Pandanus kirkii*	I	1.9	0.28	6.79
3	*Azadirachta indica*	E	28.1	10.71	2.62	*Grewia plagiophylla*	I	0.7	0.52	1.35
4	*Ficus benjamina*	E	3.4	2.54	1.34	*Dictyospermum album*	E	1	0.76	1.32
5	*Tamarindus indica*	I	2.2	3.59	0.61	*Azadirachta indica*	E	8.5	6.86	1.24
6	*Sideroxylon inerme*	I	3.8	11.96	0.32	*Mangifera indica*	E	3.1	3.00	1.03
7	*Delonix regia*	E	4.2	13.51	0.31	*Ficus lingua*	I	0.9	1.28	0.70
8	*Adansonia digitata*	I	3.6	23.18	0.16	*Lannea schweinfurthianum*	I	0.4	0.63	0.63
9	*Lannea welwitschii*	I	0.6	4.41	0.14	*Delonix regia*	E	2.2	3.70	0.59
10	-					*Cocos nucifera*	E	1.3	2.50	0.52
11	-					*Lecaniodiscus fraxinifolius*	I	1.2	2.76	0.43
12	-					*Sideroxylon inerme*	I	0.9	3.27	0.28
13	-					*Plumeria rubra*	E	0.1	1.05	0.10
14	-					*Afzelia quauzensis*	I	0.1	1.68	0.06
15	-					*Casurina equisetifolia*	E	0.2	5.71	0.04
16	-					*Cordia goetzei*	I	0.1	3.30	0.03
17	-					*Markhamia zanzibarica*	I	0.03	1.19	0.03
18	-					*Zanthoxylum chalybeum*	I	0.03	1.47	0.02
19	-					*Carpodiptera africana*	I	0.03	1.86	0.02
20	-					*Adansonia digitata*	I	0.2	52.63	0.00

4.3.4 Hypothesis 4: Human Food

Human Food Consumption

Both groups have negative relationships between human food and wild food (grass for Hotel group; fruit for University group) consumption (Table 4.9).

Table 4.9 Results from correlation analysis for human food composition and the main natural food item consumption. [a] indicates Pearson's correlation coefficient otherwise Spearman's rank correlation coefficient. Significant relationships are highlighted with *p=<0.05 or **p=<0.01.

Natural Food Item	r/p	Human Food Consumption	
		Hotel group	University group
Fruit	r	-0.197	-0.708[a]
	p	0.356	0.001**
Grass	r	-0.747	-0.197[a]
	p	<0.001**	0.356

Human Food Availability

Using visitor numbers as a proxy for human food availability, neither group had a significant relationship between fruit, grass or human food consumption and human food availability (Table 4.10).

Two partial correlations were run to determine the relationship between fruit or grass consumption and human food availability whilst controlling for fruit or grass availability [FAI(Trees) or FAI(Grass)] for University group. The same test could not be conducted on the data for Hotel group as this is a test for parametric data. There was no statistically significant relationship between fruit consumption and human food availability whilst controlling for fruit availability (r=-0.294, n=17, p=222). However, there was a statistically significant positive correlation between grass consumption and human food availability whilst controlling for grass availability (r=-0.380, n=14, p=0.033*).

Table 4.10 Results from correlation analysis for fruit, grass and human food consumption, and human food availability. [a] indicates Pearson's correlation coefficient otherwise Spearman's rank correlation coefficient. NB the results are not significant after the application of False Discovery Rate Control..

Variables	r/p	Human food availability	
		Hotel group	University group
Fruit Consumption	R	0.061	-0.314[a]
n=24	p	0.78	0.135
Grass consumption	r	0.161	-0.044 [a]
n=24	p	0.453	0.837
Human food consumption	r	0.003	0.424[a]
n=24	p	0.988	0.039

Human food availability is negatively correlated with rainfall (Spearman's rank correlation coefficient, r=-0.479, n=24, p=0.018*), indicating that availability of human food increases with a decrease in rainfall. No significant relationship was found between human food availability and temperature (Spearman's rank correlation coefficient, r=-0.033, n=24, p=0.880).

4.3.5 Food Consumption and Behaviour

Both groups have a positive relationship between time spent feeding and fruit consumption, and in Hotel group fruit consumption also had a negative relationship with time spent resting (Table 4.11).

University group exhibited a further two relationships with human food consumption; a negative relationship between human food consumption and feeding and a positive relationship with resting.

Table 4.11 Results from correlation analysis for dietary composition and activity budget data. [a] indicates Pearson's correlation coefficient otherwise Spearman's rank correlation coefficient. Significant relationships are highlighted with *p=<0.05 or **p=<0.01. Only the results marked with * or ** remain significant after the application of False Discovery Rate Control.

Group	Variable	r/p	Feeding	Moving	Resting	Socialising
Hotel	Fruit	R	0.511	0.035	-0.449	-0.090
		P	0.011*	0.869	0.028	0.677
	Grass	R	0.088	0.047	0.080	-0.263
		P	0.681	0.829	0.709	0.214
	Human	R	-0.361	-0.125	0.205	0.289
		P	0.083	0.561	0.338	0.171
University	Fruit	R	0.548[a]	-0.143[a]	-0.465	-0.075[a]
		P	0.006**	0.506	0.022*	0.727
	Grass	R	-0.178[a]	0.042[a]	0.079	0.171[a]
		P	0.406	0.847	0.713	0.425
	Human	R	-0.625[a]	0.069[a]	0.486	-0.148[a]
		P	0.001**	0.747	0.016*	0.490

4.4 Discussion

The aim of this chapter was to investigate the impact anthropogenic habitat modification had on the behavioural ecology of vervet monkeys in coastal Kenya. Living in areas with different types and levels of anthropogenically modified habitats was expected to result in differences of behaviour and ecology between the two groups. University group inhabited an area that was considered to be more natural than Hotel group, although both groups had access to human foods via hotels and private residences within their home ranges. The results indicated that University group had a smaller home range, spent more time in feeding behaviours, but less time in resting and moving behaviours than Hotel group. University group consumed more grass, seeds and leaves, but less fruit than Hotel group. They also ate more human food, but the difference was not significant. The diet of both groups comprised approximately 70% plant matter, with University consuming a significantly more diverse plant diet. Both groups displayed a preference for exotic species based on selection ratios. There were few significant relationships between vervet monkey behavioural ecology and environmental variables with either group, indicating that seasonality had little influence in this location.

4.4.1 Hypothesis 1: Ranging Behaviour

Knowledge of a groups ranging behaviour is important for understanding its behavioural ecology (Ehlers Smith *et al.* 2013). University group had a smaller home range than Hotel group as predicted. The result may have been influenced by the University location having higher natural food availability and the group consuming more human food than Hotel group. A number of previous primate studies have recorded smaller home range size for groups occupying anthropogenically modified habitats compared to more natural environments (Table 4.12). These limited home range patterns are most likely due to year round access to favoured food items such as fruit that results from the heterogeneous mix of indigenous and exotic plant species, in addition to access to human food with higher nutrient and calorie content than natural food (Sengupta *et al.* 2015).

As predicted, day journey length of University group significantly reduced with an increase in temperature and was the only ranging behaviour in the analysis that was influenced by an environmental factor. Day journey lengths of groups living in anthropogenically modified habitats have been reported to be smaller than those of groups living in more natural environments (Table 4.12). However, results from this study do not support this observation and day journey lengths that fall within the expected range (700 - 2500m) of the species living in natural habitats were recorded. While the group size of the Diani vervet monkeys was smaller than the groups reported by Brennen *et al* (1985) and similar to both Saj (1999) and Chapman *et al* (2016) research groups, it was larger than the average vervet group size within Diani and were both consistently in the top three largest vervet groups recorded in the annual Diani primate census in all research years (Colobus Conservation, unpublished data). Although more data from other Diani groups would be valuable, the large day journey length compared to the home range size within an anthropogenically modified habitat, may be reasonably explained by larger primate groups needing to cover more ground in order to sufficiently forage (Clutton-Brock and Harvey 1977).

Table 4.12 Ranging and activity budget data for populations of vervet monkeys (*Chlorocebus sp*.). Socialising includes aggressive and non-aggressive interactions. HR home range, DJL day journey length.

Location		**Study**	**Group**	**Range Use**		**Time allocation %**					**Reference**
Area	Country	**length months**	**size**	HR (ha)	DJL (m)	Feeding	Moving	Resting	Social	Other	
Blydeberg	South Africa	12	33	77	-	39	15	17	26	3	(Barrett 2005)
Bole Valley	Ethiopia	6	18.8	30	700	27.4	28.9	31.8	11.4	0.5	(Dunbar and Dunbar 1974b)
Lajuma	South Africa	12	17.8	114.1	1580.7	42.8	21.7	25.7	9.8	-	(Willems 2007)
Mt Assirik	Senegal	14	28	178.4	1515	44.8	-	46.7	8.5	-	(Harrison 1983c, 1985)
Old Oyo	Nigeria	18	20	-	-	32.9	30.2	9.7	7.5	19.9	(Adeyemo 1997)
Samara Reserve	South Africa	10	40	119	2500	31.7	24.55	32.95	9.95	-	(Pasternak *et al.* 2013)
Windy Ridge	South Africa		23	-	-	32.8	21.2	23.4	22.6	-	(Baldellou 1991)
Odobullu Forest	Ethiopia	8	A - 57.5 B - 48	A - 18.1 B - 12.3	A - 956 B - 898	65.7	14.4	10.7	7.1	2.4	(Mekonnen *et al.* 2010)
Amboseli*	Kenya	4	43	8	456	18.9	16.5	43	19.9	1.7	(Brennan *et al.* 1985)
Diani*	**Kenya**	**24**	**H - 23** **U - 23**	**21.7** **10.9**	**979.4** **1104.7**	**15.6** **26.8**	**24.1** **19.0**	**52.1** **43.5**	**3.3** **4.5**	**4.9** **6.2**	**This study**
Entebbe*	Uganda	5	21	12	596	26.3	14.2	44.3	10.7	-	(Saj 1998)
Lake Nabugabo*	Uganda	46	25.3	11.6	-	34.3	21.2	18.3	5.5[a]	20.7	(Chapman *et al.* 2016)

* - populations inhabiting anthropogenically modified landscapes, a - play only

4.4.2 Hypothesis 2: Activity Budgets

Due to habitat assessments showing that University group inhabited an area with a higher natural food availability than Hotel group it was predicted that University group would spend less time in feeding behaviours and more time resting. However, the analysis revealed the opposite was true. Additionally, University group spent significantly less time moving than Hotel group. A possible explanation for this could relate to the composition of each groups diet. A significantly larger proportion of University group's diet consisted of grass than Hotel group, while Hotel group consumed relatively larger amount of fruit than University group. Grass requires more time to forage and process than fruit (Coiner-Collier *et al.* 2016). Furthermore, grass is highly abundant throughout the range of University group and does not require travelling time between feeding bouts. Compared to other studies of *Chlorocebus* inhabiting anthropogenically modified habitats (Table 4.12), Hotel group displayed the lowest feeding and highest resting activity budgets, while University's feeding behaviour fell within the expected range, but their resting behaviour was also comparatively high, with only Entebbe vervet group devoting more time to resting behaviour. Generally vervet groups living in natural environments spend a similar amount of time in feeding and resting behaviours or the largest portion of their activity budget is spent in feeding behaviours (Table 4.12). However, in anthropogenically modified environment two of the three vervet group studies reported increased levels of resting and reduced levels of feeding behaviour (Table 4.12). A number of studies have linked these changes in activity budget, along with reduced home range sizes, to high calorie food intake, such as human food (Saj 1998; Saj *et al.* 1999; Sengupta *et al.* 2015).

As predicted, the activity budget was influenced by rainfall, with both groups significantly increasing the amount of time spent feeding with an increase in rainfall. Only a limited number of vervet studies have reported the direct impact of rainfall on activity budgets (Barrett 2005; Lee 1984; McFarland *et al.* 2014a; Willems 2007). The assumption generally made by these studies was that fruit availability increases during wet periods and due to the relatively high calorie and nutrient content associated with fruit, less is required to meet an individual's dietary requirements, reducing the overall amount of time spent feeding. In contrast to the Diani groups, all these studies report a reduction in time spent in feeding activities during wet months. As already reported there was unusually no relationship between natural food availability (FAI) and rainfall, but human food availability had a significant negative correlation with rainfall. As a higher calorie and nutrient richer food source than wild fruit, its availability

produces the reverse effect on vervet activity budgets in relation to rainfall fluctuations, resulting in the Diani vervet monkeys spending more time in feeding behaviours during wet months due to the absence of their highest calorie food resource. Mekonnen *et al* (2010) is the only other vervet study that reports a significant increase in feeding behaviour during the wet season, this is attributed to an increase in fruit availability and consumption during the dry months of the Bamboo forest.

4.4.3 Hypothesis 3: Diet

Dietary Composition

Both vervet groups had the same food types in their top three most consumed items: fruit, grass and human food. For both groups fruit and grass were the most consumed food items, with human food placed third. Contrary to predictions University group did not consume significantly more fruit than Hotel group. However, University group consumed significantly more grass and leaves than Hotel group. The lower than expected fruit consumption by University group compared to Hotel group was likely influenced by University group consuming relatively more human food than Hotel group.

Grass is an unusually large dietary component for the Diani groups. In an environment with two high calorie food sources (wild fruit and human food) available I did not predict that grass would contribute so heavily to either group's diet. A combination of factors may influence the relatively high level of grass consumption. Firstly obtaining human food, that has not been provisioned, is a high risk activity due to potential persecution by humans (Merkle *et al.* 2013). Human food was always present in the Diani environment but ease of access to it fluctuated due to tourist numbers, the management of kitchens, restaurants and garbage piles by hoteliers and residents, and the employment of guards to chase away monkeys. Secondly, the only terrestrial predators within Diani are humans and dogs; properties where dogs are generally absent or discouraged from chasing monkeys offer a safe environment for vervet monkey to feed on grass, an otherwise inaccessible food resource. In areas where the grass is cut frequently it is generally also watered, producing young, fresh shoots, while in areas that are not cut the grass bears flowers and seeds, both of these have increased digestibility compared to tree foliage (Corden *et al.* 2007). Additionally, being cellulose based grass has a high fibre content which may be lacking from the Diani vervet diet, due to the high consumption of human food. As such it is likely that the vervet monkeys in Diani graze on grass while waiting for an opportunity to access human food. This is supported by the results of the partial correlation which showed there was a significant positive relationship between grass

consumption and human food availability for University group. These factors could arguably be true for all anthropogenically modified habitats. Saj *et al* (1999) was the only study in an anthropogenically modified habitat to record grass consumption as an individual food item (Table 4.13). This study site was in a zoo and therefore the vervet monkeys had access to additional human food supplies from animal enclosures, the extent of which made guarding difficult (Saj 1998). This ease of access to human food meant that the Entebbe zoo vervet group had a human food consumption of 50.2%, meaning that consuming grass to supplement their diet would not be required.

Interestingly, the vervet group studied in the same location as University group in 1977 by Moreno-Black and Maples had a dietary fruit consumption of 76.6% compared to 27.6% during this study. Additionally, the vervet monkeys were not recorded to consume grass and only accessed human food when given as handouts from the tourists. Only baboons were reported to feed on grass and human food or forage from garbage piles. Without comparable habitat surveys it is not possible to be certain of the cause of this difference, however in the 35 year gap between data collection at the site, the anthropogenic disturbance has dramatically increased. With this change the level of natural indigenous habitat had decreased, while the level of open grassland spaces, exotic trees and human food availability all increased.

Numerous *Chlorocebus* sp. studies have reported dietary composition (Table 4.13), unsurprisingly the Diani vervet groups do not closely replicate any of these studies, including those based in anthropogenically modified environments with provisioned human foods. This difference to all other studies is likely due to the level of habitat modification. While Diani was far from a natural environment, it was not completely urbanised and it had a more heterogeneous mix of natural habitat and human modification than described by Saj (1998). Brennan, *et al* (1985), did not report a dietary breakdown of the vervet group studied, but as this group inhabited a lodge area in an otherwise natural habitat, the results would make an interesting comparison to Diani. Similarly, Chapman, *et al* (2016) did not record human food as a category, but as this group of vervets also inhabit an area with a mix of indigenous and exotic species in an anthropogenically modified environment the comparison would be most interesting.

Table 4.13 Diet composition data for populations of vervet monkeys (*Chlorocebus sp*.).

Location		**Study**	**Group**	**No of**	**Diet %**							**Reference**
Area	Country	**length Months**	**size**	**species eaten**	Fruit	Flowers	Leaves	Grass	Animal	Human food	Other	
Blydeberg	S. Africa	12	33	42	67.3	1.4	1.4	2.9	3.9	-	23.1	(Barrett 2005)
Bole Valley	Ethiopia	6	18.8	32	50.6	17.6	18.7	a	7.4	-	5.7	(Dunbar and Dunbar 1974b)
Lajuma	S. Africa	12	17.8		76	0.9	14.5		0.3	-		(Willems and Hill 2009)
Mt Assirik	Senegal	15	23		63	13	-	-	13.1	-	10.9[b]	(Harrison 1983b)
Samara Reserve	S. Africa	10	40	26	-	-	-	-	-	-	-	(Pasternak *et al.* 2013)
Odobullu Forest	Ethiopia	8	A - 57.5 B - 48	11	9.6	3.1	81.3	-	2.3	-	3.8	(Mekonnen *et al.* 2010)
Amboseli*	Kenya	4	43	23								(Brennan *et al.* 1985)
Diani*	Kenya	6	14	40	76.6	6.4	10.6				6.5	(Moreno-Black and Maples 1977)
Diani*	**Kenya**	**24**	**H - 23**	**25**	**37.3**	**8.4**	**3.7**	**20.7**	**7.3**	**16.2**	**6.4**	**This study**
			U - 23	**53**	**27.6**	**3.7**	**7.3**	**29.9**	**5.9**	**24.1**	**1.6**	
Entebbe*	Uganda	5	21	43	6.7	9.1	3.7	9.8	17	50.2	3.6	(Saj 1998)
Lake Nabugabo*	Uganda	46	25.3	40 + 9[d]	69	7.6	4.0	-	10.6	c	-	(Chapman *et al.* 2016)

a - grass consumption was recorded as leaves, flowers and seeds, b - includes leaves and grass, c - crops divided between fruit, flowers and leaves, d - the additional 9 species are crop species and therefore removed to permit comparison to this study. S. Africa = South Africa

Natural Diet

The natural food consumption between the two research groups varied dramatically. Contrary to predictions Hotel group consumed a smaller variety and less diverse range of plant species than University group, who consumed more than double the number of plant species recorded for Hotel group. Vervet plant species consumption in other locations range from 11-42 in natural habitats, to 23-43 in anthropogenically modified habitats. In general, vervet monkeys in natural habitats have a lower level of plant species variety in their diets. These ranges indicate that Hotel group is representative of other vervet monkey dietary studies, but University group consumes a more diverse variety of plants than previously recorded.

Results from Shannon-Weaver dietary diversity showed that University groups natural diet was more diverse than Hotel groups in 22 out of the 24 months. Interestingly, the dietary diversity of the two groups generally displayed opposite trends i.e. when Hotel group had a relatively high dietary diversity, University groups' diversity index was relatively low. Selection ratios highlighted that Hotel group were consuming only 37.5% of the tree species recorded in habitat assessments, while University consumed 83.3%. Only two species *A. indica* and *D. album* were preferentially selected by both groups, suggesting that these are favoured food species of vervet monkeys in Diani. Selection ratios show that both groups displayed a preference for exotic species over indigenous species. Of the 15 tree species not consumed by Hotel group, only four where found within the University home range and all were eaten by the University group. There are two possible reasons for this apparent selective behaviour by Hotel group. Firstly, the home range of Hotel group had a higher percentage of exotic tree species in terms of biomass than University group, these trees may have been inedible for vervet monkeys. Secondly, the Hotel group vervet monkeys probably experienced a higher level of competition from other primates within their home range due to high numbers of baboons in the area, but lower levels of food availability. On numerous occasions during data collection the vervet group would quickly and quietly vacate an area on detecting an approaching baboon group. However, on the approach of Sykes monkeys the vervet group rarely vacated their location and either the two groups peacefully intermingled or the groups began a dispute, generally over a food source. This suggests that the baboon groups potentially out competed the Hotel vervet group for shared and limited resources (section 4.5).

4.4.4 Hypothesis 4: Human Food

Contrary to predictions, human food consumption was higher in University group than Hotel group and there was no relationship between human food consumption and its availability for either group. For both groups, an increase in human food consumption correlated with a decrease in the consumption of a natural food item; for University group this was fruit and grass for the Hotel group. However, when the FAI of fruit and grass was controlled for in a partial correlation there was a significant positive relationship between grass consumption and human food availability for University group.

Both groups exhibited similar trends relating to food consumption; (1) an increase in human food consumption resulted in a decrease in fruit or grass consumption and (2) consumption of fruit and grass did not increase with an increase in availability. These results indicate that human food is likely a preferred food source to natural food. However, since preference can only really be tested when all possible food items are equally abundant and accessible (criteria that are almost impossible to meet in primate field research), this study can only suggest that vervet monkeys in Diani prefer human food over all wild food. It is my opinion that insufficient evidence to support this statement further is due to the limitations of the method used to calculate human food availability. Using visitor numbers to Colobus Conservation as a proxy for human food availability was sufficient to indicate a general fluctuation in human food availability throughout the entire research site. However, it was unable to account for site specific variations such as hotel occupancy rates, primate management strategies implemented, kitchen and restaurant management, garbage control and baboon competition. These results suggest that while the natural habitat structure and the anthropogenically modified environment within and around it, may dictate the presence of vervet monkeys, individual management of different sites influences the frequency and severity of the people-primate interactions. The analysis of this study would have benefitted from individual calculations of human food availability at both sites and future analysis of baboon and vervet competition in these areas would be of interest.

In summary, the Diani vervet monkey population showed high levels of adaptability in using exotic trees and human food, exploiting predictable food sources such as garbage piles, unguarded restaurant kitchens and buffet areas. I showed that vervet monkeys varied their food choices in response to local variations in resource availability, exploiting a 'preference' for human food and exotic plant species. Further supporting the species adaptability in relation to dietary flexibility in seasonal and/or disturbed habitats. The ability of the vervet population to

use anthropogenic food resources has resulted in their persistence within a densely primate populated area (Sol *et al.* 2012). Although this flexibility allows populations of vervet monkeys to thrive in quite small and heavily disturbed habitats, the long-term survival of populations living in these environments is uncertain as the habitat continues to degrade people-primate interactions and persecutions are certain to increase. Therefore, it is imperative that an understanding of the urban ecology of primates is gained to ensure improved conservation and management strategies.

4.5 Baboon Competition

Research conducted on behalf of Colobus Conservation by a Masters student researching diet and spatial ecology of yellow baboons (*Papio cynocephalus*) in Diani produced home range maps of the five known baboon groups within Diani. The data was collected over a three month period, September - December 2012. Four of the baboon groups had an overlapping home range with Hotel or University group. During data collection the research teams all experienced vervet monkeys vacating an area quickly and quietly on detecting approaching baboons, suggesting that vervet monkeys avoid contact and spatial overlap with baboons in Diani. When the LoCoH home ranges for Hotel and University group were mapped alongside GPS locations for each of the four baboon groups it can be seen that there was very little range overlap between the two species (Figure 4.3 and 4.4). Areas where home ranges of vervet monkeys and baboons do overlap were locations where anthropogenic food was especially concentrated, i.e. unguarded garbage site and restaurant kitchens and were highlighted as baboon hotspots (Heinicke 2013). However, as suggested baboons and vervet monkeys would rarely occupy these areas at the same time. This preliminary data indicates that habitat utilization of baboons and vervet monkeys is different but in areas of overlap baboons out competed vervet monkeys for resources. From experience, I would hypothesis that this differential habitat utilization is in part driven by human persecution of baboons in areas of high human occupancy, which in turn enables vervet monkeys to inhabit these largely baboon free areas.

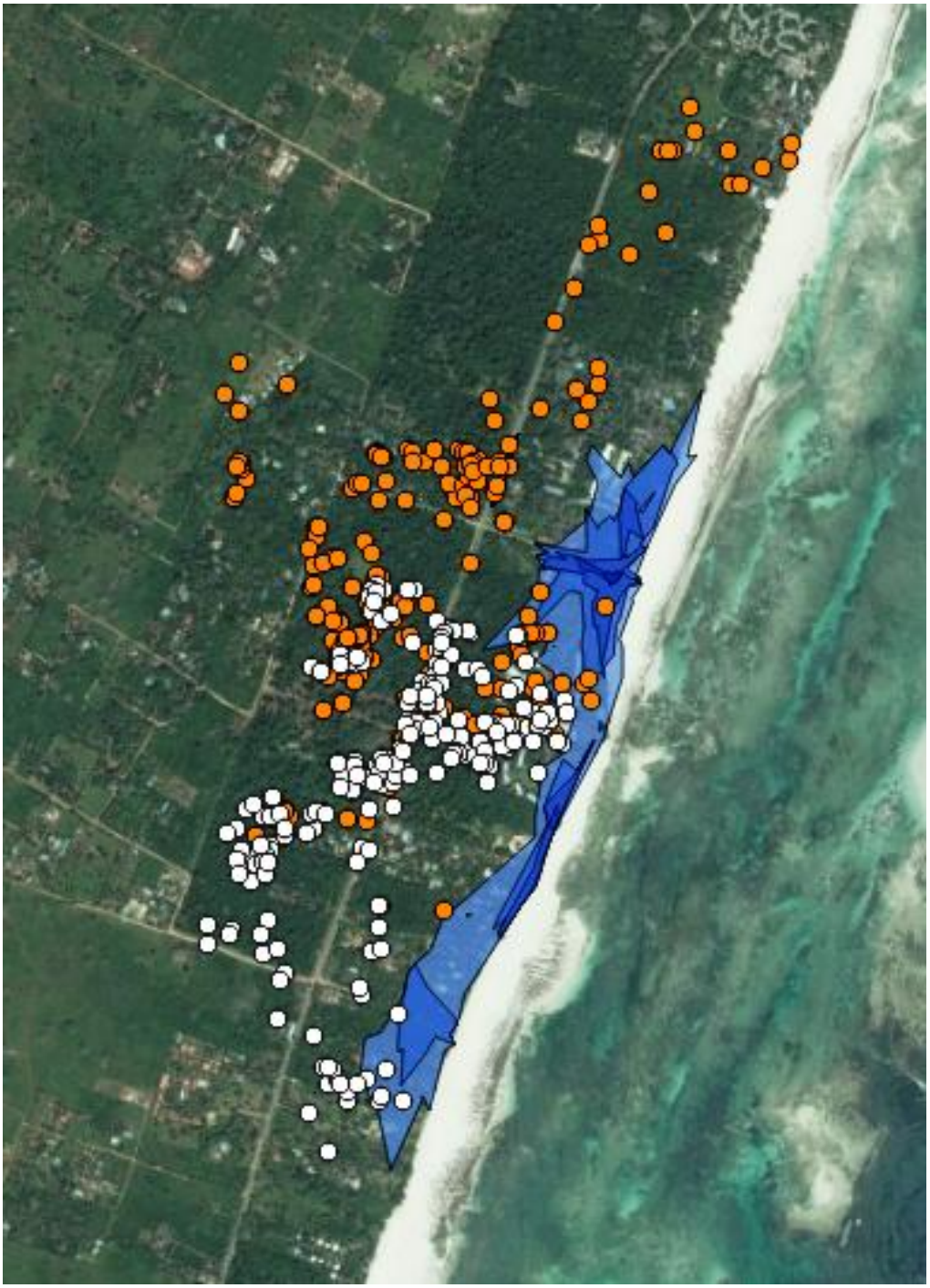


Figure 4.3 LoCoH utilisation distribution for home range of Hotel group, 21.7 ha with GPS locations of two baboon groups. Blue areas represent Hotel groups home range and shading indicates level of use by each group, light and transparent areas represent lower levels and darker and opaque areas higher levels of use. Orange circles represent recorded locations of baboon group B1 and white circles represent recorded locations of baboon group B2. Scale 1:20,000 ©2016 DigitalGlobe ©2016 GeoEye Earthstar Geographics SIO ©Microsoft Corporation. Permission for replication of baboon location data granted by Stefanie Heinicke, Georg-August University and Colobus Conservation.

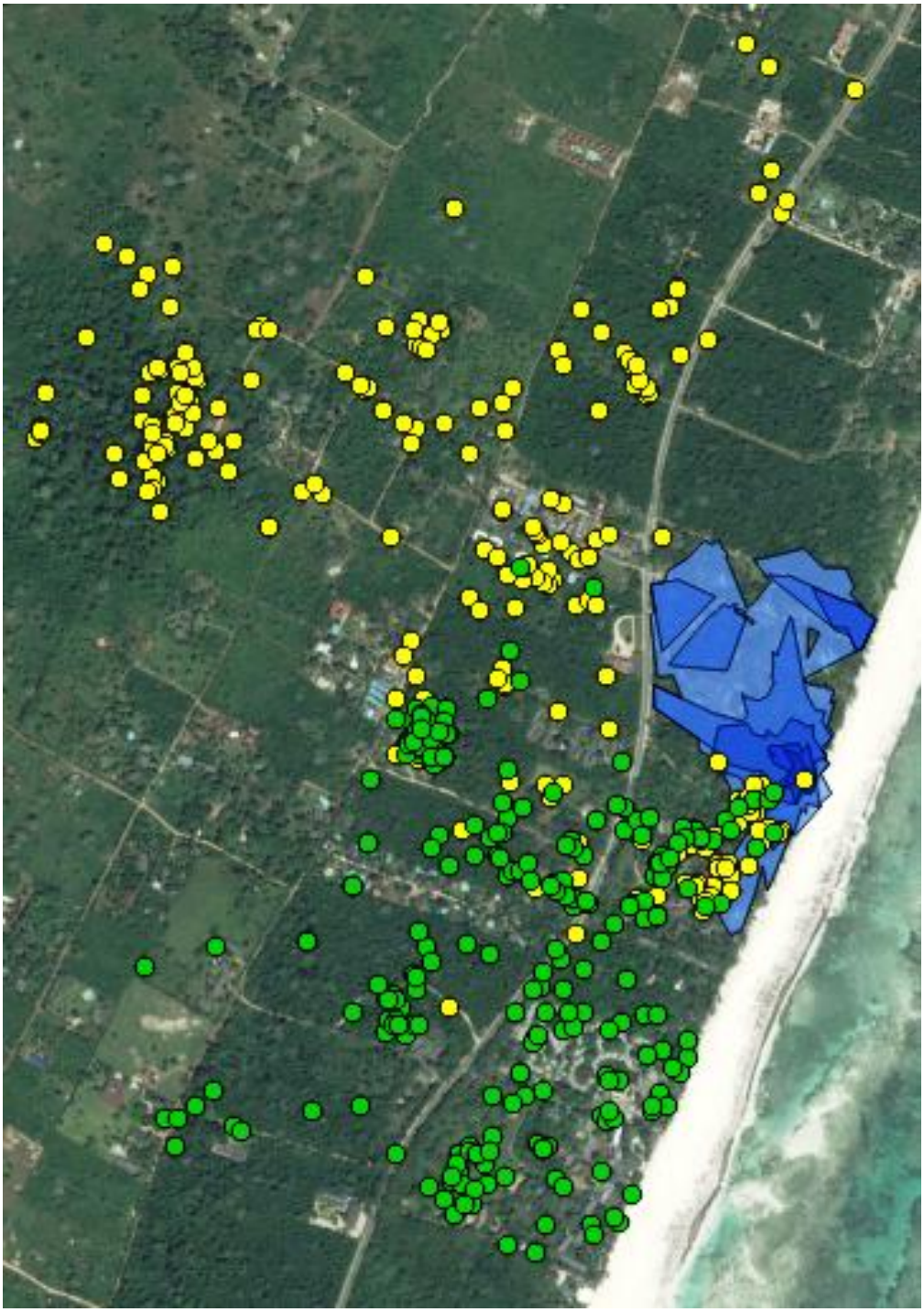


Figure 4.4 LoCoH utilisation distribution for home range of University group, 10.9 ha with GPS locations of two baboon groups. Blue areas represent University groups home range and shading indicates level of use by each group, light and transparent areas represent lower levels and darker and opaque areas higher levels of use. Yellow circles represent recorded locations of baboon group A1 and green circles represent recorded locations of baboon group A2. Scale 1:15,000 ©2016 DigitalGlobe ©2016 GeoEye Earthstar Geographics SIO ©Microsoft Corporation. Permission for replication of baboon location data granted by Stefanie Heinicke, Georg-August University and Colobus Conservation.

4.6 Conclusion

For vervet monkeys to persist in this rapidly changing anthropogenically modified environment they have learnt to exploit all available food resources including exotic plants, herbs, grasses and human food. However, access to human food resources has important population consequences and has been linked to increased densities of birds (Coulson *et al.* 1987; Sol *et al.* 2012), range extensions of opossums (Kanda 2005) and decreased hibernation periods of black bears (Beckmann and Berger 2003). Preventing groups of both vervet monkeys and baboons, from consuming human food sources should be a chief management priority. Other field studies have illustrated that reduced levels of negative people-primate interactions are dependent on preventing primates from accessing human food in anthropogenically-modified habitats (Hoffman and O'Riain 2012a). As an alternative, the remaining forest fragments and secondary growth of Diani, much of which is currently devoid of vervet monkeys can provide natural food sources. However, it is expected that such a management strategy would lead to resource competition between all six of the Diani primate species and may lead to a reduction to the primate population size. In depth behavioural ecology studies must be conducted for all species, in conjunction with habitat and population assessments as described in Chapter 3, to enable extensive population modelling to predict likely outcomes on the implementation of such primate management strategies. With a thorough understanding of primate ecology within Diani, the development of effective management and conservation plans are plausible and primate-people coexistence can be sustained at this unique site where vervet monkeys, and five other non-human primates, manage risks in an anthropogenically modified landscape.

Chapter 5 Rehabilitation Release of Vervet Monkeys (*Chlorocebus pygerythrus hilgerti*)

Abstract

Historically, primate translocations and reintroductions have been criticised for a lack of scientific rigour, especially relating to monitoring and reporting of outcomes. A lack of guidelines for measuring success has resulted in individual programmes employing different parameters, hampering learning in the field. Close monitoring of comparable populations, in a comparable time frame alongside the release groups means a more detailed understanding of successes and failures will be provided. This chapter presents data on survivorship patterns, ranging data, activity budgets and feeding ecology of a group of twelve, wild-born, rescued, rehabilitated and released vervet monkeys. These data are compared to wild vervet control groups inhabiting the same anthropogenically modified habitat to provide a baseline against which release success can be measured. The survivorship of Release group was not significantly different to the control groups, but home range size of Release group was considerably smaller than that of the control groups. Release group's activity budget was largely representative of the control groups, however they did spend significantly more time in social activities that either of the control groups. While the feeding ecology of Release group was largely representative of the control groups, they did consume less grass, but more leaves and anthropogenic foods. This vervet release was a success according to verifiable indicators and criteria, and by comparison with other primate translocations. Demonstrating that wild-born orphaned vervet monkeys can be rehabilitated and released into the wild, and display species appropriate behaviour and survivability, making the project successful from a rehabilitation and welfare perspective.

5.1 Introduction

The IUCN guidelines for Reintroductions and Other Conservation Translocations consider rehabilitation releases to be 'outside the scope of the guidelines' (IUCN/SSC 2013). Similarly the non-human primate reintroduction guidelines do not consider welfare releases to be a translocation or reintroduction approach as they are motivated by goals other than conservation (Baker 2002). However, both sets of guidelines recognise that rehabilitation releases occur and recommend they follow the procedures for the most relevant conservation translocation technique (Baker 2002; IUCN/SSC 2013). Conversely, the guidelines for the

reintroduction of great apes (Beck *et al.* 2007) acknowledge the necessity of welfare based reintroductions (rehabilitation releases) under correct conditions, where there is evidence to indicate that the great apes welfare will be improved and provided reintroduction is not conducted solely to dispose of surplus animals or relieve overcrowding. In the interest of accountability, this rehabilitation release adheres to the IUCN Guidelines for Non-human Primate Reintroductions (Baker 2002), The Best Practice Guidelines for Reintroduction of Great Apes (Beck *et al.* 2007) and The Guidelines for Reintroduction and Other Conservation Translocations (IUCN/SSC 2013).

Historically, primate translocation programmes have come under criticism due to a lack of scientific rigour in all elements of the process, including release site selection, predator awareness training and post-release monitoring. A lack of detailed methodology and post-release monitoring made it impossible to understand what factors resulted in the success or failure of the translocation and reintroduction of red colobus (*Procolobus kirkii*) in Zanzibar (Struhsaker and Siex 1998). Similarly, inadequate information exists for hundreds of orangutans (*Pongo abelii; P. pygmaeus*) released from rehabilitations centres in Malaysia and Indonesia since the 1970s (Warren and Swan 2002). However, in recent years a more stringent approach has become the trend and reporting on successes and failures has increased. For example pre-release considerations including release site selection for gibbons (Cheyne 2006; Wade and Malone 2013) and pre-release training (Schwartz *et al.* 2016), detailed post-release monitoring of released wild-born orphaned chimpanzees (Ancrenaz 2001; Goossens *et al.* 2005; Humle *et al.* 2010), dietary adaption of released lemurs (Britt and Iambana 2003), rehabilitation release of vervet monkeys (Guy 2013; Guy *et al.* 2011, 2012; Wimberger *et al.* 2010b) and reintroduction of orangutans (Russon 2008), behavioural ecology and group cohesion of released gorillas (Le Flohic *et al.* 2015), rehabilitation and translocation of slow lorises (Moore *et al.* 2014), alongside species specific proposed guidelines for the entire process (Beck *et al.* 2007; Campbell *et al.* 2015; Cheyne *et al.* 2012; Guy and Curnoe 2013) .

The IUCN guidelines do not offer any protocol or standardised method of assessing whether a translocation has been successful. In general, translocations are considered successful if they result in self sustaining populations (Baker 2002; Beck *et al.* 2007; Fischer and Lindenmayer 2000; Griffith *et al.* 1989). However, when dealing with long-lived animals like primates this parameter is a long-term measure (Pinter-Wollman *et al.* 2009), and generally requires a greater time investment than funding permits. As a result individual translocation programmes

have employed various parameters as measures of success and to assess the ability of released animals to become established in their new environment. For example, survivorship and reproductive success of release animals are directly related to population viability, and are commonly reported measures of primate translocation programmes (Goossens *et al.* 2005; Guy 2013; Guy *et al.* 2011, 2012; Humle *et al.* 2010; Kleiman *et al.* 1991; Osterberg *et al.* 2015; Wimberger *et al.* 2010b). In addition, the mortality rate of release groups can be compared to data published on wild groups, as was done for released vervet monkeys (Wimberger *et al.* 2010b), with the conclusion that the release group had a higher mortality rate than wild groups.

Detailed analysis of behaviour and interactions of newly released animals within their environment, offer greater insight into the ability of individuals to adapt and become established within the habitat (Pinter-Wollman *et al.* 2009; Strum 2005). Additionally, providing measurable results that other releases can learn from Details of home range patterns provide information on whether released individuals remain at the release site and use the habitat in a similar way to their wild counterparts. For example, when habitat type, and variation between the sexes, were taken into account the home range size and day journey length of thirteen chimpanzees released in Guinea were within the reported ranges of wild groups (Humle *et al.* 2010). Two of three vervet rehabilitation release studies also reported that the home range of release groups were within the ranges reported in wild groups (Guy *et al.* 2012; Wimberger *et al.* 2010b). However, a third study of a vervet release group recorded an exceptionally large home range of 7km^2 (Guy *et al.* 2011). This large range was influenced by an adult male who was recorded alone on a number of occasions at the extremes of the home range. However, even when this individual was excluded from calculations the home range remained large at 4.6km^2. Furthermore, foraging efficiency and activity budgets can indicate release animals chances of long-term survival (Britt and Iambana 2003; Farmer *et al.* 2006). Several vervet rehabilitation release studies noted that the release groups exhibited a range of natural behaviours and consumed natural food items, but direct comparisons to wild groups were not made (Guy *et al.* 2011, 2012; Wimberger *et al.* 2010b). Farmer *et al.* (2006) reported that thirty seven chimpanzees released in Congo displayed behaviour that was generally reflective of wild groups, but with significantly less grooming. The same study went on to report that the diet of the released individuals was broadly similar to that reported in wild groups, being a fruit dominated diet, but the range of species consumed was smaller. In line with this study, Britt and Iambana (2003) reported significant dietary

overlap between released white ruffed lemurs and wild individuals recorded as part of the same study. However, the ruffed lemur release groups also consumed a slightly smaller range of plant species.

Despite the recognition of using behavioural measures to indicate success of a translocation, few primate post-release studies include detailed measures of the behavioural and feeding ecology of released groups and comparable data from control groups in a relevant location collected in the same time frame as the release occurred. Measures of translocation success must be both verifiable and broadly applicable, with indicators evaluated relative to a detailed performance target or controls groups (Strum 2005). Environmental factors within a release location may affect food supply; and close monitoring of the control populations and release groups provides a more detailed understanding of successes and failures (Strum 2005). As Chapter 4 revealed, due to the anthropogenic environment and the impact this has upon the habitat, wild vervet groups in Diani have a behavioural ecology that is notably different to published data on this species. Diani vervet monkeys depart from other populations in many aspects of their behaviour, including ranging, activity budgets and feeding ecology. In addition, seasonality barely impacts on their behavioural ecology. Accordingly, measures of success for the release group will be made against a time appropriate subset of the results presented for the Diani vervet population in Chapter 4, rather than the published vervet literature as a whole.

The goals of this study were to investigate whether an artificially formed group of wild born, orphaned, ex-pet and/or displaced vervet monkeys could be successfully released back into the Diani environment. Success is defined as the release group (Release group) displaying behaviours that are representative of the indigenous populations (Hotel group and University group) including activity budgets, feeding ecology, home range area and survivorship. This will be achieved through statistical analysis of long term observational data of one group of vervet monkeys post-release, compared to baseline data from two naturally occurring wild control groups of vervet monkeys inhabiting the same anthropogenically disturbed habitat within the same time frame. Key hypotheses were;

Hypothesis 1: The survivorship of Release group will be different to survivorship observed in the control groups. As per previous studies (Guy 2013; Guy *et al.* 2011, 2012; Wimberger *et al.*

2010b), I predict that Release group will have a lower survivorship than the control groups due to inexperience in the wild environment.

Hypothesis 2: Post-release, home range and day journey lengths of Release group will change over time and become more representative of that of the control groups. I predict that home range and day journey length of Release group will increase over time. Secondly, as per previous studies (Guy *et al.* 2012; Humle *et al.* 2010; Wimberger *et al.* 2010b) I predict that upon cessation of supplementary feeding, and in order to meet dietary requirements, Release group will develop a home range and day journey length that is representative of the control groups.

Hypothesis 3: Post-release, the activity budget of Release group will change over time and become representative of the control groups. I predict that feeding and moving will increase over time due to supplementary feeding ending and the group having to invest more time in foraging. Secondly, I predict that resting behaviour will reduce over time as a result of increased feeding and moving behaviour and a more natural diet. Finally, in line with Farmer *et al.* (2006), I predict that once Release group are independent of supplementary food their activity budget will be representative of the control groups.

Hypothesis 4: Post-release, the feeding ecology of Release group will change over time and become more representative of the control groups. I predict that the consumption of natural food items including fruit, grass, flowers and leaves will increase due to the reduction of supplementary feeding. Secondly, I predict that this increase in natural food items will result in an increase in dietary diversity and equitability. I also predict that once Release group are independent of supplementary food their food item consumption will be representative of the control groups. Finally, and according to previous studies (Britt and Iambana 2003), I predict that Release group will have dietary overlap with the control groups, but their consumption of natural species will be less diverse. The dietary overlap of Release group will be greater with Hotel group than University group as a result of greater habitat overlap with Hotel group (Chapter 3).

5.2 Methods

5.2.1 Study Site

Release Site

The vervet release took place within the grounds and area surrounding Colobus Conservation. The area was an anthropogenically modified habitat, with a small number of residential properties. The natural habitat was a mosaic landscape of secondary forest, remnant forest trees, natural grass areas and the occasional manicured lawn, all interspersed with exotic species. The area had resident wild populations of colobus monkeys, Sykes monkeys and was visited several times a week by a group of baboons, but there was no permanent presence of vervet monkeys (section 3.3). The nearest vervet group was the control Hotel group and their core area was located 1km away. This group were recorded using the release area on only a few occasions per year during the peak of the dry season. Despite low densities of vervet monkeys, surveys of the area indicated an adequate availability of fruiting trees and other vervet foods (section 3.3.2). For a detailed insight into the release site refer to chapter 3.

Control Sites

Both control sites were in anthropogenically modified areas. Hotel site consisted of two large hotel complexes, a number of holiday cottages and a few private residences. Green areas largely consisted of manicured lawns, open tropical gardens mixed with remnant forest trees. University site was centred around a University field station neighbouring a hotel complex with staff quarters and a few private residences. Numerous remnant forest trees interspersed with exotic species formed a thin, but largely continuous canopy. Both sites had resident populations of colobus monkeys, Sykes monkeys and baboons. For detailed site descriptions refer to Chapter 3.

5.2.2 Release Method

Release group consisted of twelve individuals that had spent 3-39 months in captive rehabilitation, at Colobus Conservation prior to release. They had arrived as a result of various human/wildlife interactions. Upon admission to the rescue facility all individuals were given a full health check, treated medically as required and quarantined either individually, in human care or as part of a small group, for a minimum of thirty days. Once medically healthy, individuals less than a year old began rehabilitation in orphan care and the nursery enclosure, before being transferred to the pre-release enclosure. Older individuals were integrated directly into the pre-release enclosure. Prior to release the group underwent predator and electricity awareness training to ensure they had appropriate responses to location specific

dangers. In addition, they were given life skills training for the entirety of their rehabilitation including environmental enrichment to encourage foraging behaviour and daily exposure to wild foods. Care was taken not to encourage pest behaviours and therefore no 'crop' food or enrichment involving human food packaging was presented. Moreover, direct hand feeding never occurred unless medically required. Only individuals displaying appropriate predator awareness skills, consuming wild foods and recorded sleeping high in the enclosure were considered viable for release. The full pre-release protocol is in Appendix 1.

All release group individuals were fitted with radio-collars (Telonics Inc., USA), and allocated individually coloured ear tags at least one week prior to release (Figure 5.1). It was vital that any tracking device used did not negatively impact up on the survival of an individual. Therefore the weight of an individual's tracking device did not exceed the maximum 5% of their body mass (Animal Care and Use Committee 1998). In accordance, mammal zip tie collars (supplied by Advance Telemetry Systems, model number: M1555), weighing 20g and with a battery life of 502-897 days, were used. The vervet release group consisted of adults, sub-adults, juveniles and infants and was representative in composition of wild vervet groups within Diani (section 2.3.2.1). Release from the pre-release enclosure occurred mid morning on the 27th May 2012 once the group had eaten their morning food, and the release site was clear of other wild primate groups. The enclosure doors were fixed at a position that allowed the vervet monkeys ample room to move freely in and out of the enclosure but prevented baboons from doing the same. The enclosure remained in this state until no release individual had been observed using the enclosure for refuge for a minimum of one week. Studies have shown that newly released animals that have access to a shelter with which they are familiar, have a decreased post-release predation mortality than those animals who do not have a shelter, or are not familiar with the shelter provided (Kawabata *et al.* 2011). Following the soft-release protocol the group received regular supplementary food for 16 weeks and was monitored for 18 months post-release; both gradually reduced in frequency over time. A census of Release group was conducted daily noting the condition of each individual. Any individual not with the group was located using radio telemetry and if they were suffering from a life-threatening injury or condition, an intervention was carried out. Direct contact between observers and the vervet group was avoided to limit disease transmission, except if required for medical intervention. The full release protocol is in Appendix 1.

Figure 5.1 Sub adult male fitted with a radio collar and individually coloured ear tags.

5.2.3 Post-release Monitoring and Data Collection

Release Group

Release group was monitored post-release for an 18 month research period, May 2012 - November 2013, and data relating to life history continued to be collected for four years post-release. Data collection consisted of an intensive post-release monitoring phase where the group were followed daily from dawn till dusk for the first three months. Over time this intensity reduced in half-day increments, until by 15 months post-release the group was being monitored on average only one full day per week. Behavioural data collection ended 18 months post-release. The behavioural and dietary data in this chapter were collected using instantaneous focal sampling (Altmann 1974) of adult and sub-adult individuals, while ranging behaviour and survivorship was based on data collected for all age classes. Instantaneous sampling was conducted at one minute intervals for a twenty minute focal period, with two focal follows conducted per hour during each research period. The geographical location of the focal individual was recorded at the start of each focal period, using a handheld Garmin GPS eTrex unit. These data were recorded even if activity data were not obtainable for the full focal period, provided the focal individual's location could be confirmed at the start of the focal period. Release individuals were individually identifiable by their ear tags, whilst wild

individuals who immigrated or were born into the group were identified by their natural markings (e.g. sizes, coat colour, and facial features) and physical abnormalities (e.g. scars, damaged limbs, digits and tails). For a more comprehensive description of the methods used see Section 2.4.3.

Control Groups

A time appropriate subset of the data collected from Hotel group and University group as presented in Chapter 4 was used as baseline comparative data in order to evaluate Release group's 'success'. In contrast to Release group, the analysis of instantaneous focal sampling for the control groups was conducted on adults only as the sample size of sub-adults during this period was inconsistent. Ranging behaviour and survivorship was analysed using data collected from all age classes. For a more comprehensive description of the control groups see section 4.2.

5.2.4 Statistical Analysis

Analysis was conducted on all 18 months of post-release focal follow data. Only data on released individuals was analysed with all immigrating males and wild born individuals excluded. Released infants and juveniles were also excluded from the dataset due to extended periods where neither age category was present or the sample size was small. Post-release changes in behavioural and feeding ecology were analysed using three distinct time periods; Period 1: 1-3 months post-release, Period 2: 4-6 months post-release and Period 3: 7-18 months post-release. These periods were selected to assess changes in behavioural and feeding ecology in relation to supplementary feeding and post-release monitoring intensity. Comparisons to control group's behavioural and feeding ecology was conducted on a sub-set of data presented in Chapter 4 that directly corresponded with Period 3 (December 2012 - November 2013) of the Release group analysis (Table 5.1).

Table 5.1 Number of research days per study group used in Chapter 5 analyses

	Number of Research Days	Release group	Hotel group	University group
Period 1: Months 1-3	Half day follows	0	-	-
June - August 2012	Full day follows	91	-	-
Period 2: Months 4-6	Half day follows	52	-	-
September - November 2012	Full day follows	38	-	-
Period 3: Months 7-18	Half day follows	81	49	73
December 2012 -November 2013	Full day follows	51	41	42

5.2.5 Hypothesis 1: Survivorship

Survival of Release group was compared to the survival of the control groups over the 18 month post-release period using Kaplan-Meier Survival analysis. Only individuals known to be alive and recorded as group members on or before 27th May 2012 (release day), were included. Immigrating individuals and births were not added. Survival was defined as individuals known to be alive, either within the original study group or following immigration into a different group. Individuals missing or confirmed as dead were classified as completed. Log-rank statistics were used to compare survival between the three groups. Factors influencing released individual's survivorship were investigated using Spearman's rank correlation.

5.2.6 Hypothesis 2: Ranging Behaviour

Home range and use distributions were calculated using adaptive Local Convex Hulls (T-LoCoH) for each post-release period separately and a comparison of both control groups for wet and dry season (see section 2.5.2). T-LoCoH variables selected to calculate home ranges were different for each group (Table 5.2). In all periods, and all groups, k values were selected that minimised the appearance of 'holes' within the home range map (Getz *et al.* 2007; Lyons *et al.* 2013). Holes were permitted if they corresponded with areas that the vervet monkeys could not possibly use, i.e. large swimming pools, with no overlapping canopy.

Table 5.2 Variable details for fixed number of points: T-LoCoH.

T-LoCoH variables	Release group			Hotel	University
	Period 1	**Period 2**	**Period 3**	**Period 3**	**Period 3**
Data points entire home range	1789	1029	1855	626	1413
Data points wet season home range	N/A	N/A	804	333	835
Data points dry season home range	N/A	N/A	1051	293	578
Value of s	0.0025	0.0023	0.001	0.0005	0.0025
Value of k	15	15	15	15	15

Day Journey Length

Using GPS locations recorded during full-day follows. Beginning between 0600-0700h and ending around 1800h depending on access permissions, day journey length was determined for each group based on the shortest point-to-point movements of the group between consecutive GPS locations. Full day follows that lacked GPS locations for one or more consecutive hours were not included in this analysis.

One-way ANOVA with Tukey tests were performed to assess difference in day journey length of Release group between the three post-release periods and difference between Release group and the two control groups.

5.2.7 Hypothesis 3: Activity Budgets

Behavioural activities were separated into five categories: feeding, moving, resting, social and other. Using instantaneous focal sampling data, mean monthly proportion of time spent in each activity category was calculated for each group. From these data overall means were calculated for each study period. One-way ANOVA with post hoc Tukey tests or Kruskal-Wallis with post hoc Mann-Whitney U tests were performed to assess difference in activity budget of Release group between the three post-release periods. Difference between Release group and the two control groups were analysed using a combination of one-way ANOVA with post hoc Tukey tests or Kruskal-Wallis with post hoc Mann-Whitney U tests.

5.2.8 Hypothesis 4: Feeding Ecology

Using data collected on feeding behaviour from instantaneous focal sampling, mean monthly proportion of diet composition was calculated. Dietary data were separated into ten categories: fruit (including fruits, seeds and seed pods), flowers, leaves, grass, animal matter, human food, supplementary food, enclosure food, poultry food, and other.

Differences in dietary consumption of Release group across the three post-release periods were assessed using one-way ANOVA with post-hoc Tukey tests or Kruskal-Wallis tests with post hoc Mann-Whitney U tests were performed. For analysis between Release group and the control groups, one new category called anthropogenic food subsumed human food, supplementary food, enclosure food and poultry food. Release group had access to three food types that the control groups did not: supplementary food, enclosure food and poultry feed. Supplementary food was food made available to Release group as part of the soft-release protocol and, with the exception of the occasional scattering for intervention purposes, its' distribution was limited to the first 16 weeks post-release. Due to the location of the release site Release group were also able to access other animal food in two major forms. Firstly, from Colobus Conservation enclosures housing other monkeys not included in this release, and scattered poultry feed in neighbouring plots. All of these food sources are high calorie and easily digestible food sources akin to human food (obtained from hotels). In order to enable comparisons to the control groups a new category combining these food sources along with human food was created and termed anthropogenic food. Differences between the groups were then assessed using Kruskal-Wallis tests with post hoc Mann-Whitney U tests.

Dietary Diversity and Equitability

The diversity and equitability of each groups diet was calculated using the Shannon-Weaver index (H) and equitability (E_H). This measures how diverse and equally represented different food categories were within the diet of Release group in the three post-release periods and within the comparative period for control groups. Food categories were recorded to species level where possible and food item level when not i.e. plant species, grass, animal matter and anthropogenic. The Shannon-Weaver index measures dietary diversity using the formula:

$$H=-\sum pi(\ln(pi))$$

where pi is the proportion of a given species in a given sample. Values range from 0 to 5.0, with higher values indicating greater levels of diversity (Krebs 2014).

Shannon-Weaver equitability measures how equally different food categories were represented in the given sample of each group, using the formula:

$$E_H=H/\ln S$$

where S is the total number of categories recorded. Values range between 0-1, with 1 indicating that an equal number of records exist for each species in the sample (Krebs 2014).

One-way ANOVA with Tukey tests were used to assess difference in the dietary diversity and equitability between the three groups over time.

Dietary Overlap

The proportional overlap of the groups' diet were measured using Schoener's overlap index.

$$P_{hur}=[\sum_{i=1}^{n}(\text{minimum } p_{ih}, p_{iu}, p_{ir})]$$

where p_{ih}, p_{iu}, p_{ir} are the proportions of food category i found in the diets of each group (based on percentage of feeding time). The index ranges from 0 (no overlap) to 1 (all items in equal proportions), with values above 0.6 usually considered to be indicative of significant overlap (Wallace 1981).

Further exploration involved comparing the overlap of the three groups in pairs (i.e. Hotel: University, Hotel: Release and University: Release).

5.3 Results

5.3.1 Hypothesis 1: Survivorship

The fate of all released monkeys was known to at least 18 months post-release and their presence or absence in the group until 4 years post-release. By the end of the 18 month post-release monitoring period four released individuals were known to have died with the remaining 8 individuals continuing to inhabit the release site as part of a stable, cohesive group. This represents a 66.6% survival rate (Table 5.3). One further individual died and two individuals were noted as missing from the group at four years' post-release, resulting in a confirmed four year survival rate of 42%. New individuals joined the group post-release in the form of immigrating adult males and infants births (Table 5.4 and 5.5). At four years' post-release Release group contained a total of 14 individuals, 5 original release members, 1 wild male and 8 surviving individuals born into the group. This represented a 16.67% increase in group size. By four years post-release all surviving females had given birth and were successful in caring for their offspring; notably the first wild born infant (BR) was in the late stages of her first pregnancy.

Table 5.3 Details of released individuals, with their fate at 18 months and 4 years post-release. * Approximated time frames based on estimated age on arrival and known circumstances of the individual prior to arrival, HWI - Human wildlife interaction, WVC - Wildlife vehicle collision

ID (code)	Sex	Arrival date at CC	Age on arrival	Time in the wild prior to rehabilitation*	Time in pre-release group (months)	Age at release	Background	Fate Nov 2013	Fate May 2016
Handy Joe (HJ)	M	Unknown	Unknown	> 2 years	3	Adult	Individual released by CC in 2009 who lived on-site as a lone male	Died 06/01/13 HWI	N/A
Kinky Tail (KT)	F	29/09/2009	Juvenile	Unknown	31	Adult	Pet	Alive	Alive
Face (FA)	F	05/09/2010	Sub-adult	Unknown	19	Adult	Pet with previous failed release by owner	Alive	Alive
Broken Arm (BA)	M	05/02/2009	Infant	10 weeks	35	Sub-adult	Orphan - hand reared at CC	Alive	Alive
Eye (EY)	M	05/02/2009	Infant	8 weeks	35	Sub-adult	Pet - hand reared at CC	Alive	Missing - April 2015
Short Tail (ST)	M	08/02/2009	Infant	6 weeks	35	Sub-adult	Captured by poachers - hand reared at CC	Alive	Died 03/11/2014 Necropsy inconclusive
Diego (DI)	F	05/06/2010	Infant	6 months	22	Sub-adult	Captured by poachers	Died 14/10/2013 WVC - Pregnant	N/A
Emily (EM)	F	30/03/2010	Infant	2 weeks	22	Juvenile	Orphan – hand reared at CC	Alive	Missing - May 2014
Houdini (HO)	F	01/08/2011	Juvenile	1 year	9	Juvenile	Suspected infanticide victim	Alive	Alive
Rafiki (RA)	F	16/08/2011	Juvenile	1 year	8	Juvenile	Head injury in HWI	Alive	Alive
Malindi (ML)	F	23/09/2011	Infant	8 weeks	6	Juvenile	Pet – hand reared at CC	Died 26/04/2013 Head injury	N/A
Mambi (MM)	M	24/09/2011	Infant	4 weeks	6	Infant	Orphan – hand reared at CC	Died 05/06/2012 Natural causes	N/A

Table 5.4 Details of immigrant males, and their fates, that joined the release group up to 4 years post-release

ID (code)	Age	Sex	Date joined	Fate - Nov 2013	Fate- May 2016
Frankie (FF)	Adult	Male	August 2012	Alive	Emigrated - early 2014, recorded as lone male until Jan 2015
Al (AL)	Adult	Male	07/01/2013	Died - 25/09/2013, WVC	
New Male (NM)	Adult	Male	November 2013	Alive	Died - 24/11/2015, Necropsy inconclusive
Baobab Male (BM)	Adult	Male	July 2015	N/A	Alive

Table 5.5 Details of births, and their fate, to females from the release group up to 4 years post-release

Name	Mother	Date of birth	Sex	Fate - Nov 2013	Fate - May 2016
Brooklyn (BR)	FA	03/10/2012	Female	Alive	Alive and pregnant
Kilele (KI)	KT	31/12/2012	Female	Alive	Alive
Finn (FI)	FA	13/11/2013	Male	Alive	Died - 07/01/2014, witnessed infanticide by NM
Kenny (KE)	KT	16/02/2014	Male	N/A	Died - 16/05/2014, witnessed infanticide by NM
Fire (FR)	FA	23/10/2014	Female	N/A	Alive
Kelly (KL)	KT	31/12/2014	Female	N/A	Alive
Baby Houdini (HB)	HO	20/12/2014	Unknown	N/A	Died - 23/12/2014, insufficient maternal care
Happy (HA)	HO	02/07/2015	Male	N/A	Alive
Ruddy (RU)	RA	04/02/2016	Unknown	N/A	Alive
KT Junior (KJ)	KT	08/02/2016	Unknown	N/A	Alive
Feugo (FU)	FA	12/04/2016	Unknown	N/A	Alive

Survival curves were similar across all three groups (Figure 5.2). Mean ±SEM Hotel group survival was 533 ± 15 days (1 confirmed death, 1 disappearance - suspected death, total 20 individuals, 95% CI 504-562 days). Mean ±SEM University group survival was 492 ± 23 days (2 confirmed deaths, 8 disappearances - 4 suspected deaths, 2 suspected emigrations and 2 unknown outcome, total 26 individuals, 95% CI 447-537 days). Mean ±SEM Release group survival was 458 ± 49 days (4 confirmed deaths, 0 disappearances, total 12 individuals, 95% CI 362-554 days). Insufficient data were available to determine median survival. There was no significant group difference in survival (Log-rank statistic *L*=3.214, df=2, *p*=0.200).

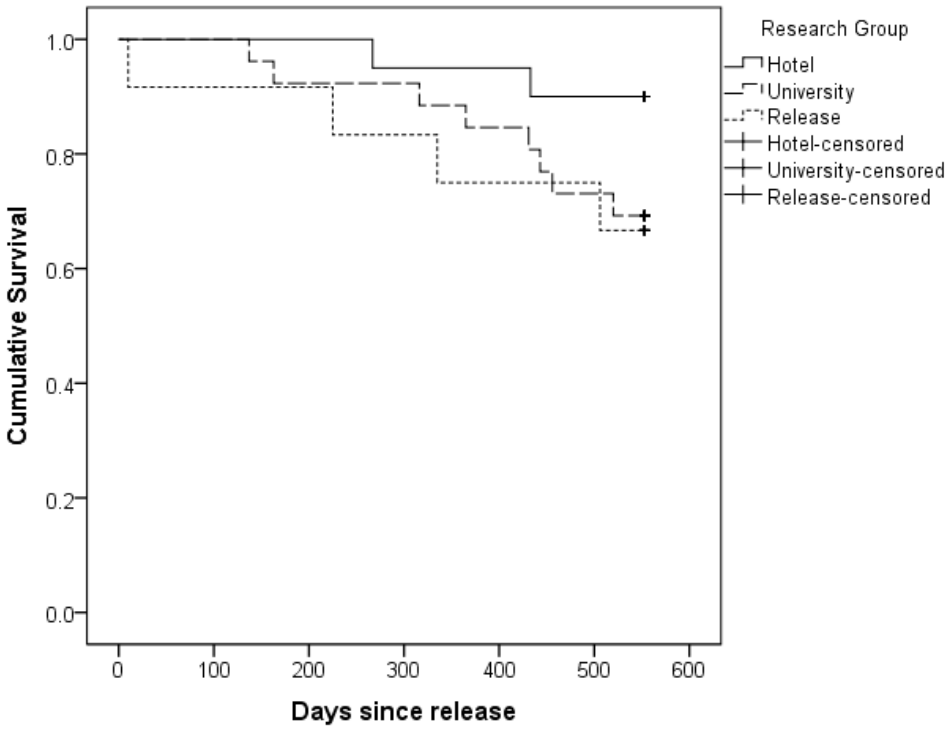


Figure 5.2 Cumulative survival curve for Release group compared to the control groups.

Post-release survival at 18 months of individuals in Release group was correlated with the length of time spent in Release group prior to release (Spearman's rank correlation; n=12, r=0.700, p=0.011*). However, survival post-release did not correlate with either length of time in the wild prior to entering Colobus Conservation care (Spearman's rank correlation; n=10, r-0.038, p=0.917) nor age at release (Spearman's rank correlation; n=12 r=-0.209, p=0.515).

5.3.2 Hypothesis 2: Ranging Behaviour

Release Group

The home range for Release group increased in size following release (Table 5.6), with the group radiating outwards from a central core (Figure 5.3). Day journey length remained largely constant and there was no statistically significant difference in day journey length between post-release monitoring periods (One way ANOVA; $F_{(2,17)}$=0.917, p=0.421).

Table 5.6 Home range (95%) and core home range (50%) totals for three periods post-release

T-LoCoH variables	Months Post-release		
	1-3	**4-6**	**7-18**
Core home range (50%)/ha	0.16	0.16	0.29
Home range (95%)/ha	1.33	2.55	3.78
Day journey length/m	875 (730 - 1058)	1035 (977 - 1087)	857 (428 - 1201)

Comparison with Control Groups

The home range and core area used by Release group was considerably smaller than that of the control groups (Table 5.7), but followed the same trend of using a larger area in the wet season than the dry season. The day journey length of Release group was also smaller than that of the control groups. This difference was significant between the three groups (one-way ANOVA $F_{(2,29)}$=5.297, p=0.011*). Tukey tests indicate University group's day journey length was significantly different to both Hotel group (p=0.038*) and Release group (p=0.022*), while there was no difference between Hotel and Release group (p=0.959) (Figure 5.4).

Table 5.7 Home range (95%) and core home range (50%) for December 2012 - November 2013, wet seasons and dry seasons, for Hotel, University and Release group.

Period	**Hotel group**		**University group**		**Release group**	
	Home Range	Core Range	Home Range	Core Range	Home Range	Core Range
Total	19.1ha	1.4ha	10.8ha	1.4ha	3.78ha	0.29ha
Wet months	14.5ha	0.6ha	9.0ha	1.4ha	3.89ha	0.25ha
Dry months	9.7ha	1.4ha	8.0ha	1.3ha	2.50ha	0.24ha

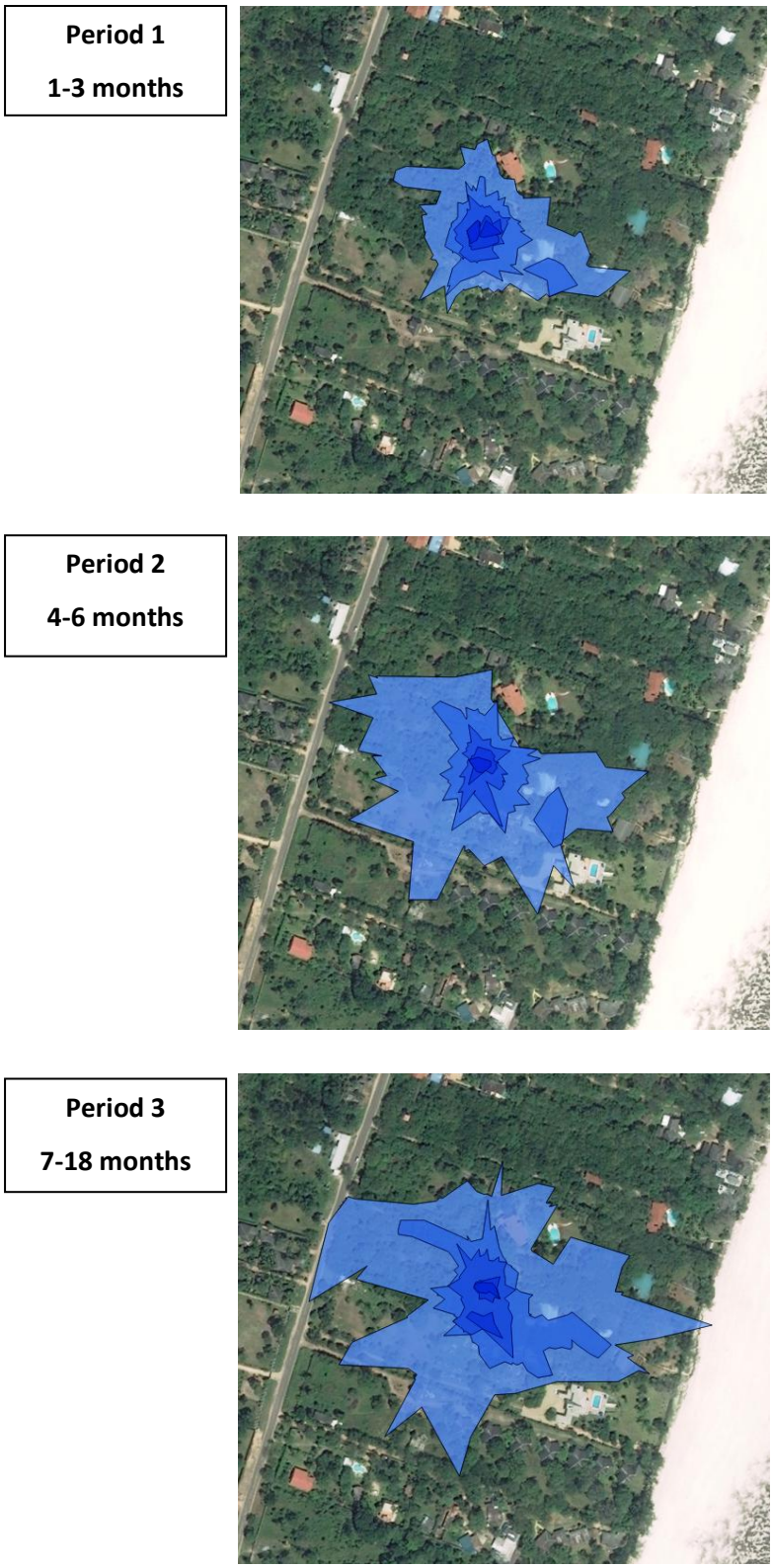


Figure 5.3 LoCoH utilisation distribution for home range of Release group, Period 1 - 1.33ha, Period 2 - 2.55ha and Period 3 - 3.78ha. Blue shading indicates level of use by Release group, light and transparent areas represent lower levels and darker and opaque areas higher levels of use. Scale 1:3,000 ©2016 DigitalGlobe ©2016 GeoEye Earthstar Geographics SIO ©Microsoft Corporation

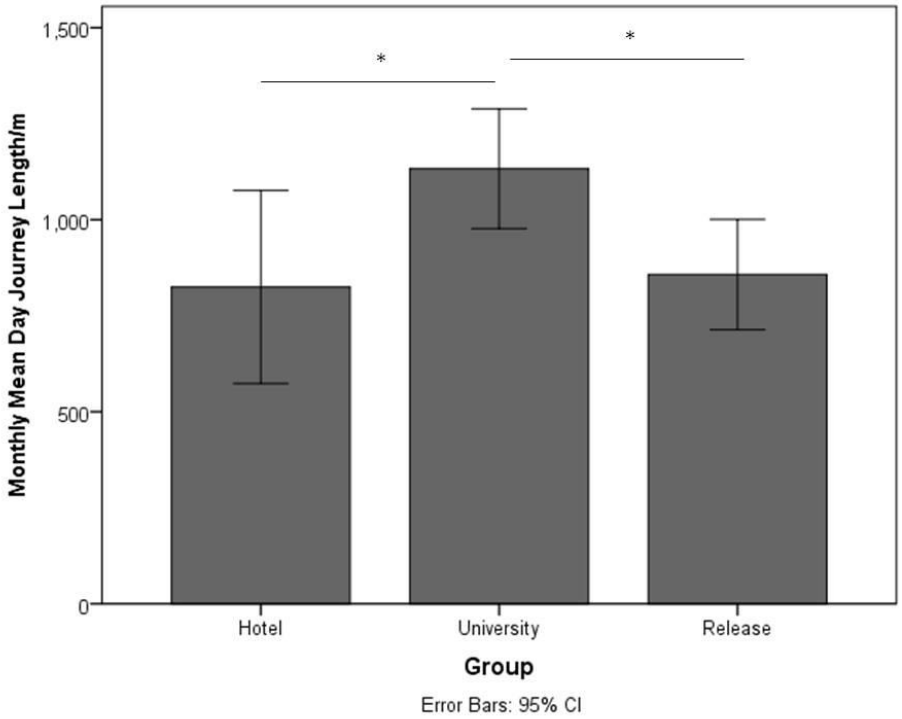


Figure 5.4 Day journey length of Hotel, University and Release group, n=12. Significant differences calculated using one-way ANOVA and Tukey test between groups are highlighted with *p=<0.05.

5.3.3 Hypothesis 3: Activity Budgets

Release Group

In the 18 months following release there were significant differences to Release groups activity budget (Figure 5.5). Both social and other behaviours significantly increased over time (Kruskal-Wallis test: Social, x^2=8.602, df=2, p=0.014*; One-way ANOVA: Other, $F_{(2,17)}$=6.450, p=0.010*), whilst the remaining behaviours did not (Feeding, $F_{(2,17)}$=0.292, p= 0.751; Moving, $F_{(2,17)}$=2.512, p=0.115; Resting, $F_{(2,17)}$=0.664, p=0.529). Post-hoc Mann-Whitney U test indicated the significant difference for social behaviour occurred between Periods 1 and 3 (p=0.014*). Likewise Tukey tests indicated that the significant differences for other behaviour (p=0.017*) occurred between Periods 1 and 3 post-release only.

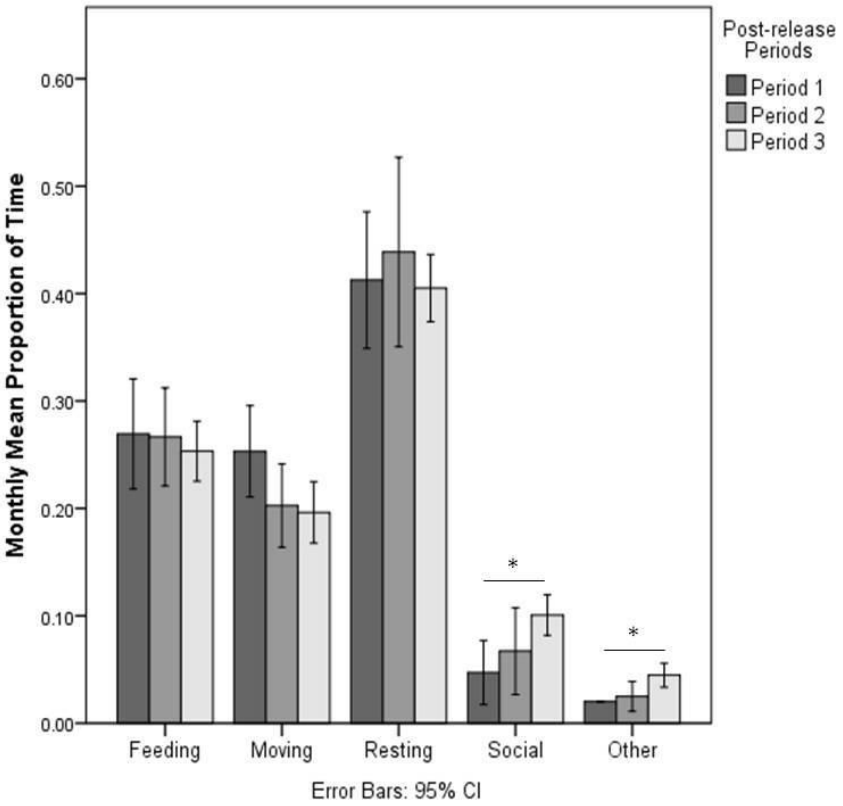


Figure 5.5 Release groups activity budget across three post-release periods. Significant differences calculated using one-way ANOVA or Kruskal-Wallis tests between time periods are highlighted with *p=<0.05 or **p=<0.01.

Comparison to Control Groups

Time spent in feeding, resting and social behaviour was significantly different between the three groups (one-way ANOVA: Feeding, $F_{(2,35)}$=17.826, p=<0.001***, Resting, $F_{(2,35)}$=13.617, p=<0.001***; Kruskal-Wallis test: Social, x^2=18.588, df=2, p=<0.001***), whilst the remaining behaviours were not (one-way ANOVA: Other, $F_{(2,35)}$=1.832, p=0.176; Kruskal-Wallis test; Moving, x^2=0.884, df=2, p=0.643). Tukey tests indicated that Hotel group spent significantly less time feeding than both University and Release group (Feeding; Hotel: University, p=<0.001***, Hotel: Release, p=<0.001***) but there was no difference between University group and Release group (University: Release, p=0.829). Hotel group also spent significantly more time resting than both University and Release group (Feeding; Hotel: University, p=<0.001***, Hotel: Release, p=<0.001***) but there was no difference between University group and Release group (University: Release, p=0.995). Post-hoc Mann-Whitney U tests indicated that all three groups were significantly different to each other in social behaviour (Mann-Whitney U, Hotel: University, Z=-1.965, p=0.049*; Hotel: Release, Z=-3.294,

p=0.001***; University: Release, Z=-3.868, p=<0.001***) with Release group spending more time socialising than both Hotel and University (Figure 5.6).

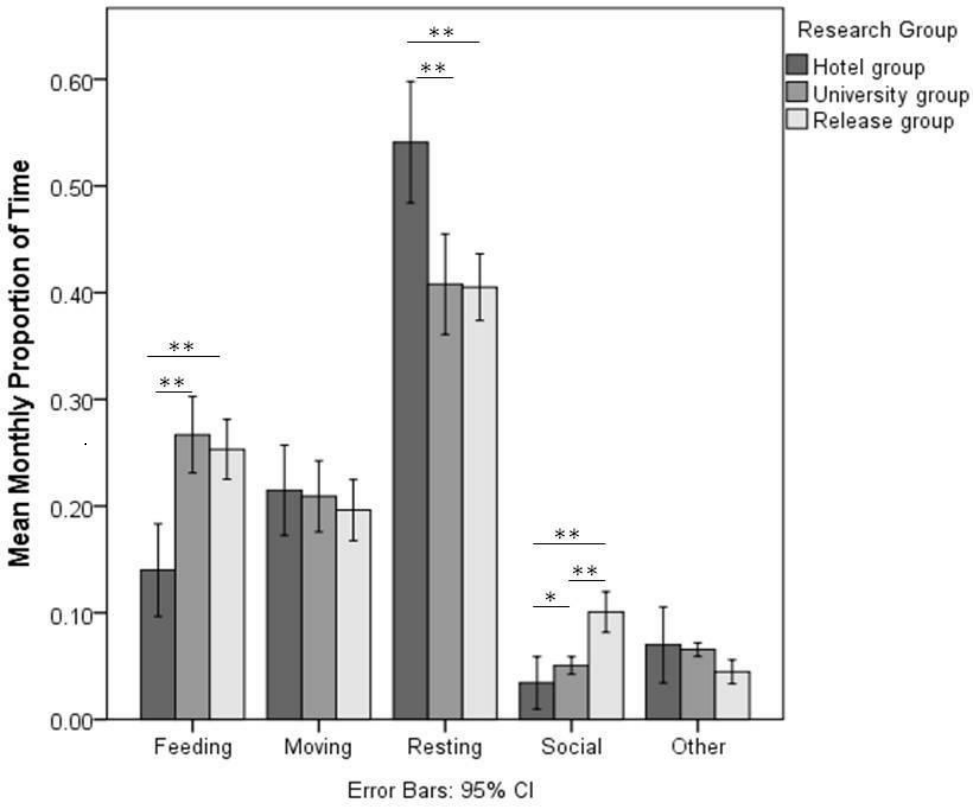


Figure 5.6 Mean monthly activity budget of Hotel, University and Release group. Significant difference were calculated using one-way ANOVA with Tukey tests or Kruskal-Wallis with Mann-Whitney U and are highlighted with *p=<0.05 or **p=<0.01.

5.3.4 Hypothesis 4: Feeding Ecology

Release Group

In the 18 months following release there were significant changes to the consumption of grass, flowers, enclosure food, animal, supplementary and human food in Release group's diet (Table 5.8). Post-hoc Tukey tests indicated that the significant difference for grass consumption occurred between Periods 1 and 3 (p=0.028*); for flower consumption occurred between Period 1 and Period 2 (p=0.043*); and for the consumption of enclosure food occurred between Period 1 and Period 3 (p=0.006**), and Period 2 and Period 3 (p=0.013*). Post-hoc Mann-Whitney U indicated the significant difference for the consumption animal food items occurred between Period 2 and Period 3 (p=0.021*); for supplementary food consumption between Period 1 and Period 3 (p=0.008**), and Period 2 and Period 3 (p=0.008**) and for

human food consumption between Period 1 and Period 3 (p=0.009**), and Period 2 and Period 3 (p=0.03*).

Diet composition

Release group ingested 89 different species throughout the 18 months post-release (n=6671 feeding records). During Period 1 (n=2986), 54 different species were consumed, whilst 42 species in Period 2 (n=2008) and 67 in Period 3 (n=1677) were consumed (see Appendix 2 for a full list of species and plant parts consumed). Dietary diversity was not statistically different across the three post-release periods (One-way ANOVA; $F_{(2,17)}$=0.777, p=0.478), but dietary equitability was ($F_{(2,17)}$=10.031, p=0.002**, Figure 5.7). Tukey tests revealed that the dietary equitability score was different between Period 1 and Period 3 and Period 2 and Period 3 (Period 1: Period 3, p=0.003**, Period 2: Period 3, p=0.02*), but not for Period 1 and Period 2 (Period 1: Period 2, p=0.543).

Table 5.8 Food item consumption of Release group across three post-release periods. Significant differences between groups are highlighted with *p=<0.05 or **p=<0.01.

Food Item	**Period 1**	**Period 2**	**Period 3**	**ANOVA**		
	n=3	**n=3**	**n=12**	F	df	P
Fruit	25.0	14.2	20.8	1.095	2,17	0.360
Leaves	9.4	8.2	9.4	0.064	2,17	0.938
Grass	22.4	20.2	12.3	5.644	2,17	**0.015***
Flower	1.7	9.3	4.3	3.824	2,17	**0.045***
Enclosure	0.6	2.0	15.8	10.093	2,17	**0.002****
Other	5.8	3.8	5.7	0.598	2,17	0.562
				Kruskal-Wallis test		
				x^2	**df**	**P**
Animal	6.5	9.5	4.3	6.404	2	**0.041***
Supplementary	28.0	26.7	1.1	11.614	2	**0.003****
Human	0.0	4.7	15.6	9.968	2	**0.007****
Poultry	0.3	1.4	10.5	4.742	2	0.093

Comparison to Control Groups

Kruskal-Wallis test revealed the consumption of leaves, grass and anthropogenic food items were all significantly different between the three groups (Table 5.9) Post-hoc Mann-Whitney U tests indicate that leaf consumption was significantly different between all three groups, with Release group consuming significantly more than both Hotel and University group (Mann-Whitney U: Hotel: University, Z=--2.487, p=0.013*; Hotel: Release, Z=-2.906, p=0.004**; University: Release, Z=-2.078, p=<0.038*). University group consumed significantly more grass than Release group (Mann-Whitney U; University: Release, Z=-3.291, p=0.001**), but not than Hotel group (Mann-Whitney U; Hotel: University, Z=-1.560, p=0.119), and there was no difference between Hotel and Release groups grass consumption (Hotel: Release, Z=-1.098, p=0.272). Finally, the consumption of anthropogenic food was different between all three groups, with Release group consuming more than Hotel and University (Mann-Whitney U: Hotel: University, Z=-2.025, p=0.043; Hotel: Release, Z=-2.893, p=0.004**; University: Release, Z=-3.291, p=<0.001***) (Figure 5.8).

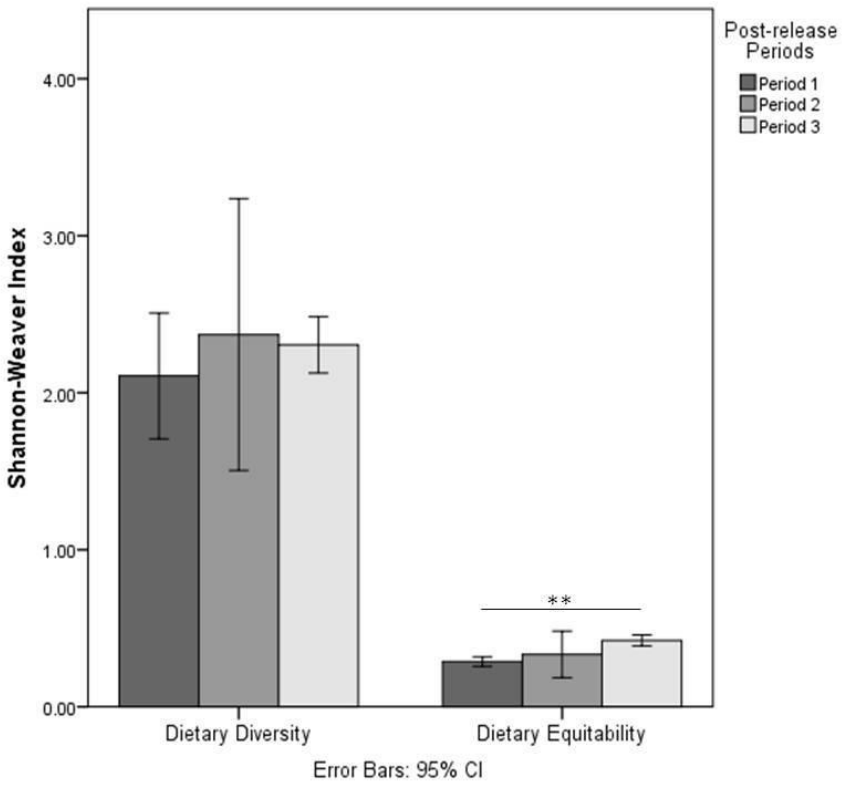


Figure 5.7 Mean monthly Dietary Diversity and Equitability for Release group in three post-release time periods. Significant difference were calculated with one-way ANOVA with Tukey tests and are highlighted with *p=<0.05 or **p=<0.01

Table 5.9 Food item consumption of Hotel, University and Release group. Significant differences between groups are highlighted with *p=<0.05, **p=<0.01 or ***p=<0.001.

Food Item	Hotel	University	Release	Kruskal-Wallis test		
	n=12	n=12	n=12	x^2	Df	P
Fruit	24.6	27.6	20.8	0.959	2	0.6.19
Flowers	10.9	4.5	4.3	0.470	2	0.791
Leaves	6.4	4.8	9.4	11.847	2	**0.003****
Grass	23.8	30.0	12.3	9.687	2	**0.008****
Animal	5.3	6.2	4.3	5.358	2	0.069
Anthropogenic	17.2	24.5	43.1	14.401	2	**0.001*****
Other	11.7	2.4	5.7	4.812	2	0.090

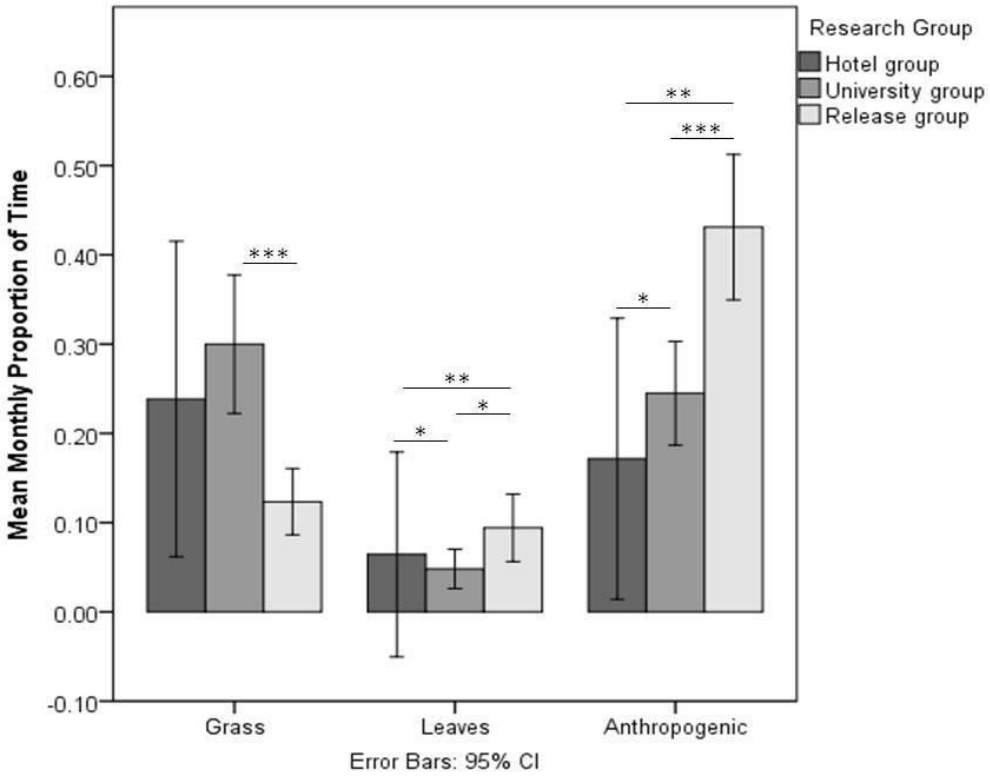


Figure 5.8 Mean monthly food item consumption of Hotel, University and Release group. Significant difference were calculated using Kruskal-Wallis with Mann-Whitney U post-hoc test and highlighted with *p=<0.05, **p=<0.01 or ***p=<0.001

Dietary diversity was significantly different between the three groups (one-way ANOVA, Diversity, $F_{(2,35)}$=35.083, p=<0.001***), but equitability was not (one-way ANOVA, Equitability, $F_{(2,35)}$=0.638 p=0.535. Tukey tests showed that the dietary diversity of each group was different to the others (Hotel: University, p=<0.001***, Hotel: Release, p=<0.001***, University: Release, p=0.021*) (Figure 5.9).

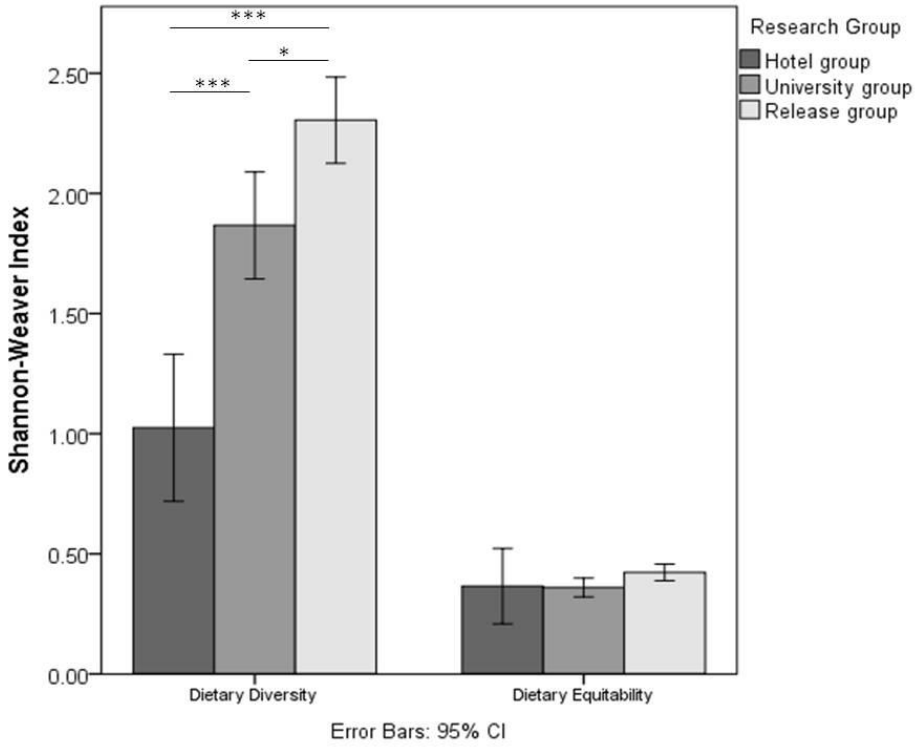


Figure 5.9 Dietary Diversity and Equitability for Hotel, University and Release group. Significant difference were calculated with one-way ANOVA with post-hoc Tukey tests and highlighted with *p=<0.05, **p=<0.01 or ***p=<0.001

Comparing the top five consumed food categories (i.e. plant species, anthropogenic, animal matter) between the three groups revealed many similarities. The top two most consumed items in all three groups was grass and anthropogenic food. A further two categories, animal matter and the plant species, *Azadrachtica indica,* featured in the top 5 of both University and Release group (Table 5.10).

Table 5.10 Top five most consumed food categories for Hotel, University and Release displayed as a percentage of diet.

Group	Category	Type	Status	Primary food item	% in diet
Hotel	Grass	Grass	Mixed	Grass	23.8
	Anthropogenic	-	Artificial	Taken from a person	17.2
	Adansonia digitata	Tree	Indigenous	Flower	9.8
	Ficus benjamina	Tree	Exotic	Fruit	9.1
	Terminalia catappa	Tree	Exotic	Fruit	6.1
University	Grass	Grass	Mixed	Grass	30.0
	Anthropogenic	-	Artificial	From a garbage pile	24.5
	Tamarindus indica	Tree	Indigenous	Seeds	10.9
	Animal matter	-	Indigenous	Insects	6.2
	Azadrachtica indica	Tree	Exotic	Fruit	4.6
Release	Anthropogenic	-	Artificial	From monkey enclosures	43.1
	Grass	Grass	Mixed	Grass	12.3
	Azadrachtica indica	Tree	Exotic	Fruit	8.6
	Animal matter	-	Indigenous	Insects	4.3
	Ficus sycomorus	Tree	Indigenous	Fruit	4.1

Schoener's index revealed a low annual (0.19) and monthly (0.05-0.37) dietary overlap of food categories between the three groups (Figure 5.10). However, when the groups were compared as pairs the annual and monthly dietary overlap increased in all cases, most notably for University and Release group, but remained not significant (<0.6) (Figure 5.11).

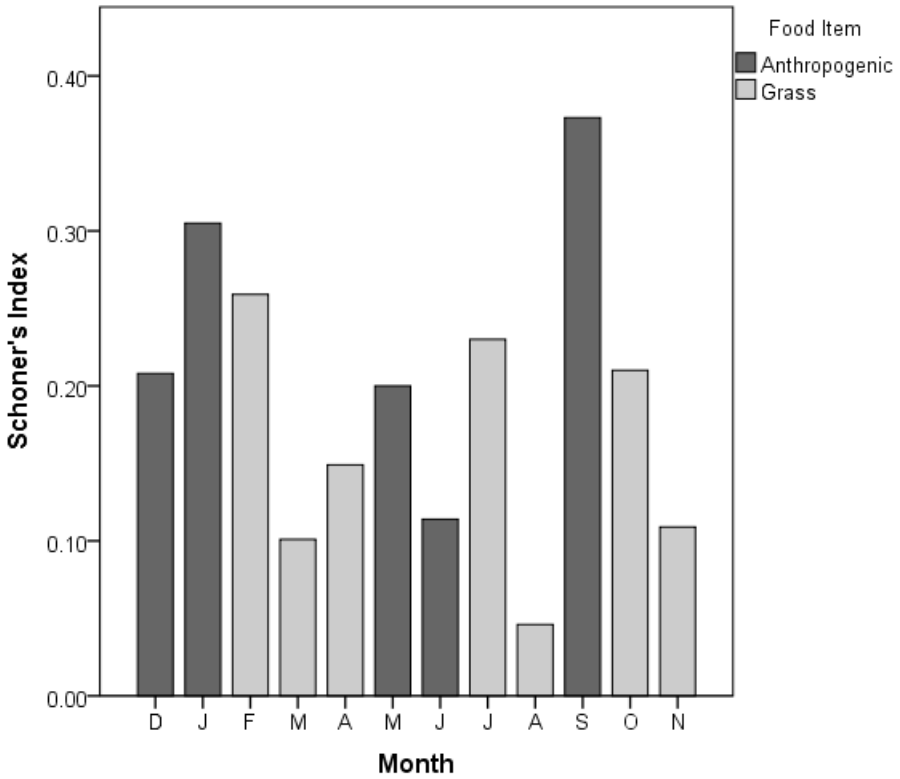


Figure 5.10 Monthly dietary overlap of Hotel, University and Release group. Bar colour indicates the food category that was the highest overlapping category between the three groups each month.

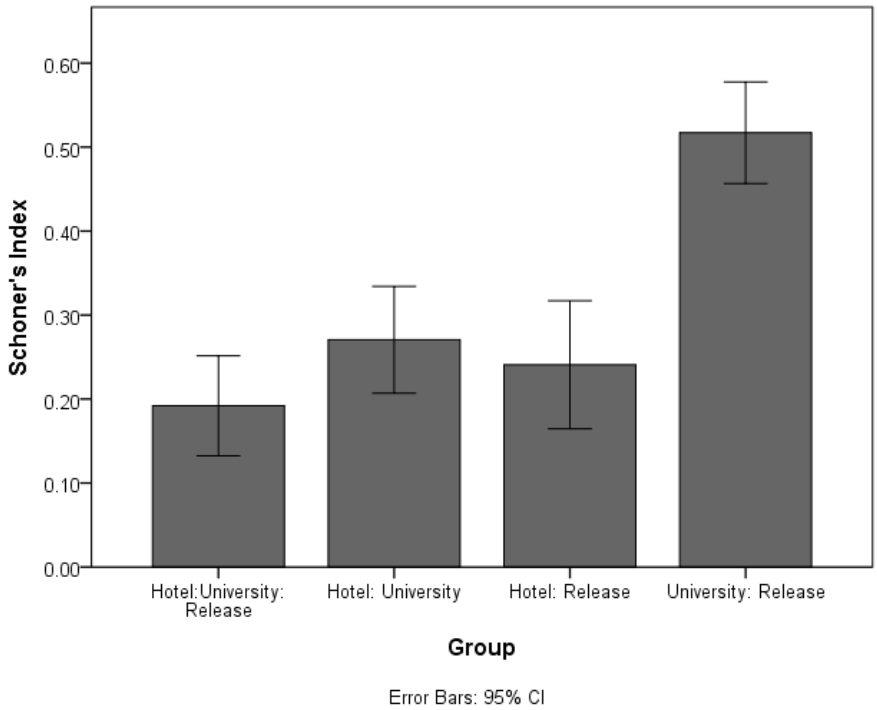


Figure 5.11 Annual dietary overlap of Hotel, University and Release displayed as a group of three and subsequently in pairs.

5.4 Discussion

The rehabilitation and release of wild born orphan, ex-pet and displaced primates is not common and there are many lessons still to be learned. Ideally, suitable methods, improvements and a thorough understanding of these processes should be developed with the use of non-endangered and generalist species before replication using endangered or specialist species (Strum 2005). This release programme was one such opportunity, where the consequences of releasing wild born, rescued and rehabilitated individuals into a novel habitat, in close proximity to wild conspecifics could be investigated. Information on home ranges, activity budgets and feeding ecology, in the months following release, represent a unique perspective that goes beyond the issue of whether the animals survive the release process. In addition long-term observations of indigenous control groups provide information for evaluating post-release performance. Lessons learnt from this release process can be transferred to other semi-terrestrial primates.

5.4.1 Hypothesis 1: Survivorship

Contrary to predictions, survivorship of Release group was not significantly different from that of the control groups. However, because the control groups were not radio collared a number of individuals in University group were recorded as missing, fate unknown. Due to events leading up to the disappearance of these individuals it is suspected that at least four of these individuals were missing due to death, while another two may have emigrated into other areas and groups, there was no indication of the possible outcome of the final two. At one year post-release three individuals had died in Release group, resulting in a one-year post-release survivorship of 75%. Other vervet rehabilitation releases report a 37.5-62% survival at 6 months post-release (Guy 2013; Guy *et al.* 2012) or a 32-50% survival at one year post-release (Guy *et al.* 2011; Wimberger *et al.* 2010b), therefore a one year post-release survival rate of 75% is considered a good outcome (Table 5.11). There are four main differences in protocol between these four vervet rehabilitation releases in South Africa and the one reported on in this chapter. Firstly, post-release monitoring of the Diani vervet group was more intense than for any of the other vervet releases. Wimberger *et al.* (2010) monitored their groups daily for two months post-release, but only half a day per group. In the three releases presented by Guy and Guy *et al*, post-release monitoring is recorded as occurring once or twice daily, for the first few weeks post-release in the 2012 and 2013 studies and for 9 months in the 2011 study. Details of monitoring time are not presented, however, once and twice daily monitoring suggests the groups where not followed from dawn to dusk. The presence of research

Table 5.11 Group composition and survivorship data for published post-release monitoring studies.

Species	Country	Number released	Release group composition compared to wild groups	Survivorship	Reference
Chimpanzee (*Pan troglodytes*)	Congo	37 (over 5 years)	Not analysed but notably different	62-86% (14% dead 24% missing) - 3-8 years post-release	(Goossens *et al.* 2005)
Golden lion tamarin (*Leontopithecus rosalia*)	Brazil	71		38%	(Kleiman *et al.* 1991)
White ruffed lemur (*Varecia variegata variegata*)	Madagascar	13 (in 3 groups)		38%	(Britt *et al.* 2004)
Chimpanzee (*Pan troglodytes*)	Guinea	13	Not analysed but notably different	75% - up to 27 months post-release	(Humle *et al.* 2010)
Vervet monkey (*Chlorocebus aethiops*)	South Africa	29 (in one group)	Significantly different	62% - 6 months post-release	(Guy 2013)
Vervet monkey (*Chlorocebus aethiops*)	South Africa	31 (in one group)	Different	32% - 1 year post-release	(Guy *et al.* 2011)
Vervet monkey (*Chlorocebus aethiops*)	South Africa	16 (in one group)	Not significantly different, but group noted as small for the environment	37.5-56% - 6 months post-release	(Guy *et al.* 2012)
Vervet monkey (*Chlorocebus aethiops*)	South Africa	Group 1 - 35 Group 2 - 24	Different	17% - 1 year post-release 50% - 1 year post-release	(Wimberger *et al.* 2010b)
Western Lowland Gorilla (*Gorilla gorilla gorilla*)	Congo and Gabon	51 (over 10 years)	Not analysed but notably different	98% - 1 year post-release	(King *et al.* 2011)
Vervet monkey (*Chlorocebus aethiops*)	**Kenya**	**12 in one group**	**Not significantly different, but noted that number of adults should be higher**	**75% - 1 year post-release** **42% - 4 years post-release**	**This study**

assistant and/or Colobus Conservation staff members was considered a major influence for reducing the risk of predators and human wildlife interactions throughout the duration of this release, therefore increasing post-release survivorship. Secondly, all studies report on transporting the monkey to their pre-release enclosure and releasing them after 1-4 days. As discussed in Chapter 6, the Release vervets in this thesis did not go through the stress of transportation and was considered an advantage to maintaining cohesion, and therefore increased survival. Thirdly, as predator attacks are a major source of post-release mortality (Baker 2002; Beck *et al.* 1991), the release group detailed in this study received predator and electricity awareness training prior to release and all individuals had to demonstrate appropriate responses to be included within the final release group. The South African releases do not detail what, if any predator awareness training the release groups were subject to. Finally, supplementary feeding in two of the three studies (Guy *et al.* 2011, 2012) was only given for a duration of 5 weeks and is possibly not an adequate amount of time for vervet monkeys to develop their wild foraging skills.

The amount of time an individual had spent in Release group, pre-release, increased their chances of survival post-release. However, neither age nor length of time in the wild pre-capture had an impact on individual survivorship. This indicates that firm group bonds that develop slowly over time are a key factor to post-release survivorship in group living species. Similarly, Humle *et al.* (2010), reported on the benefits of a lengthy rehabilitation in a group setting, in an environment similar to the future release site, for post-release survival of chimpanzees.

After four years of post-release monitoring, 11 wild births had been recorded of which 8 were still surviving. Two of the three deaths were the result of witnessed infanticide attacks from a wild immigrant male who was not a group member at the time of conception, while the third was due to insufficient maternal care from a first-time, inexperienced mother. In all cases the females went on to successfully raise infants. Additionally, by the end of the monitoring period the first pregnancy of the wild born generation was recorded. These numerous births are indicators of energy reserves and reproductive ability, and are therefore directly linked to survival and a measure of successful release (Griffith *et al.* 1989; Kleiman *et al.* 1991; Pinter-Wollman *et al.* 2009). Additionally, infants born in the wild post-release are expected to be better able to cope with the wild than their parents, and their birth is linked to release sustainability (Beck *et al.* 2002). Other releases have detailed successful post-release

reproduction, including orang-utans (Yeager 1997), black and white ruffed lemurs (Britt *et al.* 2004), golden lion tamarins (Stoinski *et al.* 2003), chimpanzees (Goossens *et al.* 2005) and vervet monkeys (Wimberger *et al.* 2010b).

5.4.2 Hypothesis 2: Ranging Behaviour

Against predictions, Release groups day range remained largely constant throughout the post-release period, but as predicted it was representative of the indigenous control groups. The home range size of Release group was very small and contrary to prediction was not representative of the indigenous control groups. Release group home range was limited to the north due to other indigenous populations and to the east due to the ocean. No other vervet group inhabited the areas to the west or south of the release site, both of which were deemed suitable as vervet habitat (section 3.4.1.2) and therefore there was ample scope for home-range expansion. To the west there was a road but the group were recorded crossing this on numerous occasions post-release, and it was not considered a limiting factor. It is likely that access to enclosure and poultry food resulted in Release group not needing to increase their home range as ample anthropogenic food resources were available to them in their immediate surroundings. In contrast to this study, other release programmes report that release groups establish a home range that is representative of the species and habitat type. However, all of these releases occurred in more natural areas and the only anthropogenic food source was that provided as supplementary food during the soft release phase (Table 5.12). Like other wild vervet groups living in close proximity to anthropogenic food sources, the Diani vervet control groups had a smaller home range than groups living in natural environments (section 4.4.1). The availability of additional anthropogenic food sources in the form of enclosure food and poultry food at Release site, that the control groups did not have access to, is the most likely influence on the very small home range size of Release group.

5.4.3 Hypothesis 3: Activity Budgets

Following release the only significant changes in behaviour were to social and other categories, which both increased over time. Social behaviours included all aggressive encounters, mutual grooming, mating and play, while other behaviours included self grooming, scratching, nursing of infants, vocalisations and predator awareness. With the exception of predator awareness all the above behavioural sub-categories remained constant or increased. The increase in both social and other behaviours could be the result of infant births within the group. Infant births attract attention within vervet groups and behaviours such as grooming and play have been recorded to increase (Henzi 2001; Muroyama 1994). An increase in social behaviour related to births of infants indicates that post-release births enhance social bonding within the group,

Table 5.12 Details of ranging, activity budget and food consumption data for published post-release monitoring studies in comparison to wild conspecifics. DJL, day journey length.

Species	Country	Study length	Group size	Behaviour recorded within the range reported for wild groups				Reference
				DJL	Home range size	Activity budget	Food consumption	
Chimpanzee (*Pan troglodytes)*	Guinea	27 months	13	Yes	Yes - for habitat type and sex variations			(Humle *et al.* 2010)
Vervet monkey (*Chlorocebus aethiops*)	South Africa	1 year	31		No - much larger than average (7km^2)	Noted to exhibit a range of natural behaviours		(Guy *et al.* 2011)
Vervet monkey (*Chlorocebus aethiops*)	South Africa	6 months	16		Yes - larger than average, but within an expected range	Noted to exhibit a range of natural behaviours	Noted to consume a range of natural food items and species	(Guy *et al.* 2012)
Vervet monkey (*Chlorocebus aethiops*)	South Africa	1 year	1 - 35 2 - 24		Yes - small than similar size groups in the same area but within an expected range	Noted to exhibit a range of natural behaviours	Noted to consume a range of natural food items and species	(Wimberger *et al.* 2010b)
Chimpanzee (*Pan troglodytes)*	Congo	3-8 years	37 (over 5 years)			Generally reflective, but groomed significantly less than wild groups	Broadly yes, with a fruit dominated diet, but consumed a smaller number of species.	(Farmer *et al.* 2006)
White ruffed lemur (*Varecia variegata variegata*)	Madagascar		13				Significant dietary overlap at plant family level	(Britt and Iambana 2003)
Vervet monkey (*Chlorocebus aethiops*)	**Kenya**	**18 months**		**Yes**	**No, much smaller than expected**	**Yes, with the exception of social behaviour**	**Broadly yes, but differences in anthropogenic food consumption and low dietary overlap**	**This study**

making the group more likely to remain cohesive. This means that post-release births may contribute to translocation success in more ways than increasing numbers and new generations. Wimberger *et al.* (2010) considered the presences of a new infant in a post-release vervet group to contribute to group cohesion. In contrast the behaviour categories, feeding and resting, that were predicted to change over time post-release, remained more constant. The prediction was based on the reduction of supplementary food and Release group having to increase their feeding activity budget in order to meet their nutritional requirements. However, due to access to enclosure and poultry food, one food resource was simply replaced by another equally calorific source and no significant increase in feeding was recorded.

As predicted, Release group engaged in activity budgets that were representative, of the general trends of the control groups. Their activity budget more closely resembled University groups activity budget than Hotel groups. Only one major discrepancy between Release group and both control groups was observed: Release group spent significantly more time in social activity. The significance is unclear but it may relate to the groups first exposure to infants being born into the group, which was a novel experience post-release as discussed above. Due to the artificial environment in which Release group was formed they did not experience the arrival of a new infant born to a group member until after they were released. The inclusion of sub-adults within the analysis of Release group, who are known to engage in play behaviour more frequently than adults, may also have contributed to the higher than expected occurrence of social behaviours as only adults were included for control groups.

5.4.4 Hypothesis 4: Feeding Ecology

Contrary to predictions, the proportion of natural food in the diet of Release group did not increase over time following release. Rather as the provisioned supplementary food decreased, human and enclosure food portion of the diet increased. During the same time period that consumption of enclosure food increased there was also an increase in its availability. Directly post-release few monkeys remained captive in the nursery or pre-release enclosures and therefore the availability of enclosure food was low. Over time as monkeys were admitted to Colobus Conservation and orphaned individuals were hand reared, the number of individuals within the enclosures increased and in turn so did the availability of enclosure foods. This increased availability of a major anthropogenic food sources was likely responsible for there not being an increase in natural food consumption over time.

As predicted Release group's diet was broadly representative of the diet of the control groups. There was no significant difference in the consumption of four out of the seven food items recorded, with anthropogenic food, grass and fruit being the most consumed foods items in all groups. However, while the same seven items were consumed by all three groups, there were significant differences in the consumption of three of these categories. The relatively low consumption of grass by Release group may, in part, reflect variation in abundance of these food sources within the home ranges of the group (Chapter 3). Release group had access to additional anthropogenic food sources that Hotel and University group did not; enclosure food and poultry food. While every effort was made to limit the access Release group had to these food sources they were able to target enclosure food left-overs that dropped through the enclosure floors and by raiding during cleaning periods. Additionally, poultry food was scattered on the ground and human guarding only lasted while the poultry ate, any left-overs were then freely available for the release monkeys. Furthermore, the captive monkeys were observed food sharing with the released monkeys on numerous occasions. The ability of Release group to exploit this resource was in part a failing in the management of the release site, and access to enclosure food could have been reduced with enclosure modifications and more stringent cleaning protocols. Reducing access to poultry food could have been targeted through more robust education of the neighbouring residential properties. Neither of these food sources had been predicted pre-release, and the policy to adapt and intervene in cases where an unfavoured outcome arose should have been implemented more forcefully, with stronger deterrent measures applied. The human derived food portion of the anthropogenic food category for Release group was only 15.6% of the diet in Period 3 and lower than both Hotel and University group (Table 5.9). Indicating that access to human food was more adequately managed through secure garbage areas and frequent collection, due to this being a predicted food item and careful planning pre-release to limit access.

Dietary overlap between the three groups was remarkably low, with only eight overlapping food categories. This highlights the variation in plant species between the ranges of the three vervet groups. Contrary to predictions, based on the fact that Hotel site had a higher habitat overlap with Release site, than either did with University site, the highest dietary overlap occurred between University and Release group. The low dietary diversity of Hotel group appeared to be a limiting factor in the dietary overlap of the groups. Release group consumed a larger variety of plant species than either Hotel or University groups, despite their habitat being less species diverse. This may be due to exploration and learning what plant species are

edible and favoured within their new novel environment. The reverse of this was reported by Britt and Iambana (2003) who recorded a significant dietary overlap between release groups and wild counterparts, with the release groups consuming a lower variety of plant species (Table 5.12). Similarly, reintroduced chimpanzees in Congo consumed a smaller number of plant species than expected from wild studies (Farmer *et al.* 2006). It is possible that the highly flexible and generalist nature of vervet monkeys contributed to this higher than expected diversity in plant species consumption. Additionally, details of wild food exposure prior to release are not outlined by Farmer *et al.* (2006), and it is therefore possible that the vervet group had more experience in wild food selection than the chimpanzees due to their pre-release exposure.

Despite Release group individuals having been removed from the wild at an ecologically naive age, the pre-release environment provided adequate social and individual learning opportunities about potential foods. It could be argued that without access to additional anthropogenic food sources Release group would not have been able to survive the release process, and because of it Release group were not really wild or independent of human care. It is my opinion that without access to this additional food source, Release group would have been forced to increase their home range in order to locate sufficient nutrients to sustain the group. Data presented in Chapter 3 indicated that with a larger home range the release site did provide sufficient food resource to support Release group. Combined with their consumption of a high variety of plant species it appears that that Release group had the skills, and opportunity to survive without this additional enclosure food source.

5.5 Conclusion

The post-release monitoring of this rehabilitation release was not long enough to measure if Release group were self sustaining and therefore translocation success on the basis of the IUCN guidelines could not be assessed. With the first wild born infant in the group recorded as pregnant at the end of this study there is strong evidence to suggest they will become self sustaining. However, the individual success indicator of this project was outlined as Release group displaying behaviours that were representative of the indigenous populations. Measured against verifiable indicators Release group displayed survival rates, day journey lengths, activity budgets and a general feeding ecology that fell within the excepted ranges set by the control groups and therefore was deemed successful. However, it should not be expected that a release group will display an exact replication of indigenous group behaviour

because a release group is adapting to a novel environment (Farmer *et al.* 2006). The consumption of enclosure and poultry food that Release group were able to exploit, and which in turn likely affected home range size was a failing of this release process. The results demonstrate that wild-born orphaned, ex-pet and/or displaced vervet monkeys can be rehabilitated and released into the wild successfully, making the project successful from a welfare perspective. Success of this release can be attributed to careful planning and detailed intensive post-release monitoring, including medical intervention.

Chapter 6 Social Network Analysis: Understanding Group Cohesion and Individual Centrality in Pre- and Post-release Vervet Monkeys (*Chlorocebus pygerythrus hilgerti*)

Abstract

Group cohesion is an integral part of many layers of primate society including, anti predator strategies and sociality, and is thus critical for successful release of any group-living species. However, numerous primate translocation studies have reported a partial or complete breakdown in social structure of groups in the days, weeks and months following release. This study evaluates levels of cohesion of an artificially-formed, genetically unrelated release group of vervet monkeys, pre- and post-release. Cohesion of the release group was compared to two naturally forming wild vervet groups, inhabiting the same environment, using social network analysis. Both pre- and post-release, Release group displayed higher levels of cohesion than the control groups. Cohesion of Release group changed over time following release, with peaks in cohesion influenced by the birth of infants and troughs related to immigration of wild males. Centrality scores revealed that adult females were key group members and an individual's centrality score significantly increased with the length of time they were in the group pre-release. Resilience analysis determined that Release group was extremely stable as the theoretical removal of central individuals did not cause fragmentation or a significant reduction in cohesion. This outcome was tentatively attributed to early-life and life-long associations between group members building kin-ship like bonds, coupled with a lack of pre-release transportation which often disrupts social bonds and therefore retention of group cohesion immediately pre-release, resulting in fragmentation of groups post-release.

6.1 Introduction

Translocation can cause disruption to social bonds, increasing the chance of individuals scattering, or group fragmentation, soon after release, making individuals vulnerable to predation and compromising success rates (Aguilar-Cucurachi *et al.* 2010; Kawai 1960; Richard-Hansen *et al.* 2000; Stanley-Price 1989; Vandenburg 1967). Various factors have been suggested to account for the disruption of social bonds of released groups following

translocation. Firstly, stress of the entire process upon the individuals being released may result in social conflict and disorganization (Aguilar-Cucurachi *et al.* 2010; Richard-Hansen *et al.* 2000). Secondly, newly released individuals are in a novel and unknown environment, they do not have spatial references for finding food or re-connecting with their group and a temporary foraging subgroup fission could result in a permanent estrangement of former group members (Richard-Hansen *et al.* 2000). In addition released individuals may be subject to interactions with unfamiliar wild individuals, as home ranges and territories are established (Richard-Hansen *et al.* 2000) and finally an absence of kin-based relationships in groups that have been artificially formed (Kawai 1960; Vandenburg 1967).

Only a small number of the limited primate translocation studies discuss group cohesion post-release. Examples of social disruption following release in artificially-formed groups, include a group of wild caught Japanese macaques that split into two groups four days post-release, likely contributing to the death of many members of the smaller group, and the dominant male of both groups (Kawai 1960). Kawai (1960), concluded that the group split was due to inadequate integration and group structure, combined with numerous hierarchical disputes and 'grievances' within the larger group. Vandenbergh (1976) reported on four artificially-formed groups of wild caught rhesus monkeys released on to islands off the coast of Puerto Rico. Of the four groups only portions of two groups remained together post-release. An absence of kinship ties between individuals was deemed the major reason for lasting instability (Vandenburg 1967). More recently, 12 chimpanzees released in Haut Niger National Park, Republic of Guinea, split into units of lone individuals or pairs during the first month post-release despite being housed together for at least 7 years pre-release. Numerous attempts to reunite individuals were made over a one year period but at 27 months post-release only five individuals remained together (Humle *et al.* 2010). In another study, 32 chimpanzees were released in a series of small groups into Conkouati-Douli National Park by HELP Congo, over a five year period. Despite efforts to reintroduce cohesive groups, across these releases a total of six individuals fled immediately upon release; the remaining individuals stayed within the release zone, but their level of cohesion is not reported (Ancrenaz 2001; Goossens *et al.* 2005). In KwaZulu-Natal, South Africa, a group of 31 rescued and rehabilitated vervet monkeys were released and subsequently split into two groups within the first week of release, remaining in a state of fission-fusion for the entire 12 month post-release monitoring period (Guy *et al.* 2011). Another South African vervet rehabilitation release study saw two groups released 1.2km apart: one group split immediately upon release with one third of the group reported as

missing, while the second group remained intact (Wimberger *et al.* 2010b). Wimberger *et al* (2010) concluded that the group remaining intact may have been more cohesive due to the presence of an infant.

Wild born, translocated primate groups containing genetically related individuals also display social disruption upon release, suggesting that a lack of family ties and wild experience are not the only contributing factors to reduced group cohesion post-release. During the translocation of 28 naturally formed wild red howler monkey groups in French Guiana, 10 of the 11 groups that were monitored post-release split within four months and there was a general loss of integrity of social units even if they were caught and moved as intact social groups (Richard-Hansen *et al.* 2000). An immediate breakdown in group structure also occurred among translocated wild groups of mantled howlers in Costa Rica (De Vries 1991). Finally, a smaller proportion (4 out of 14) of black howler groups translocated from the Community Baboon Sanctuary to the Coxcomb Basin Wildlife Sanctuary in Belize split up days after release (Emmons *et al.* 1996; Horwich *et al.* 1993) however, the remaining 10 groups were considered cohesive units.

Conversely, fragmentation and dispersal do not always occur upon release following translocation. A group of rehabilitated vervet monkeys released into the Ntendeka Wilderness Area of South Africa were considered generally cohesive post-release, however, certain group members repeatedly separated from the main group for up to two days at a time (Guy *et al.* 2012). Likewise, during the reintroduction of 51 gorillas in 7 groups over 10 years in to Bateke Plateau in Congo and Gabon, only one individual dispersed from its release group in the first two years post-release (King *et al.* 2011). Of these 7 groups the cohesion of one was analysed in detail, and while the group was considered cohesive for the 10 month post-release study period their cohesion did reduce following the death of one highly social individual (Le Flohic *et al.* 2015). This study highlights that cohesion success can be reliant upon specific individuals. A translocation project of two groups of pygmy marmosets in the Brazilian Amazon resulted in both groups remaining almost fully unchanged when monitoring cessed 5 months post-release, with just one individual missing from 8 weeks post-release (Dias *et al.* 2015). Finally, while social disruption following translocation was reported in the Golden lion tamarin project, the effects were temporary and stable groups emerged soon afterwards (Kierulff *et al.* 2012).

Le Flohic *et al* (2015) presented data on post-release cohesion using play and proximity data to calculate proportion of time (density) individuals were associated or interacting and their eigenvector centrality scores over three time periods of ecological significance. Cohesion discussed in all other post-release groups is presented in a purely descriptive manner based on whether the individuals within the groups remaining in the same location, or not. Without quantitative measures, levels of cohesion are at the interpretation of the author. Social network analysis is a powerful tool that is used to describe and quantify relationship patterns, connections and social complexity at individual, group or species level (Borgatti *et al.* 2013; MacDonald and Voelkl 2015; Wey *et al.* 2008). It has provided new insights regarding the social structure of numerous animal species (Croft *et al.* 2004; Lusseau 2003, 2007; Manno 2008) and is becoming increasingly popular in the study of animal behaviour to address topics including sociality (Lusseau 2003), resilience analysis - the effect of theoretical or experimental removal of key individuals upon group cohesion (Bret *et al.* 2013; Flack *et al.* 2006; Lusseau 2003; Manno 2008), group cohesion (Bret *et al.* 2013; Le Flohic *et al.* 2015; Reffay and Chanier 2003), social learning (Coelho 2015; Kendal *et al.* 2010; Kendal *et al.* 2015), infant survival (Silk *et al.* 2003), relationships (Borgeaud *et al.* 2016; Henzi *et al.* 2009), social dynamics (Coelho 2015) and entire social systems (Kasper and Voelkl 2009).

6.1.2 Social Network Analysis: Describing Group Cohesion

Social network analysis can be divided into three broad levels of analysis, group level, subgroup or intermediate level and individual level (MacDonald and Voelkl 2015; Wey *et al.* 2008), of which group and individual level are most relevant to this study. For reference Table 6.1 contains definitions for social network analysis terms used in these descriptions.

Group Level

Group level analysis is the most common network analysis in primatology and is used to either compare the properties of different groups, or the properties of the same group over time (MacDonald and Voelkl 2015). At a group level, network measures can describe the overall structure and possible stability, vulnerability or cohesion of a group (Wey *et al.* 2008). Importantly, they go beyond simple measures of group size or composition, portraying the relationships between group members (Wey *et al.* 2008). Cohesion describes how well a group is connected and can be based on several network metrics. The simplest measure of cohesion is density. ***Density*** is the number of ties between individuals that are present, divided by the total number of possible ties in the network, regardless of the strength of the ties (thus treating all networks as unweighted). Since density is a relative measure, adjusting for the

Table 6.1 Summary of Social Network Analysis terms (based on Borgatti *et al.* 2013 and Wey *et al.* 2008)

Network term	Definition
Node	A component of a network with known relationship to others, this is normally an individual (person or animal) but can be a group. Also called vertex or point.
Tie	A relationship between two nodes of a network, these can be any social relationship. Also called edge or link. Ties can be weighted or unweighted and/or directed or undirected.
Dyad	A pair of nodes that are connected by a tie.
Unweighted	All ties have a value of 1, reflecting presence of a relationship between two nodes and absence of a relationship is denoted by 0.
Weighted	Ties reflect the strength of the relationship and can have different values.
Non-directed	Ties simply show that two nodes are connected.
Directed	There can be potential inequality in the relationship, and A-B may not be the same as B-A.

number of nodes in a network, it is comparable across groups of different sizes (Borgatti *et al.* 2013). A group with higher density has a greater proportion of ties between dyads than a group with lower density and is therefore, theoretically more cohesive (Wey *et al.* 2008). Another measure of cohesion is ***component ratio***, which enables detection of the extent to which a group consists of a single component, smaller components or isolated nodes (individuals). In a single component all group members are connected to one another directly or indirectly whereas, if the network contains several components then group members belonging to different component were never seen associating or interacting with group members of another component. Consequentially, component ratio informs us if the network is fragmented into several components or part of a simple unit. ***Connectedness*** is a more sensitive version of component ratio which measures the proportion of pairs of nodes that can reach each other by a path (of connected individuals) of any length i.e. the proportion of pairs of nodes that are located in the same component. Connectedness is typically used to evaluate changes to a network either in reality or as part of 'what-if?' simulation (Borgatti *et al.* 2013) and is applied to the same group over time. ***Reciprocity*** is a measure which reflects how many of the relationships are mutually maintained. ***Transitivity*** is the friend of a friend concept; if A has a relationship with B, and B has a relationship with C, then A has a relationship with C as

well. Reciprocity and transitivity together reveal how well balanced relationships are. For example, two groups could have the same density, but one could have higher reciprocity, indicating that the interactions are more balanced overall. With affiliative relationships, greater cohesion, reciprocity and transitivity might suggest a more tightly knit social group, in which positive interactions are consistent among triads and are mutual (Wey *et al.* 2008).

Individual Level

Individual level social network analysis is used to describe an individual's position within a social group by calculating its interactions with the group as a whole. The individual measure can reflect relationships with those directly connected to the focal individual, as well as individuals indirectly connected to the focal individual, and describes the potential effect a specific individual has upon (and receives from) others within the network. Understanding the influence an individual, or sub-set of individual i.e. adult females, have up on the group is important to this study to enable informed decisions to be made on future release group selection. This can be done using a single network metric such as one of the following centrality measures (Borgatti *et al.* 2013). ***Degree centrality*** is the simplest measure of centrality and is based on the number of direct ties an animal has, i.e. the more individuals with which an animal has relationships, the more central it is. ***Eigenvector centrality*** is a variation of degree centrality in which the number of nodes connected to a focal node are not only counted but also weighed by the nodes centrality. Eigenvector centrality can be interpreted as a "measure of popularity in the sense that a node with a high eigenvector centrality is connected to nodes that are themselves well connected. This means that a node with a low degree centrality score could have a higher eigenvector centrality score than a node with a high centrality degree, if the first node's friends are very popular while the second node's friends are not" (Borgatti *et al.* 2013). ***Betweenness centrality*** is a measure of how often a given node falls along the shortest path between two other nodes. Betweenness therefore indicates how important an animal is as a point of social connection. Animals with high betweenness centrality are likely to be important for group stability, and their removal (by death or dispersal) may fragment the group into smaller subgroups (Flack *et al.* 2006; Lusseau and Newman 2004).

The social structure of vervet monkeys is typically multi-male, multi-female groups of 20-30 individuals, there is a linear dominance hierarchy among males, and a kinship relationship among females (Cheney and Seyfarth 1990). Males emigrate as they near maturity, while females stay in the family group and take their place in the female bonded society wherein the

mother's rank predetermines the daughter's. Remaining within their natal group means that females form life long bonds with their kin (Cheney and Seyfarth 1990). Recent network analysis of three wild vervet groups in Kwazulu Natal, South Africa supports the theory that demographic variation of females and juveniles have higher centrality scores than males, and therefore are more influential to the stability with of the group (Borgeaud *et al.* 2016). This research highlights that group social structure and the levels of group cohesion required to survive life in the wild is strongly connected to kin relationships and life-long bonds in vervet monkeys. In turn this raises doubt that artificially created groups, consisting entirely of unrelated individuals will be able to create and sustain a level of cohesion required for survival post-release. Furthermore, pinpointing key individuals existing in social groups, and their role in group cohesion has recently been investigated (Bret *et al.* 2013; Lusseau 2007; Sueur *et al.* 2012), by analysing the impact on group cohesion when these key individuals are removed either experimentally (Flack *et al.* 2005; Manno 2008) or theoretically (Bret *et al.* 2013; Lusseau 2003). Similar theoretical experiments, on group cohesion, can be used to evaluate whether individuals brought together for translocation have bonded into a stable social unit that will stay intact upon release.

The goals of this study were to investigate whether an artificially constructed group of genetically unrelated vervet monkeys, gradually formed from rescued and rehabilitated individuals, display species appropriate levels of in-group associations that result in the individuals being part of a cohesive group. This will be achieved through social network and statistical analysis of long term observation data of one group of rehabilitated vervet monkeys pre- and post-release compared to baseline data from two naturally occurring wild control groups of vervet monkeys inhabiting the same anthropogenically modified environment as the release site. Hypothesis 1 and 2 assess whether group cohesion is instrumental in release success, while hypothesis 3 and 4 assess release group dynamic recommendations and inform future selection processes for individuals to fit with tracking devices. For reference Table 6.2 contains definitions and interpretation of social network analysis metrics used in the analysis.

Hypothesis 1: Release group cohesion will differ from wild control groups.

I predicted that, during the pre-release monitoring phases and while still in captivity, the release group will present a higher level of cohesion than the wild groups, due to the confinement of captivity. In contrast, from immediately post-release, I predict that Release group, comprised of non-genetically related individuals, will have a lower level of cohesion

than that observed in the kin-related wild control groups. Levels of group cohesion were assessed using a combination of measures that were comparable across groups of different sizes and containing different individuals (nodes). These were degree, component ratio, reciprocity, and transitivity. Metrics for the control groups were compared to Release group to assess expected, and actual, levels of group cohesion within a comparable habitat type.

Hypothesis 2: Release group cohesion will reduce following release.

I predicted that due to the confinement of captivity enforcing proximity, providing predator protection and the provision of food promoting social activities Release group will have a higher level of cohesion pre-release than post-release. Following release and overtime, Release group will experience reduced cohesion and increased fragmentation. Levels of group cohesion were assessed using a combination of measures that enable comparison of the same group overtime. These were degree, component ratio, reciprocity, transitivity and connectedness. Comparisons of cohesion measures within Release group were analysed over six time periods, both pre- and post-release to evaluate the impact of the release process on group cohesion.

Hypothesis 3: Certain individuals will be key to group cohesion during pre- and post-release phases.

Based on published data of group cohesion of wild vervet groups (Borgeaud *et al.* 2016), I predict that adult females will have higher centrality than other age and sex classes and that this trend will be present both pre- and post-release. Comparisons of individual centrality within Release group were measured pre- and post-release using eigenvector and betweenness centrality.

Hypothesis 4: Theoretical removal of central individuals will demonstrate a negative impact on post-release cohesion.

I predict that the theoretical removal of highly central will result in reduced levels of cohesion across the whole release group. Based on the prediction that adult females will have higher centrality I also predict that the removal of central females will be more detrimental to group cohesion than the removal of central males. Resilience analysis will be performed by theoretically simulating the removal of individuals displaying the highest eigenvector and betweenness centrality values. Levels of group cohesion were calculated as outlined in hypothesis 2 for each theoretical removal and then compared to the original network.

6.2 Methods

6.2.1 Study Site

The study site was Diani Beach and Galu area (4°15'30", 4°35'30"S and 39°35'00", 39°34'30"E) of Kwale County, South Coast, Kenya. The local climate is classified as tropical humid, with long rains from April – July and short rains October – December with an annual rainfall of 900-1500mm (Jaetzold and Schmidt 1983). This area is part of the Coastal Forests of East Africa global biodiversity hotspot and was once one of the most diverse areas of forest along the Kenya coast with a rich coral rag flora (Robertson and Luke 1993). However, as an unprotected forest area that occurs on sub-divided privately owned land, the formerly continuous forest has been cleared and fragmented, so that a mosaic of small patches, in various degrees of intactness, now remains. The study area lies at 0-150m asl and is located on fossilised coral covered in a thin layer of soil. The study was conducted from December 2011 to November 2013. For a more comprehensive description of the study site see Chapter 3.

6.2.2.Study Groups

Control Groups

Two habituated groups of vervet monkeys were observed over a 24 month period, December 2011 - November 2013. Both groups occupied areas under considerable human disturbance in the form of private residents, hotels with their associated grounds and staff housing but were also adjacent to relatively undisturbed patches of forest. Hotel group ranged in size from 18-27 individuals, with 1-3 adult males and 5-7 adult females, while University group ranged in size from 19-25 individuals, with 3-5 adult males and 4-6 adult females. More detailed group size fluctuations and composition for both groups are displayed in Table 4.1 (Chapter 4). Both groups were habituated to 5–30m proximity of observers and all individuals were identified by their natural markings (e.g. sizes, coat colour, facial features) and physical abnormalities (e.g. scars, damaged limbs, digits and tails).

Release Group

Release group was observed over a 20 month research period, March 2012 - November 2013. The release group were monitored in their pre-release enclosure from March - May 2012. The 27th May 2012 marked the day of release and the group were then monitored for 18 months post-release. Release group fluctuated in size from 11 to 15 individuals over this period, with an overall total of 17 individuals recorded. The original release group contained 12 individuals, of which 8 remained constant for the entirety of the study. In the 20-month research period three individuals were born in to the group, two wild males immigrated into the group and five

individuals died (four original group members and one immigrated wild male). The group size was small compared to naturally forming wild groups in other study locations (Chapter 4, Table 4.13), but was representative of naturally forming wild group sizes in the Diani location, which average 12.2 individuals (section 2.3.2.1). All individuals present in Release group were considered focal subjects resulting in fluctuations in sample size across research periods.

6.2.3 Data Collection

Behavioural Data Collection

The behavioural data used in this chapter was collected using instantaneous focal sampling (Altmann 1974) of adult, sub-adult and juvenile individuals. Instantaneous sampling was conducted at one minute intervals for a 20 minute period, aiming to conduct two 20 minute samples per hour during each research period. Thus, for each of the 20 time points, the behaviour of the focal individual was recorded along with the identity of any individual(s) in contact with the focal individual. For a more comprehensive description of the methods used see Section 2.4.3.

Proximity Data Collection

The proximity data used in this chapter was collected using scan sampling (Altmann 1974) of adult, sub-adult and juvenile individuals. Scan sampling was conducted at 10 minute intervals in conjunction with the focal follow. At minutes 0, 10 and 20 of the focal follow a scan sample of all visible group members was conducted and recorded all individuals that were in contact, $\leq$1 meter, >1$\leq$3m, >3$\leq$5 m and >5 meters from the focal animal.

Control Groups

Data collection consisted of three consecutive research periods per week per group (Day 1: midday - dusk; Day 2: dawn – dusk; Day 3: dawn – midday), over a 24 month research period (December 2011 - November 2013). This totalled 106 half day and 83 full day research periods for Hotel group and 145 half day and 86 full day research periods for University group.

Release Group

Prior to release, data was collected on the group in their in-situ pre-release enclosure for a two month period and consisted of five research periods per week, alternating between dawn - midday and midday - dusk. Data collection was actively avoided during cleaning periods as the group was generally divided into smaller enclosure sections during this time, an act that influenced individuals' proximity to other group members. In the 3 month period immediately post-release the group was monitored daily from dawn till dusk; over time this intensity

reduced in half-day increments until by 15 months post-release the group was being monitored on average only one full day per week. This totalled 40 half day research periods pre-release and 133 half day and 180 full day research periods post-release.

Social Networks

The decision of which social networks are meaningful descriptors of the social context depicting cohesion is an important one. Here I opt to study instances of socio-positive relationships; social proximity (within 3 meters), grooming, and social contact. Specifically, up to three networks were generated, each one as a representation of gradually increasing levels of tolerance between group members. Social proximity (within 3 meters) was analysed for Release group only. A change in group cohesion over time was expected in Release group and thus a more detailed analysis of this group was conducted for within group comparison than in comparison to the control groups. Social proximity (within 3 meters) is a measure that does not require direct physical contact and is therefore inclusive of all individuals in the group. During focal follows grooming was recorded if two or more individuals engaged in grooming activity and social contact was recorded if two or more individuals were in direct contact and touch was not required for the primary behaviour recorded i.e. grooming, mating, nursing. All individuals involved in the socio-positive behaviour were recorded individually in addition to the focal individual. In the case of grooming, directionality (i.e., who groomed who) was also recorded. During proximity scans all individuals observed within a 3 meter radius of the focal individual were recorded. Grooming in primates is used to maintain social bonds (Lehmann *et al.* 2007), while social contact indicates high levels of tolerance between individuals, as such both measures are good indicators of group cohesion.

6.2.4 Social Network Analysis

The frequency of pair-wise interactions of social proximity (within 3 meters), grooming, and social contact were coded into matrices and analysed at group and individual levels. Table 6.2 provides a summary of the chosen social network measures and interpretation of values produced. UCINET version 6 (Borgatti *et al.* 2002) procedures were used to calculate all metrics (Borgatti *et al.* 2013) for social proximity, grooming and social contact data. These were then visualised as a network, in which nodes represent individuals and edges, the connections between nodes, represent social interactions, using NetDraw - Network Visualisation Software (Borgatti 2002). Weighted networks were constructed for all relationships, in which the edge strength (or thickness) characterises the frequency of interactions between two individuals (Borgatti *et al.* 2013; Lusseau *et al.* 2008). Grooming networks were also visualised as directed weighted networks (Borgatti *et al.* 2013).

Table 6.2 Summary of Social Network Analysis measures applied (based on Borgatti *et al.* 2013 and Wey *et al.* 2008)

Network Measure	Definition	Interpretation of value
Density	Proportion of connections (edges) present relative to the total number of possible connections (edges) between nodes. A measure of the network's cohesion.	Varies in values between 0.0 when no nodes are connected to 1.0 when all nodes are connected to all other nodes. The higher the value the more cohesive the network.
Component ratio	A cohesion measure that takes in to account that a network may be fragmented into components (interconnected individuals) and isolates individuals.	Varies in value between 1.0 when every individual is in isolation and 0.0 when all individuals are part of a single component. An inverse measure where the lower the value the more cohesive the network is. In order for component ratio to be on the same scale as the other measures in use it will be subtracted from 1, meaning the new score will read from 0.0 - 1.0, with 1 representing a single component.
Reciprocity	The proportion of ties that are reciprocated between individuals.	Values range from 0.0 when no ties are reciprocated to 1.0 when all ties are reciprocated. Greater reciprocity with greater transitivity suggests a tighter knit group.
Transitivity	The density of transitive triples is the number of triples which are transitive divided by the number of triples which have the potential to be transitive.	Values vary from 0.0 when no ties are transitive to 1.0 when all ties are transitive. Greater transitivity with greater reciprocity suggests a tighter knit group.
Connectedness	The proportion of pairs of nodes that can reach each other by a path of any length.	Varies in values between 0.0 to 1.0 The higher the value the more connected the network.
Eigenvector centrality	An individual's centrality is proportional to the sum of centralities of the individuals it is adjacent to. An individual is only as central as its network and eigenvector scores cannot be compared between groups with different nodes.	Higher scores indicate that actors are "more central" to the main pattern of distances among all of the actors, lower values indicate that actors are more peripheral.
Betweenness centrality	The number of shortest paths between pairs of individuals that pass through the individual in question	A score of zero indicates the individual is never along the shortest path between two other. The maximum value is reached when the individual fall along every shortest path between every pair of other.

Time Frames

The control groups were both naturally formed, wild groups living in a stable environment. As discussed in Chapter 4, the Diani vervet groups were not significantly influenced by environment factors in terms of their behaviour or ranging patterns and there was no clear breeding season. As such seasonal or annual variations were unlikely to strongly influence group cohesion. Each control group as a whole will have experienced births, deaths, emigrations and immigrations and has remained stable. With this in mind group level analysis was conducted on both the Hotel and University group for the entire 24 month data set to calculate a single result for each group, for each social network metric. This resulted in a mean sample size of 62 (8-142) focal follows per individual for Hotel group and 103 (13-189) focal followers per individual for University group. In contrast Release group experienced the stress of release which has been documented to disrupt social bonds (Aguilar-Cucurachi *et al.* 2010; Richard-Hansen *et al.* 2000; Stanley-Price 1989) and many of the life history events mentioned above were experienced for the first time. It was predicted that these events and the subsequent adjustments will impact upon group cohesion. As such, Release group social network analysis was conducted at six distinct time periods to allow for investigation of changes over time. Due to the large sample size in the first 6 months post-release it was necessary to divide this period into three, 2 month periods to ensure the sample size allowed for comparisons to other research periods (see Table 6.3 for focal follow sample size and Table 6.4 for proximity scan sample size). Periods 1-4, were all two months in duration and detail the groups' social network from two months pre release while still in the enclosure (Period 1) to six months post-release (Periods 2-4). Periods 5 and 6 were both six months in duration, focusing on the time 7-12 months and 13-18 months post-release. Due to limitations of analysing and comparing proximity data of a captive, and subsequent release group, the proximity data collected during Period 1 has not been included in this analysis.

6.2.5 Statistical Analysis

The analysed data includes all individuals of both sexes in the adult, sub-adult and juvenile age categories. Infants were excluded from the data for two reasons, firstly they attracted high levels of attention, skewing the networks. Secondly infant mortality in the wild control groups appeared to reduce group cohesion as the infants were present for only short periods of time and came in to contact with a limited number group members.

Table 6.3 Focal sample size, per individual, per research period. Codes used M - male, F - female, A - adult, SA - sub-adult, J - juvenile, I - infant, IM - immigrant whom joined the group post-release, R - original release group member, WB - wild born infant, born into the group post-release. Due to the length of the study some individuals changed age categories as detailed in the age column. * individual was not recorded with the group for the entirety of the research period. †period when individual changed age category

ID	Sex	Age	Origin	Pre-release	Post-release				
				Period 1 2 months	Period 2 Month 1-2	Period 3 Month 3-4	Period 4 Month 5-6	Period 5 Month 7-12	Period 6 Month 13-18
AL	M	A	IM	N/A	N/A	N/A	N/A	38*	35*
BA	M	SA→A	R	22	125	78	77	109	53†
BR	F	I→J	WB	N/A	N/A	N/A	56	112	46†
DI	F	SA→A	R	22	128	83	74	98	36†*
EM	F	J→SA	R	22	127	79†	77	111	53
EY	M	SA→A	R	23	127	86	72	111	30†*
FA	F	A	R	22	130	83	70	103	55
FF	M	A	IM	N/A	N/A	5*	51	95	44*
FI	M	I	WB	N/A	N/A	N/A	N/A	N/A	1*
HJ	M	A	R	22	126	83	72	30*	N/A
HO	F	J→SA	R	21	129	82	71	102†	50
KI	F	I	WB	N/A	N/A	N/A	N/A	85*	44
KT	F	A	R	22	130	84	71	107	44
ML	F	J	R	22	128	83	73	91*	N/A
MM	M	I	R	20	12*	N/A	N/A	N/A	N/A
RA	F	J→SA	R	22	128	81	74	105	46†
ST	M	SA→A	R	20	126	82	73	104	53†
Average				22	118	76	70	93	45

Table 6.4 Proximity scan sample size, per individual, per research period. Codes used M - male, F - female, A - adult, SA - sub-adult, J - juvenile, I - infant, IM - immigrant whom joined the group post-release, R - original release group member, WB - wild born infant, born into the group post-release. Due to the length of the study some individuals changed age categories as detailed in the age column. * individual was not recorded with the group for the entirety of the research period. †period when individual changed age category

ID	Sex	Age	Origin	Post-release				
				Period 2 Month 1-2	Period 3 Month 3-4	Period 4 Month 5-6	Period 5 Month 7-12	Period 6 Month 13-18
AL	M	A	IM	N/A	N/A	N/A	21*	27*
BA	M	SA→A	R	363	112	219	114	44†
BR	F	I→J	WB	N/A	N/A	169	107	43†
DI	F	SA→A	R	350	98	214	92	19†*
EM	F	J→SA	R	358	113†	218	104	44
EY	M	SA→A	R	356	118	218	109	54†*
FA	F	A	R	350	112	185	105	46
FF	M	A	IM	N/A	23*	160	85	24*
FI	M	I	WB	N/A	N/A	N/A	N/A	2*
HJ	M	A	R	341	106	204	72*	N/A
HO	F	J→SA	R	340	111	208	91†	33
KI	F	I	WB	N/A	N/A	N/A	28*	30
KT	F	A	R	352	114	221	102	32
ML	F	J	R	354	112	194	64*	N/A
MM	M	I	R	36*	N/A	N/A	N/A	N/A
RA	F	J→SA	R	342	104	215	94	39†
ST	M	SA→A	R	344	112	200	104	47†
Average				324	95	202	86	36

6.2.6 Hypothesis 1: Group Cohesion: Release Group Compared to Control Groups

Two group level measures were calculated for the social contact networks, density and component ratio, while four group level measures were calculated for the grooming networks, density, component ratio, reciprocity and transitivity. The objective was to characterise the social relationships between group members and thus the level of group cohesion. Comparisons were made between the control groups and Release group across the six release periods to assess whether Release group displayed a level of cohesion that would be expected in a naturally wild population based on direct contact behaviours. Such descriptive network measures can be used to compare interactions in one group relative to another, even if group size or the sampling period differs between the groups provided the relationship information is collected and calculated in a similar manner (Sueur *et al.* 2011).

6.2.7 Hypothesis 2: Group Cohesion: Release Group Pre- and Post-Release

The methods outlined in 6.2.6 were replicated for hypothesis 2, using direct contact behaviours, in addition to social proximity (within 3 meters). Three group level measures were calculated for the social contact and social proximity (within 3 meters) networks, density, component ratio and connectedness, while five group level measures were calculated for the grooming networks, density, component ratio, connectedness, reciprocity and transitivity. Comparisons were made within the Release group by comparing the results across the six release time periods. Trends in cohesion measures for the three networks across the six time frames were investigated using Page's L trend test (Page 1963). This tests for a hypothesised ordered trend (in this case a decreasing trend across the time periods) in the means of a number of different treatments (in this case, cohesion measures).

6.2.8 Hypothesis 3: Central Individuals

Eigenvector and betweenness centralities are the most appropriate centrality measures for this study, as they reflect the connectivity and social centrality of individuals in networks (Jacobs and Petit 2011). The grooming networks were graphed to visualise the changes of centrality over time. To test whether individuals with high centrality pre-release remained high post-release a Friedman's two way analysis of variance by rank was applied. Eigenvector, and betweenness centrality were correlated with length of time in the group pre-release using Spearman's rank correlation coefficient. Differences in the centrality measures for age and sex categories were investigated using a Kruskal-Wallis test with post-hoc Mann-Whitney U tests.

6.2.9 Hypothesis 4: Resilience Analysis

To investigate the role of central individuals on the stability of the networks and therefore group cohesion, resilience analysis was performed by simulating the removal of individuals. Using techniques described by Lasseau (2003), the removal of individuals with the highest eigenvector and betweenness centrality values and individuals deemed influential to group cohesion (targeted condition) were analysed. This method evaluates the importance of central individuals on group cohesion and may indicate different outcomes of the release program had these central individuals died early in the release process.

The theoretical networks developed were tested through the investigation of changes in the grooming network cohesion measures applied in hypothesis 2. A single mean post-release value for each measure was calculated from the five post-release time periods for each individual removed. Differences in the cohesion measures for the networks between the actual release group and those with individuals removed were investigated using Friedman's two way analysis of variance by rank. Kruskal-Wallis

6.3 Results

6.3.1 Social Proximity, Grooming and Social Contact Networks

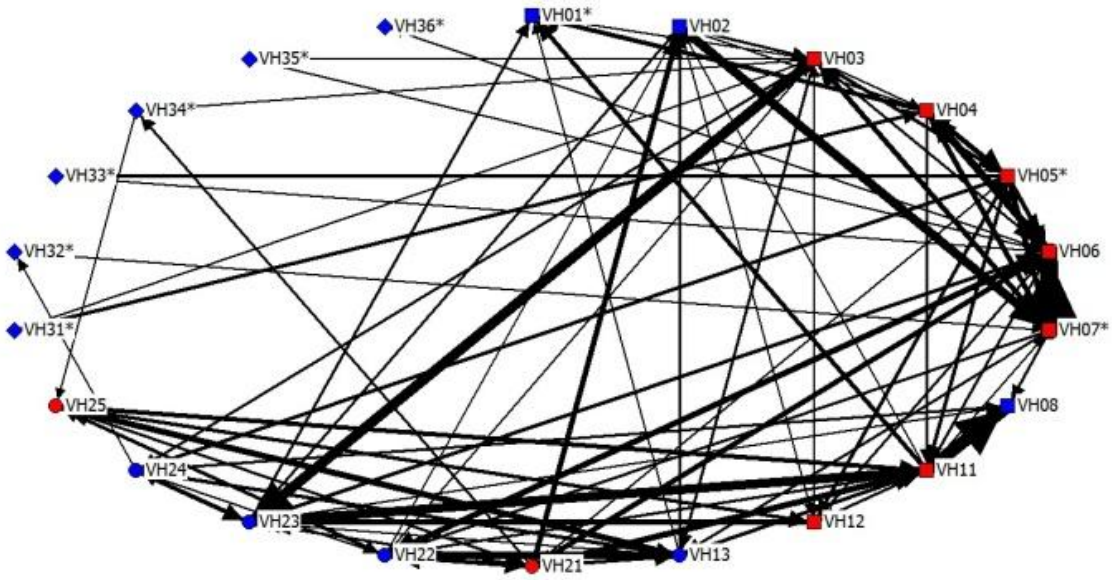
Social proximity (within 3 meters) was analysed for Release group and a total of 11,007 events were recorded for Release group (N_{P2} = 5640, N_{P3} = 1151, N_{P4} = 2261, N_{P5} = 1072, N_{P6} = 883). A total of 441 grooming events were recorded for Hotel group, 1605 for University group and 3,978 for Release group (N_{P1} = 414, N_{P2} = 657, N_{P3} = 620, N_{P4} = 813, N_{P5} = 999, N_{P6} = 475). While a total of 96 social contact events were recorded for Hotel group, 208 for University group and 1,533 for Release group (N_{P1} = 184, N_{P2} = 393, N_{P3} = 284, N_{P4} = 502, N_{P5} = 489, N_{P6} = 97). All three groups displayed a higher frequency of grooming events than social contact events across all time periods sampled and social contact was most frequently recorded in conjunction with resting or feeding behaviours. Due to the small sample size of social contact events in the control groups and because the general trends observed for cohesion measures were broadly the same as for the grooming network, social contact networks are not presented. Additionally, as a directed network more measures can be applied to the grooming networks than the social contact networks. In instances where social contact networks reveal a different trend than those of grooming networks these differences are highlighted. Social contact network results are displayed in Appendix 3.

6.3.2 Hypothesis 1: Group Cohesion: Release Group Compared to Control Groups

Grooming networks presented a density of 0.22 and 0.40 of all possible connections for Hotel and University group respectively (Figure 6.1). Release groups' grooming density was higher than both control groups across time periods 1-5 with 0.48-0.54 of all possible connections recorded. During period 6, Release groups grooming network recorded the lowest density of 0.39, which remained higher than Hotel group, but was slightly lower than University group. The inverse component ratio for the control groups were 0.9 for Hotel group and 1 for University, these figures represent a cohesive network with 1 meaning the group interact as one component with no isolates. Release groups component ratio ranged between 0.91-1. Across all groups the grooming networks consisted mostly of single components with occasional isolated individuals indicating the group members formed a single cohesive group. Reciprocity for the Hotel group was 0.34, and 0.45 for the University group. This indicates that 34% and 45% of all recorded ties are reciprocated or mutual. Release group produced higher scores for reciprocity across all time periods and ranged from 0.48 - 0.71. Finally, transitivity values were 0.35 and 0.55 for the Hotel and University group respectively, indicating that 35% and 55% of individuals were ' friends with their friends, friends'. Following the same trend as density Release group exhibited higher rates of transitivity than the control groups in time periods 1-5 with scores of 0.59-0.64. However, in time period 6 transitivity measure fell to 0.47 which is almost mid way between the results produced by the control groups (Figure 6.1 and 6.2). Frequency of grooming increased towards individuals in certain periods, for example both adult females FA and KT had increased grooming intensity in periods 4 and 5 respectively, largely from other females. Within each of these periods the respective adult gave birth to their first infants and is a likely reason for increased grooming activity (Henzi 2001; Muroyama 1994). Social contact produced similar results for the measures it was tested for; density and component ratio, with Release group displaying higher figures than the control groups. For the control groups social contact networks produced fewer connections than those recorded in the grooming network, but for Release group the social contact network produced more connections than the grooming network (Appendix 3).

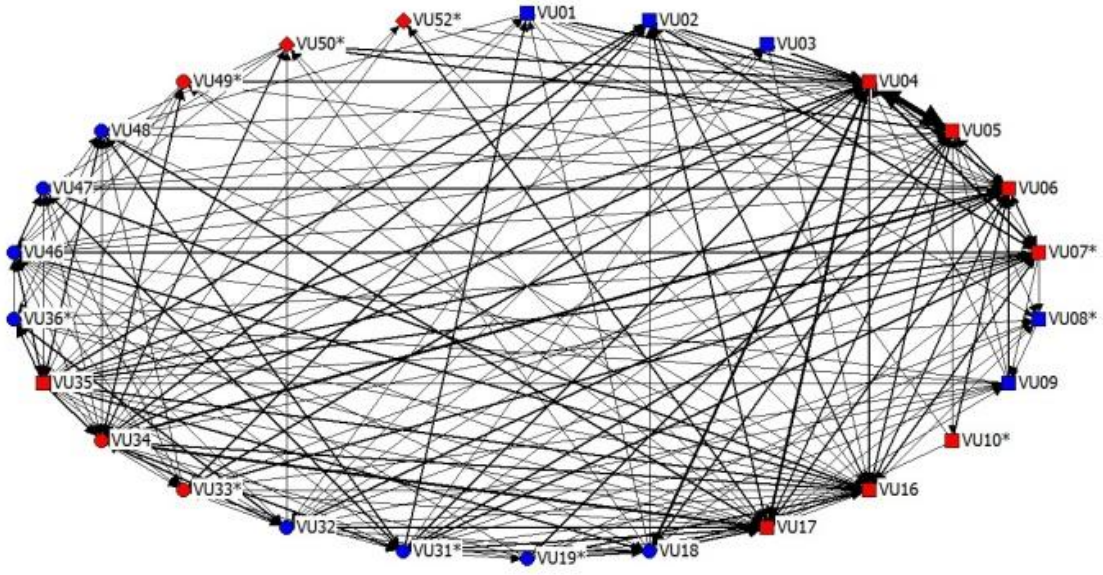
Grooming Networks

Hotel Group - 22 nodes



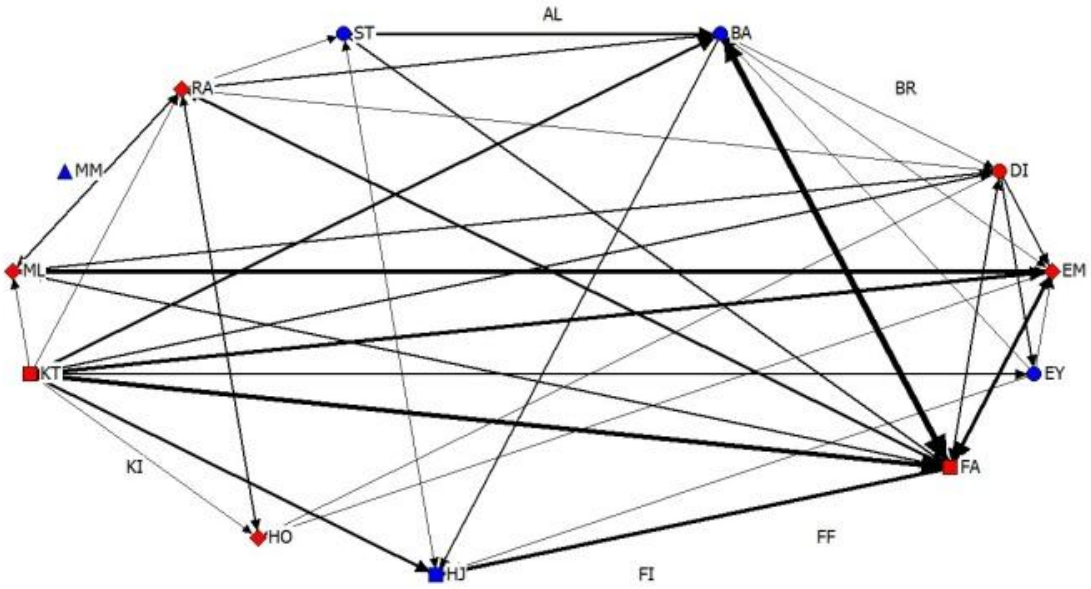
N=441, Density=0.22, Component ratio=0.90, Reciprocity=0.34, Transitivity=0.35

University Group - 26 nodes



N=1605, Density=0.40, Component ratio=1, Reciprocity=0.45, Transitivity=0.55

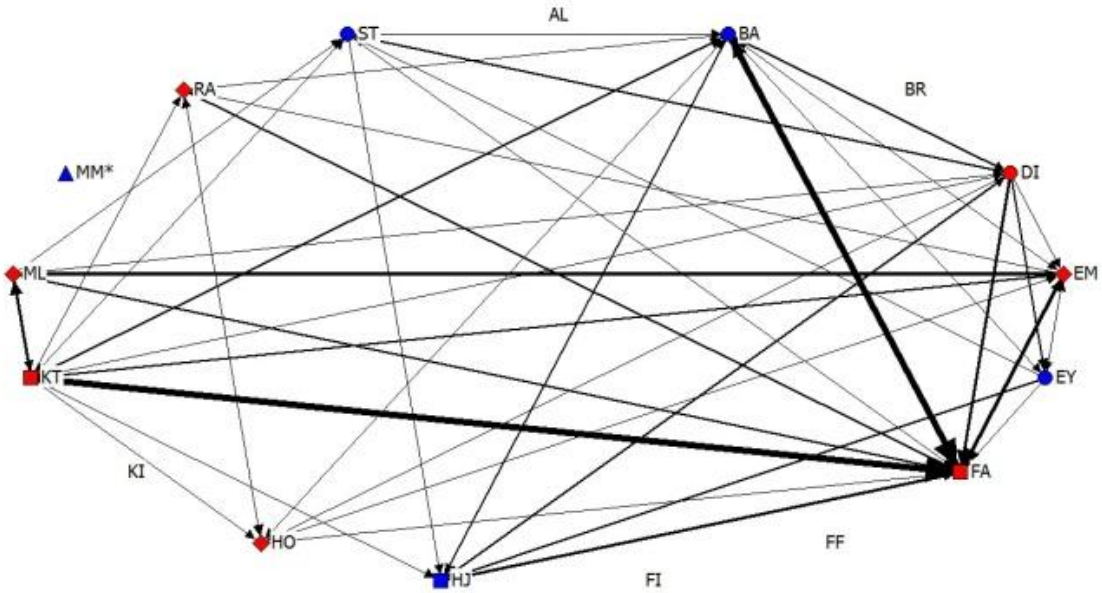
Release Group - Period 1: 11 Nodes



N=414, Density=0.48, Component ratio=1,

Reciprocity=0.51, Transitivity=0.59, Connectedness=1

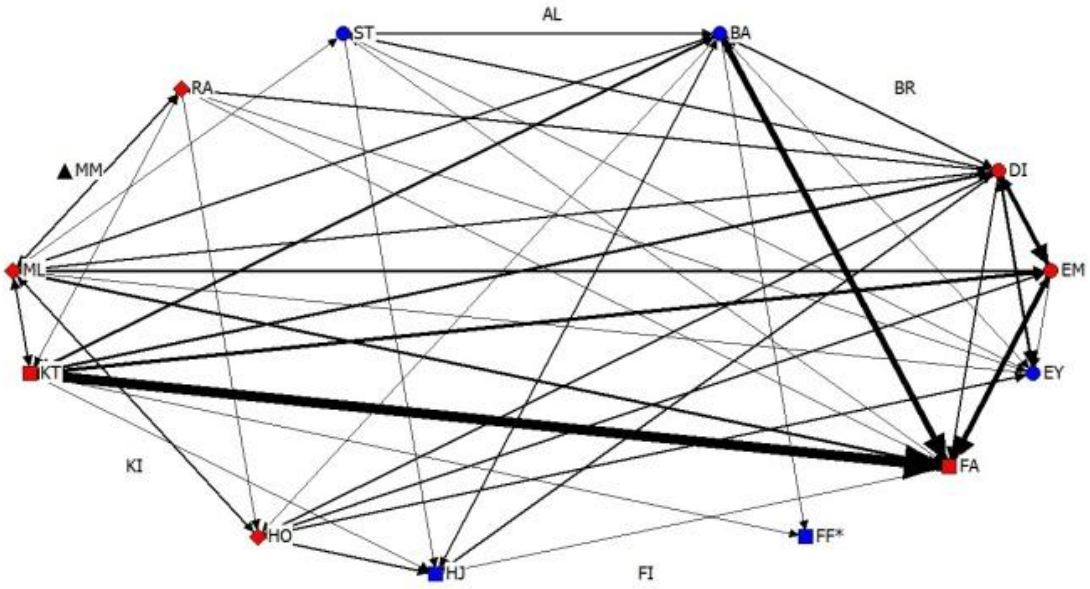
Release Group - Period 2: 11 Nodes



N=657, Density=0.54, Component ratio=1,

Reciprocity=0.48, Transitivity=0.62, Connectedness=1

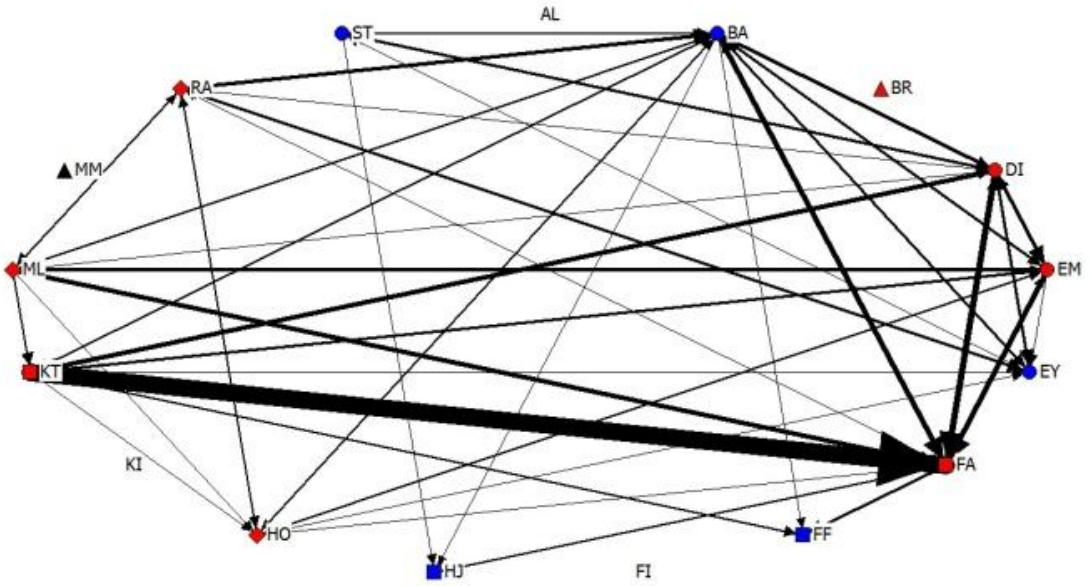
Release Group - Period 3: 12 Nodes



N=620, Density=0.48, Component ratio=0.91,

Reciprocity=0.5, Transitivity=0.57, Connectedness=0.92

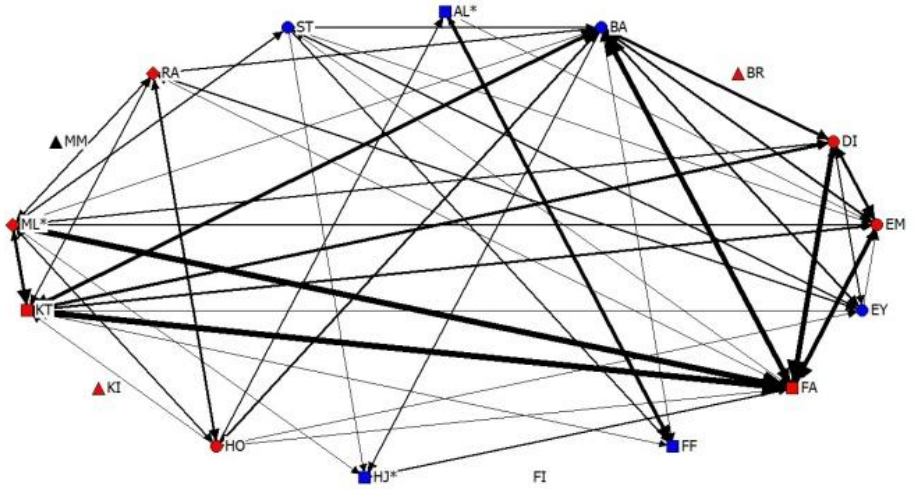
Release Group - Period 4: 12 Nodes



N=813, Density=0.51, Component ratio=0.91,

Reciprocity=0.68, Transitivity=0.64, Connectedness=0.92

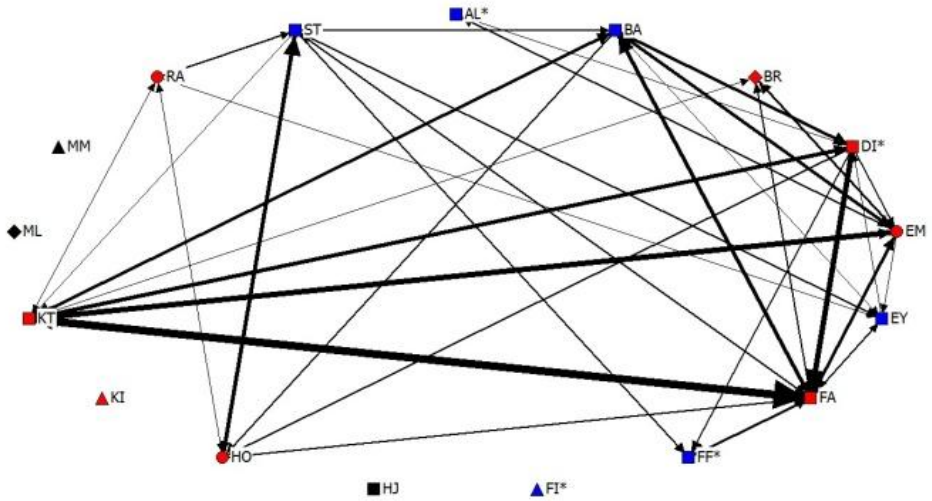
Release Group - Period 5: 13 Nodes



N=999, Density=0.49, Component ratio=1,

Reciprocity=0.71, Transitivity=0.63, Connectedness=1

Release Group - Period 6: 12 Nodes



N=475, Density=0.39, Component ratio=1,

Reciprocity=0.53, Transitivity=0.47, Connectedness=1

Figure 6.1 Graph representation of grooming events recorded in the control groups for the entire 24 month research period and Release group across six time periods defined within the 20 months research period. Nodes coloured blue indicate males, red indicates females and black indicate individuals that died. Square nodes represent adults, circle nodes represent sub-adults, diamonds represent juveniles, triangles represent infants* and the absences of a shape indicate individuals that had not yet joined the group. Thickness of edge represents the strength of association. * infants are not analysed in the data set and included in the graphs for representative purposes only

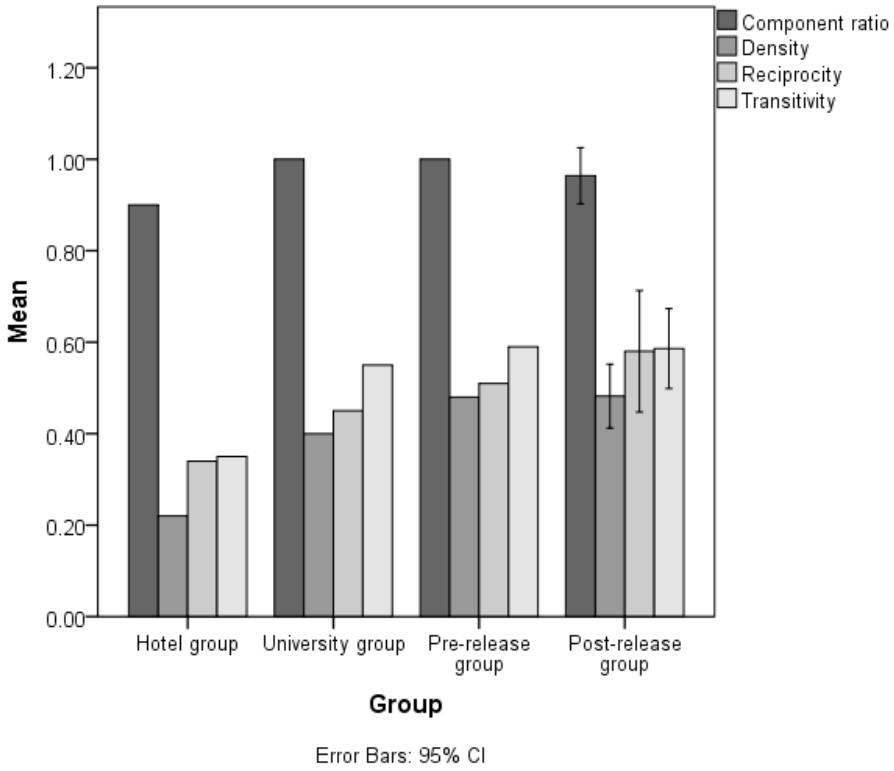


Figure 6.2 Social Network results for Hotel, University and Release group for grooming networks. Release group results are divided between pre- and post-release, with the post-release figures showing the mean value of the 5 time periods.

6.3.3 Hypothesis 2:Group Cohesion: Release Group Pre- and Post-Release

Density, component ratio, transitivity and connectedness all revealed broadly similar results across the time periods. In Period 1 the group exhibited relatively high results, with a peak in measures during period 2, directly post-release. The value of measures then decreased in to period 3, with peaks recorded again in period 4 and/or 5. Over the remaining time periods, the measures began to decline to levels more representative of the wild groups. Reciprocity, however, displayed an immediate decline following release in period 2, followed by a rapid increase and a peak in value in periods 4 and 5. It then follows a similar decline into period 6 as the other measures (Figure 6.3).

Page's L trend test for a hypothesised decreasing trend across the time periods, in the means of a number of cohesion measures was not significant (Page's trend test: $L(5,6) = 363$, $p>0.05$).

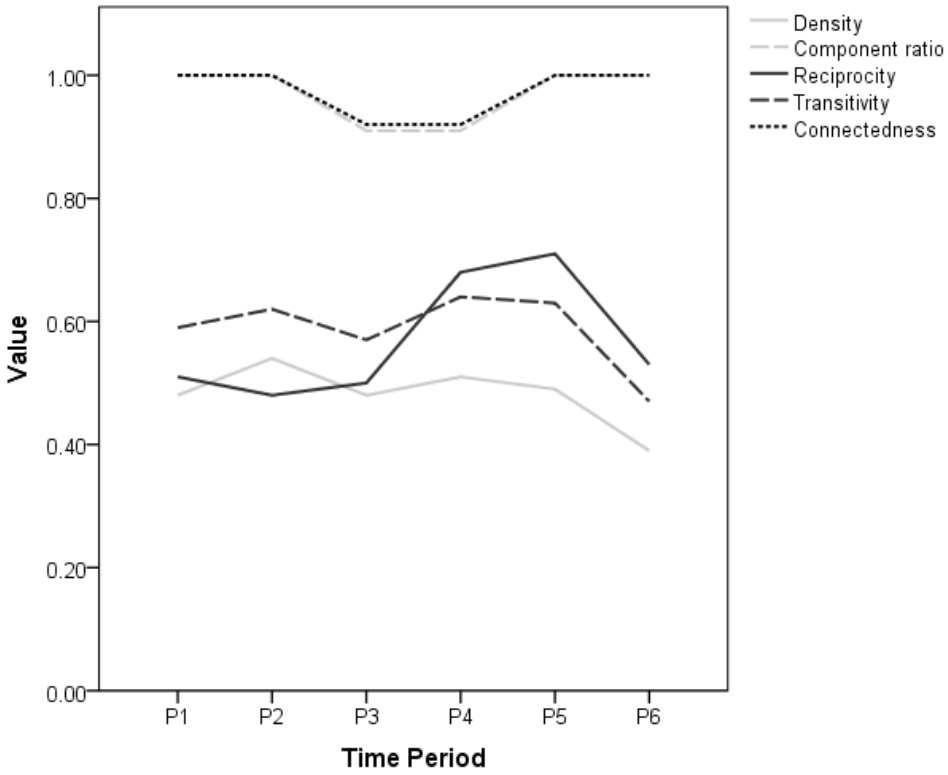


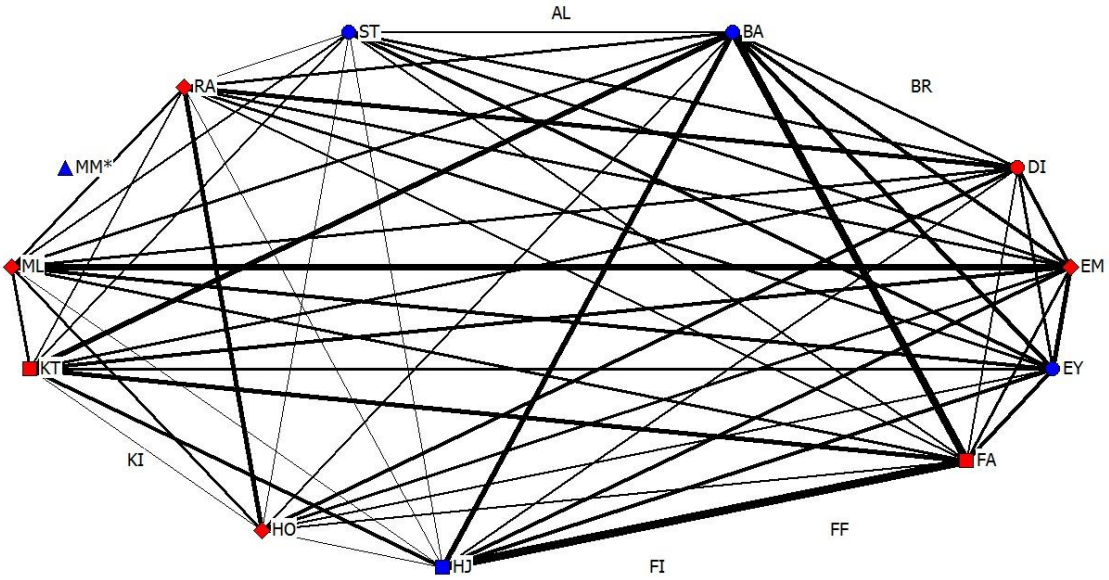
Figure 6.3 Representation of density, component ratio, reciprocity, transitivity and connectedness for the grooming network of the release group over six time periods.

Networks for social proximity (within 3 meters) presented a density of 0.84 and 1 of all possible connections for Release group across time periods 2-6 (Figure 6.4), which is substantially higher than either the grooming or social contact networks. Variations in density relate to scan sample size and in periods with lower sample sizes the density of the network is also reduced. However, period 6 has the lowest sample but does not record the lowest density value, which was recorded in period 5. This shows that Release group was more cohesive during period 6 than period 5. Despite this variation in density both the inverse component ratio and connectedness values remained constant at 1 across all five post-release time periods. These figures represent a completely cohesive network, with 1 meaning the group interact as one component with all individuals fully embedded into the group, throughout the whole 18 month post-release monitoring period.

Page's L trend test for a hypothesised decreasing trend, across the time periods, in the means of a number of cohesion measures was not significant (Page's trend test: $L(3,5) = 140$, $p>0.05$).

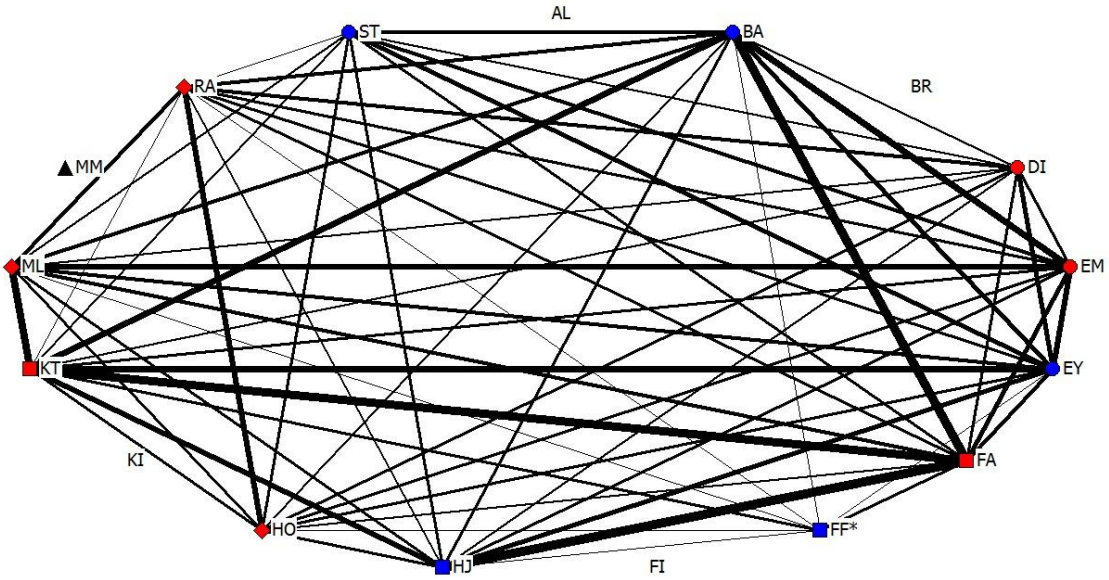
Social Proximity (within 3 meters) Network

Release Group - Period 2: 11 Nodes



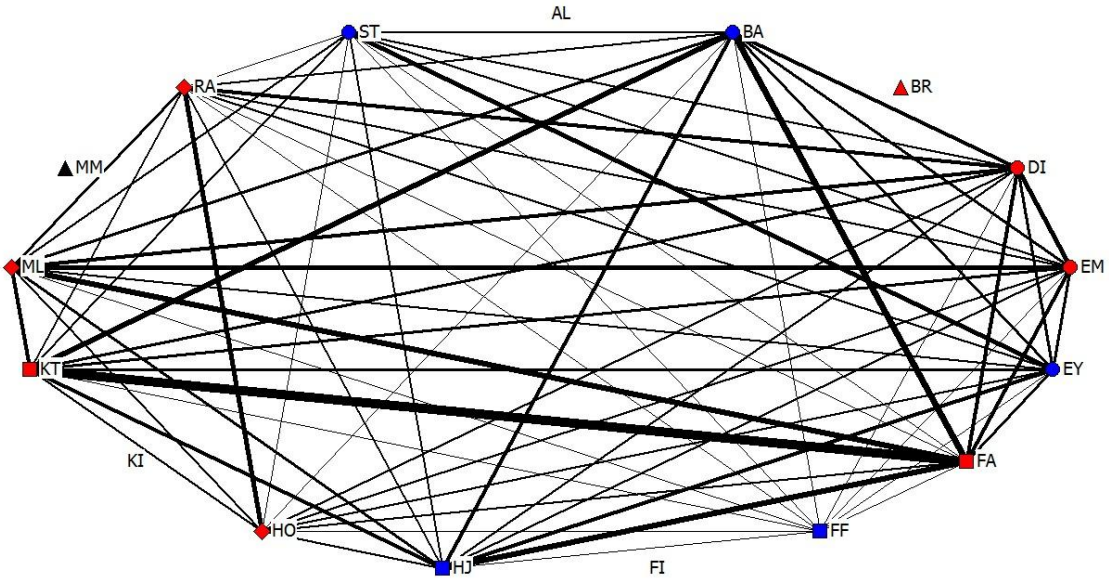
N=5640, Density=1, Component ratio=1, Connectedness=1

Release Group - Period 3: 12 Nodes



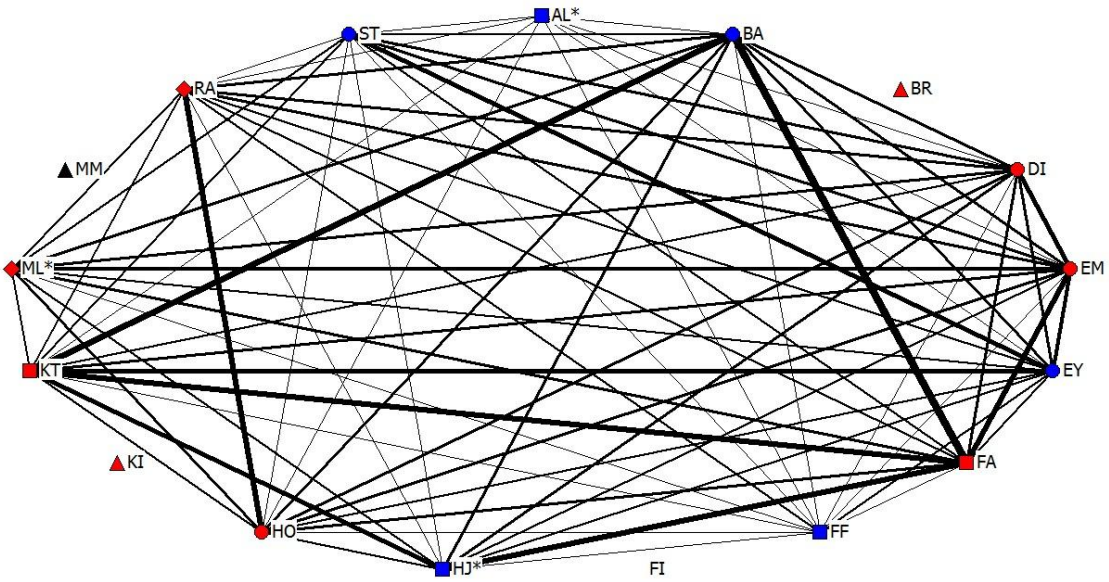
N=1151, Density=0.93, Component ratio=1, Connectedness=1

Release Group - Period 4: 12 Nodes



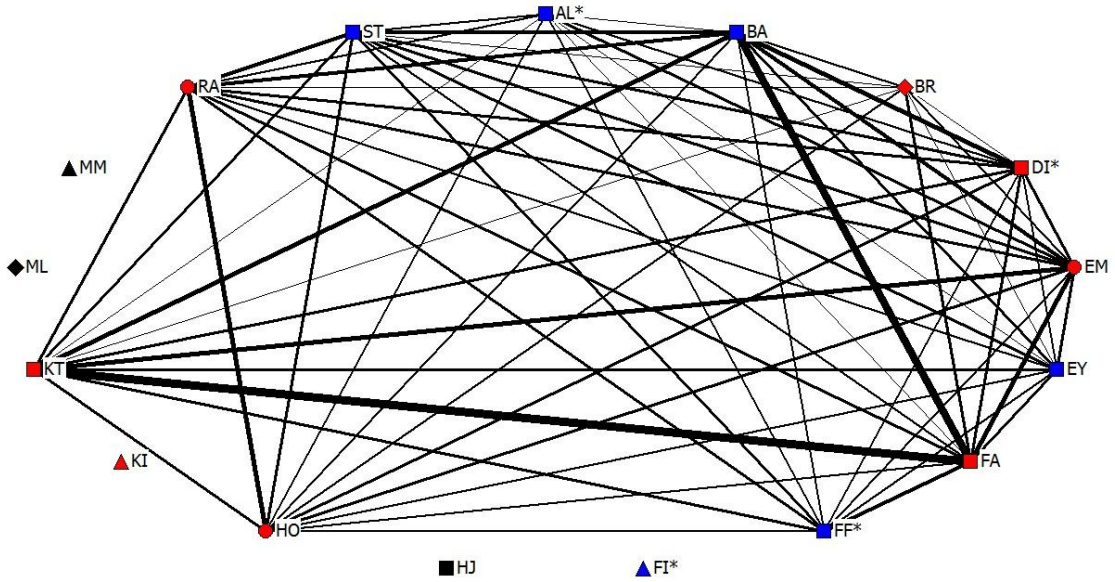
N=2261, Density=1, Component ratio=1, Connectedness=1

Release Group - Period 5: 13 Nodes



N=1072, Density=0.873, Component ratio=1, Connectedness=1

Release Group - Period 6: 12 Nodes



N=883, Density=0.91, Component ratio=1, Connectedness=1

Figure 6.4 Graph representation of social proximity (within 3 meters) events recorded in Release group across five time periods defined within the 18 month post-release research period. Nodes coloured blue indicate males, red indicates females and black indicate individuals that died. Square nodes represent adults, circle nodes represent sub-adults, diamonds represent juveniles, triangles represent infants* and the absences of a shape indicate individuals that had not yet joined the group. Thickness of edge represents the strength of association. * infants are not analysed in the data set and included in the graphs for representative purposes only

6.3.4 Hypothesis 3: Central Individuals

Data were collapsed for time period 2-4 as there was no statistical difference between the eigenvector or centrality values across the time periods (Kruskal-Wallis: eigenvector: x^2=0.612, df=2, p=0.736 betweenness x^2=0.459, df=2, p=0.795), creating four time periods for comparison (Period 1, Periods 2-4, Period 5 and Period 6). Table 6.5 and Figure 6.5 highlight that individuals with a higher eigenvector centrality pre-release remained the most central post-release. In fact the same three individuals filled exactly the same top three places across two of the four time periods. The same was true for the individuals with lower eigenvector centrality scores, with those listed in the lowest four positions pre-release, remaining in the lowest positions post-release, when the two immigrating males are not considered

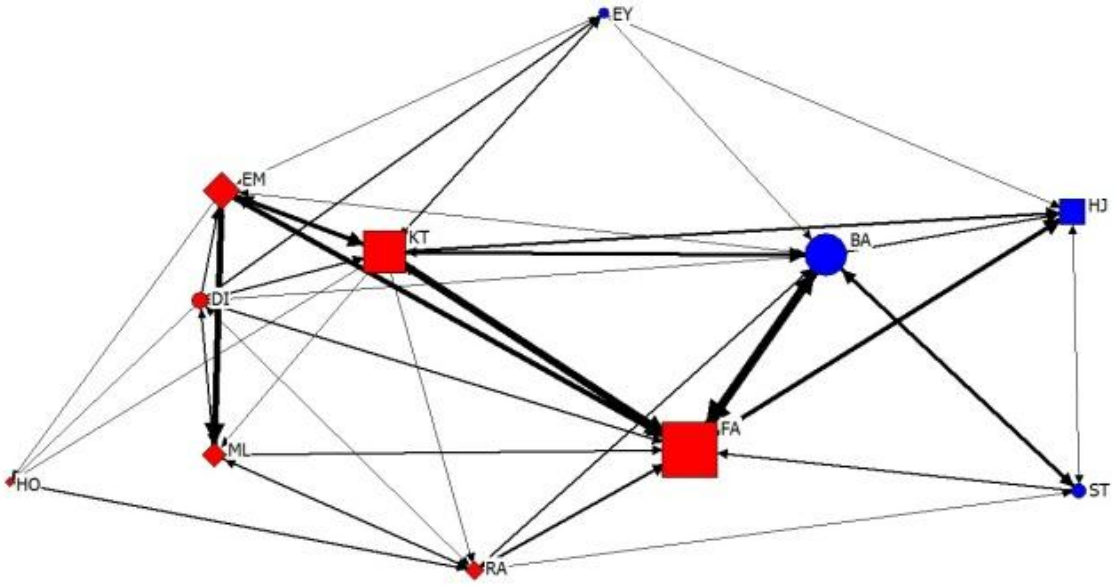
(highlighted by dark grey shading). A Friedman's two-way analysis of variance by rank position indicated that eigenvector centrality values did not significantly vary over time, x^2=2.333, df=3, p=0.506. Betweenness results were more variable across time periods for both high and low scoring individuals, but two individuals were present in the top three positions in both pre-release and two of the three post-release periods (Table 6.6 and Figure 6.6). A Friedman's two-way analysis of variance by rank position indicated that betweenness values significantly varied over time, x^2=8.867, df=3, p=0.031*.

Table 6.5 Individual details, including age and sex variations, of eigenvector centrality for the grooming network across four time periods. (M = male, F = female, A = adult, SA = sub-adult, J = juvenile, * adult male that immigrated in to group, ** juvenile female born in to group during period 3). The darkest areas of shading indicate individuals that remained largely stable in their centrality rank across the four periods.

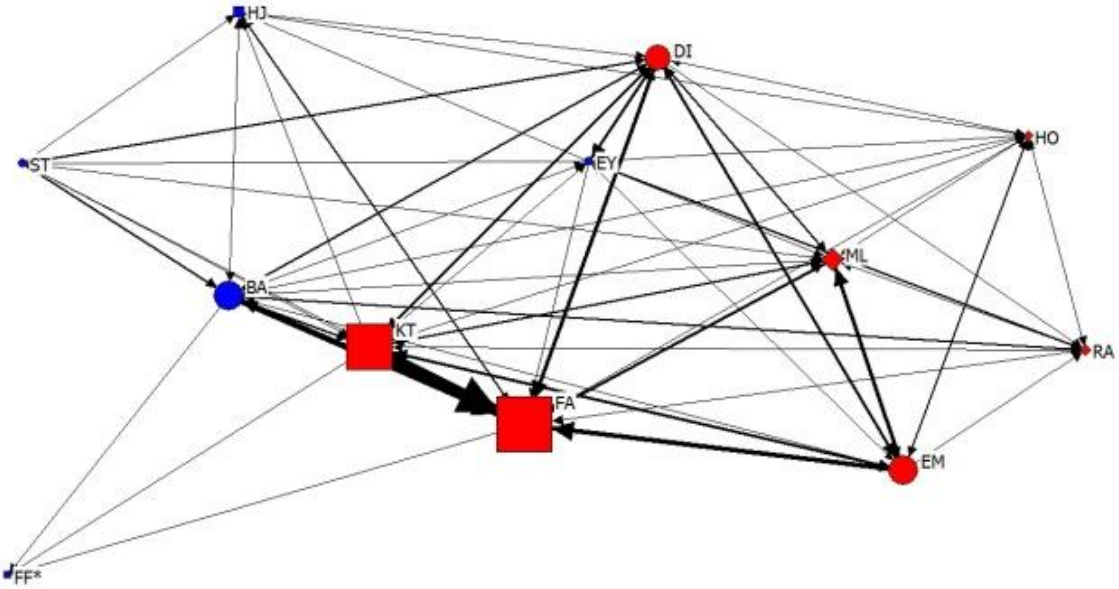
Rank	Eigenvector Centrality											
	Period 1			Period 2-4			Period 5			Period 6		
	ID	A/S	Score	ID	A/S	Score	ID	A/S	Score	ID	A/S	Score
1	FA	AF	0.589	FA	AF	0.640	FA	AF	0.584	FA	AF	0.561
2	KT	AF	0.445	KT	AF	0.533	KT	AF	0.424	KT	AF	0.546
3	BA	SAM	0.430	BA	SAM	0.316	BA	SAM	0.364	DI	AF	0.372
4	EM	JF	0.358	EM	SAF	0.300	DI	SAF	0.355	EM	SAF	0.341
5	HJ	AM	0.238	DI	SAF	0.258	ML	JF	0.329	BA	AM	0.320
6	ML	JF	0.192	ML	JF	0.185	EM	SAF	0.305	FF*	AM	0.088
7	DI	SAF	0.136	HJ	AM	0.078	RA	JF	0.081	HO	SAF	0.086
8	RA	JF	0.120	EY	SAM	0.057	HO	SAF	0.061	ST	AM	0.085
9	ST	SAM	0.105	RA	JF	0.053	EY	SAM	0.054	BR**	JF	0.063
10	EY	SAM	0.064	ST	SAM	0.043	ST	SAM	0.053	EY	AM	0.045
11	HO	JF	0.017	HO	SAF	0.037	HJ	AM	0.046	AL*	AM	0.028
12				FF*	AM	0.028	AL*	AM	0.012	RA	SAF	0.011
13							FF*	AM	0.008			

Eigenvector Centrality

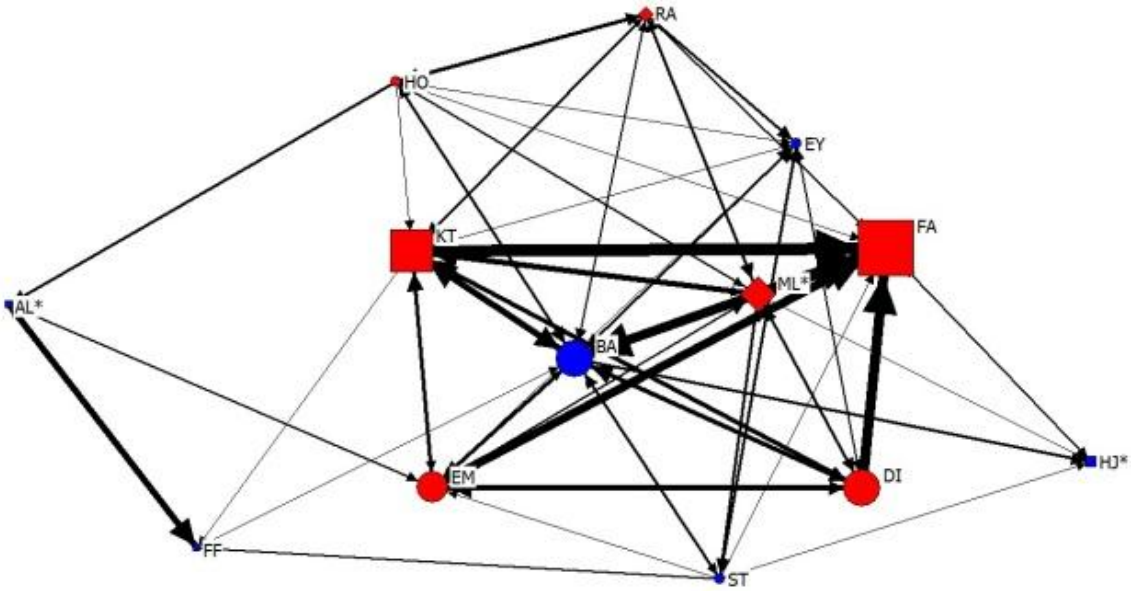
Period 1



Period 2



Period 3



Period 4

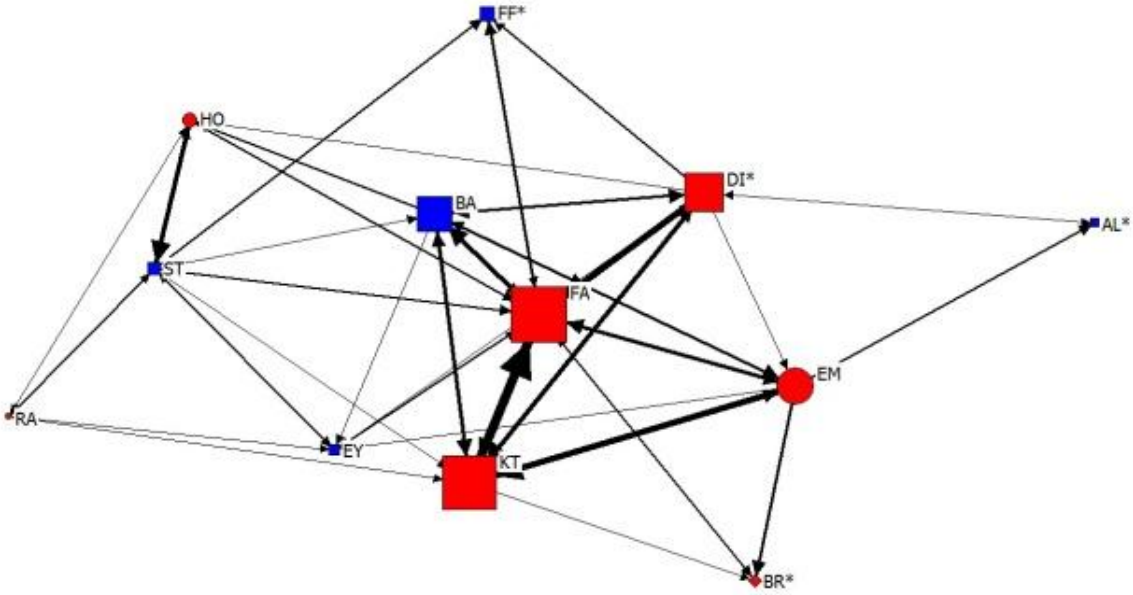


Figure 6.5 Graph representation of eigenvector centrality in the grooming network of Release group across four time periods. Nodes represent individuals and the size of the node is related to the individual's eigenvector centrality score, with bigger nodes corresponding to more central individuals. Nodes coloured blue indicate males, red indicates females. Square nodes represent adults, circle nodes represent sub-adults, and diamonds represent juveniles. Thickness of edge represents the strength of association.

Table 6.6 Individual details, including age and sex variations, of betweenness centrality for the grooming network across four time periods. (M = male, F = female, A = adult, SA = sub-adult, J = juvenile, * adult male that immigrated in to group, ** juvenile female born in to group during period 3). The darkest areas of shading indicate individuals that remained largely stable in their centrality rank across the four periods.

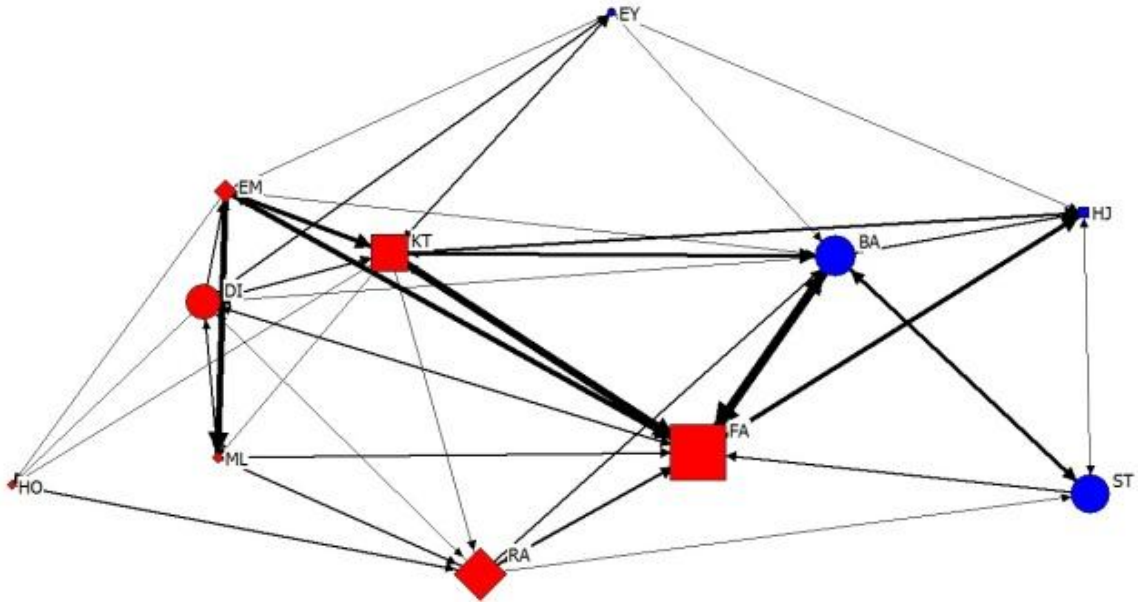
Rank	Betweenness Centrality											
	Period 1			Period 2-4			Period 5			Period 6		
	ID	A/S	Score	ID	A/S	Score	ID	A/S	Score	ID	A/S	Score
1	FA	AF	14.59	BA	SAM	8.53	BA	SAM	28.13	FA	AF	34.79
2	RA	JF	13.07	FA	AF	6.95	FA	AF	15.03	DI	AF	16.50
3	BA	SAM	10.27	DI	SAF	5.50	ML	JF	10.47	KT	AF	12.04
4	ST	SAM	9.67	KT	AF	4.89	EM	SAF	9.12	ST	AM	9.29
5	KT	AF	8.94	ML	JF	2.39	KT	AF	6.68	EM	SAF	7.75
6	DI	SAF	8.57	EY	SAM	1.63	HO	SAF	6.50	BA	AM	6.25
7	EM	JF	3.94	HO	SAF	1.38	FF*	AM	6.07	EY	AM	4.04
8	HJ	AM	1.17	RA	JF	0.79	EY	SAM	3.87	HO	SAF	3.08
9	ML	JF	1.00	EM	SAF	0.64	RA	JF	2.52	RA	SAF	2.00
10	EY	SAM	0.53	ST	SAM	0.31	ST	SAM	1.83	AL*	AM	0.25
11	HO	JF	0.25	HJ	AM	0.00	DI	SAF	1.78	BR**	JF	0.00
12				FF*	AM	0.00	AL*	AM	1.00	FF*	AM	0.00
13							HJ	AM	0.00			

Both eigenvector and betweenness centrality were correlated with the amount of time an individual had been in the group prior to release (Spearman's rank: eigenvector r=0.327, n=48, p=0.023*; betweenness r=0.431, n=48, p=0.002*), indicating that the duration of an individual's relationship with the rest of the group determined their level of centrality.

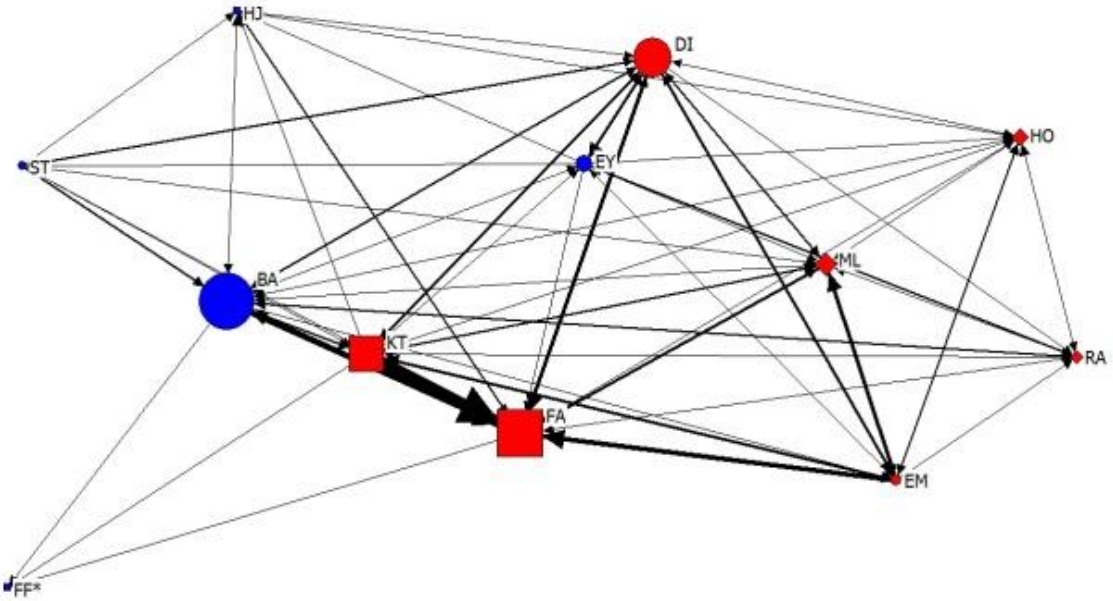
A significant difference was found in the eigenvector and betweenness values for age and sex categories, (Kruskal-Wallis: eigenvector: x^2=23.822, df=4, p=<0.001*** betweenness x^2=15.53, df=4, p=0.004**). Mann-Whitney U post-hoc test showed that adult females had significantly higher mean eigenvector centrality than all other age/sex class categories represented (adult male, p=<0.001***; sub-adult male, p=0.001***; sub-adult female, p=<0.001*** and juvenile female, p=<0.001***). Adult females also showed significantly higher mean betweenness centrality than all other age/sex class categories except sub-adult males (adult male, p=0.001***, sub-adult male, p=0.058, sub-adult female, p=0.007* and juvenile female, p=0.005*) (Figure 6.7).

Betweenness Centrality

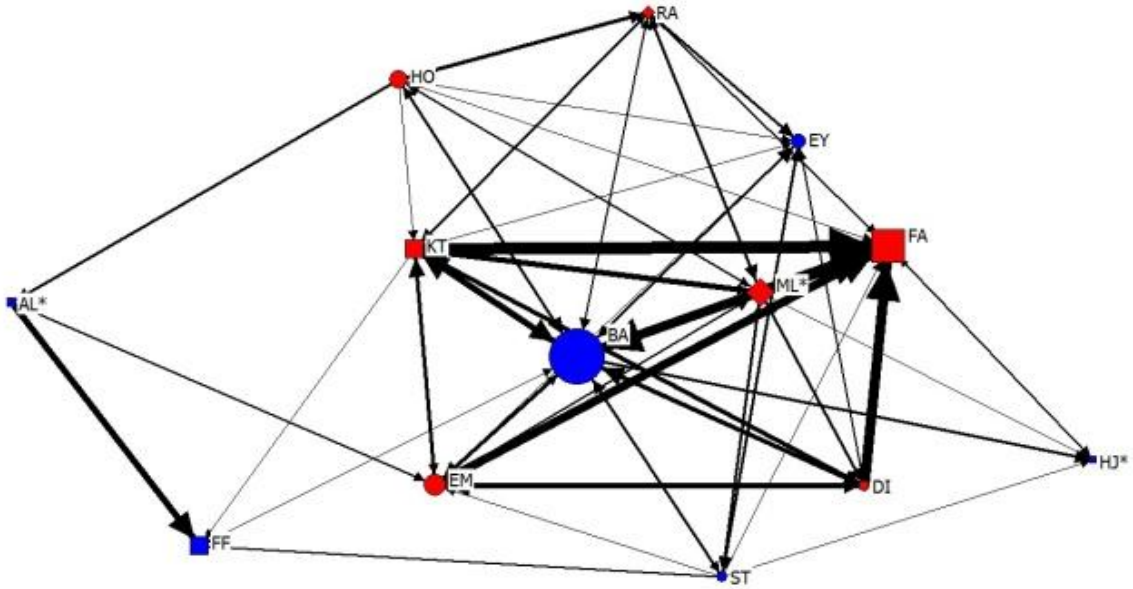
Period 1



Period 2



Period 3



Period 4

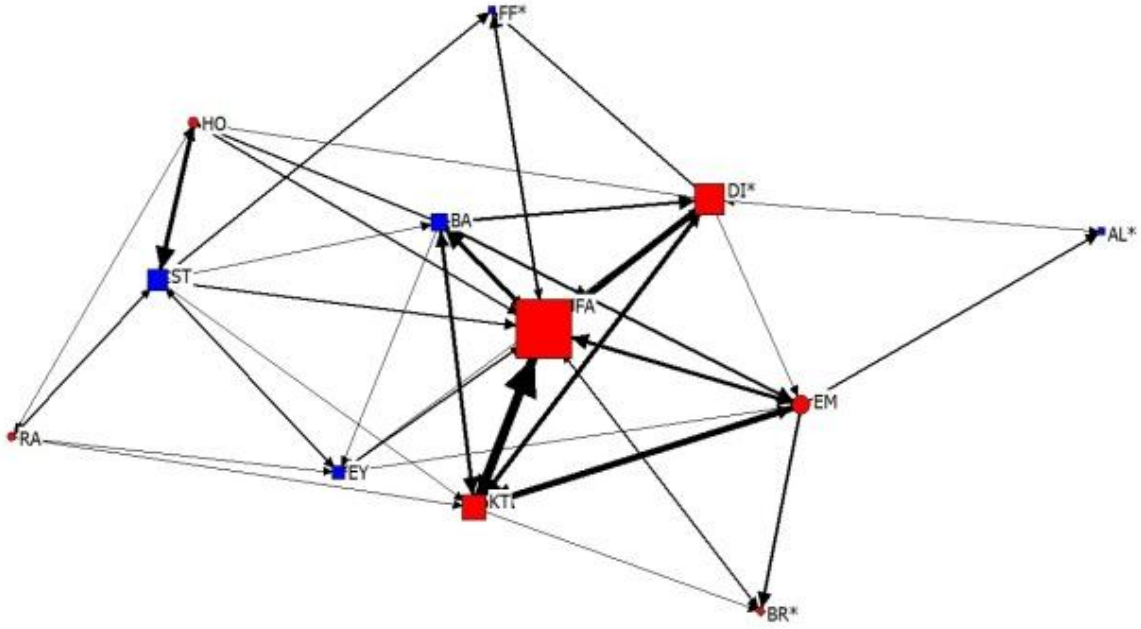
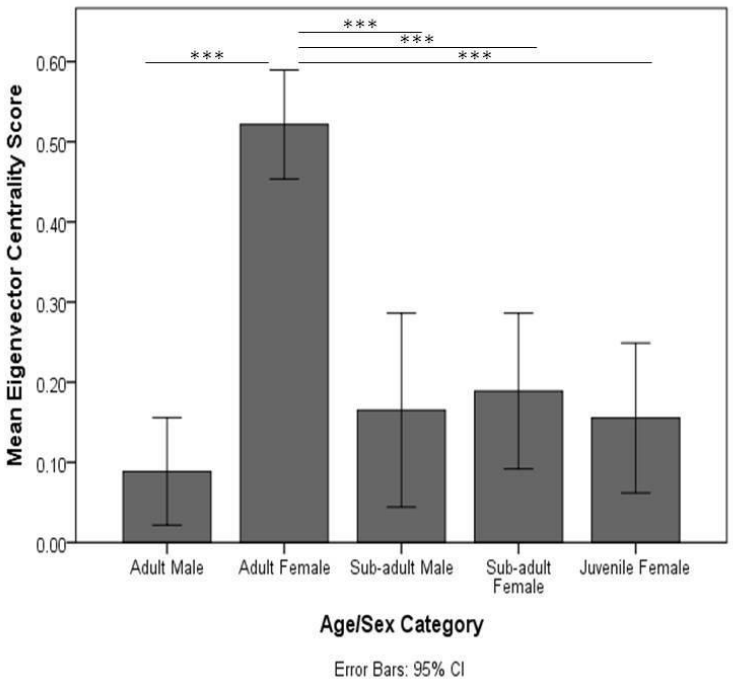
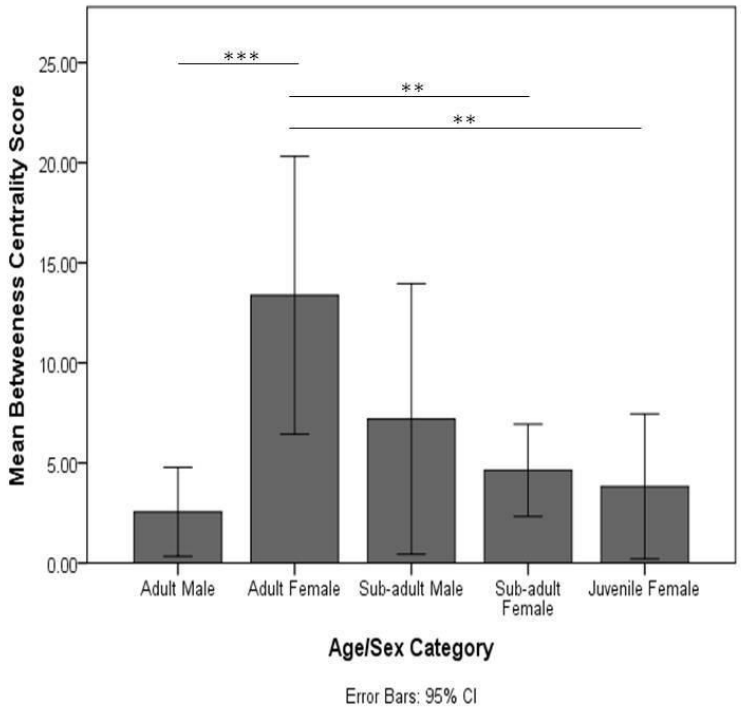


Figure 6.6 Graph representation of betweenness centrality in the grooming network of Release group across four time periods. Nodes represent individuals and the size of the node is related to the individual's betweenness centrality score, with bigger nodes corresponding to more central individuals. Nodes coloured blue indicate males, red indicates females. Square nodes represent adults, circle nodes represent sub-adults, and diamonds represent juveniles. Thickness of edge represents the strength of association.



a)



b)

Figure 6.7 Comparison of a) eigenvector and b) betweenness centrality values, between age and sex categories for Release group. Significant difference were calculated using Kruskal-Wallis with Mann-Whitney U post-hoc tests and highlighted with *p=<0.05, **p=<0.01 or ***p=<0.001.

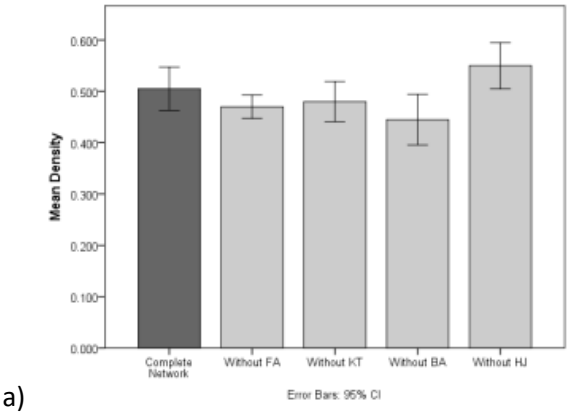
6.3.5 Hypothesis 4: Resilience Analysis

I explored the implications, for group cohesion, of losing the most central or key individuals post-release via the theoretical removal of them from the grooming network. Centrality analysis revealed that three individuals were consistently higher ranking than all other individual across the four time periods and two centrality measures. These consisted of the only two adult females FA and KT, and BA a sub-adult male who developed in to an adult during period 6. As the only adult male (a role often considered pivotal to release success) released with the group, HJ was also included in the resilience analysis.

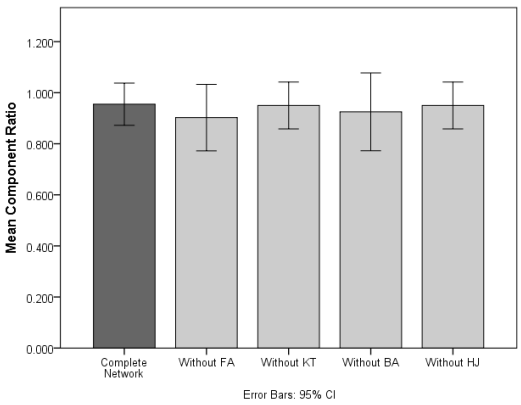
The removal of each of the four individuals saw a slight reduction in all network measures and therefore group cohesion. The exception to this pattern was in the removal of HJ which resulted in an increase in network measures (Figure 6.8). However, none of these changes where statistically significant when compared to the complete network results (Table 6.7). The false discovery rate control was calculated per theoretical grouping, for the five cohesion measures.

Table 6.7 Results from Friedman's two way analysis of variance by rank when comparing cohesion measures of theoretical grooming networks with key individuals removed against the actual grooming network recorded. None of the results are significant after the application of False Discovery Rate Control.

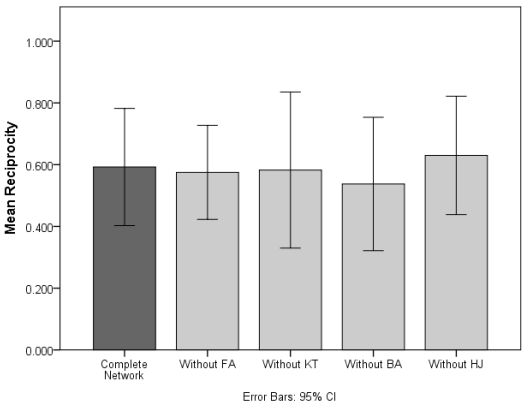
Cohesion Measures	Cohesion Networks with Key Individuals Theoretically Removed											
	Without FA			Without KT			Without BA			Without HJ		
	x^2	df	p	x^2	df	P	x^2	df	p	x^2	Df	p
Density	5.00	1	0.025	5.00	1	0.025	5.00	1	0.025	4.00	1	0.046
Component ratio	4.00	1	0.046	2.00	1	0.157	2.00	1	0.157	2.00	1	0.157
Reciprocity	1.80	1	0.180	0.20	1	0.655	5.00	1	0.025	4.00	1	0.046
Transitivity	5.00	1	0.025	5.00	1	0.025	5.00	1	0.025	4.00	1	0.046
Connectedness	4.00	1	0.046	2.00	1	0.157	2.00	1	0.157	2.00	1	0.157



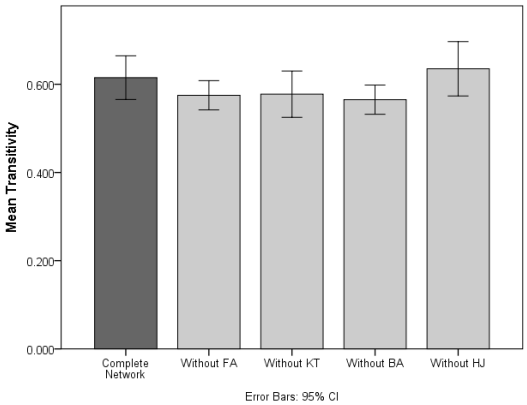
a)



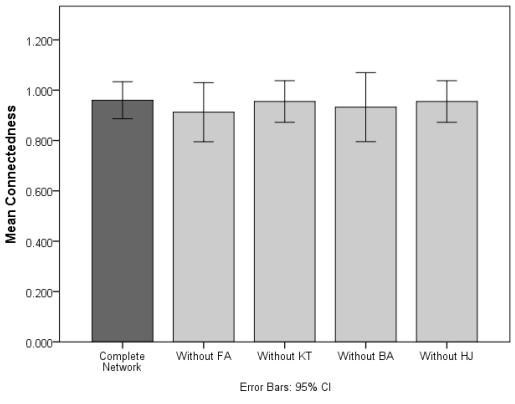
b)



c)



d)



e)

Figure 6.8 Changes in network measures after the removal of central individuals, a) density, b) connectedness, c) reciprocity, d) transitivity and e) connectedness. In all figures the blue columns represent the original complete network, while green represents the theoretical network with central individuals removed.

6.4 Discussion

In this chapter the social structure of an artificially constructed group of unrelated vervet monkeys was explored pre- and post-release over time, highlighting the role individuals played in network stability and group cohesion. Where possible the results were compared to natural wild groups living in the same location and to the literature.

6.4.1 Hypothesis 1: Group Cohesion: Release Group Compared to Control Groups

At the time of writing there were no published data on relevant social network measures for vervet monkeys. However, levels of density for both the grooming and social contact networks of all three groups was lower than the 0.75 reported in the combined analysis of 70 primates groups (Kasper and Voelkl 2009). The social contact networks of the control groups, which produced density's of 0.09 and 0.15, were closely aligned to density levels in social contact networks of semi-captive mandrills reported to be 0.16 by Bret *et al* (2013). Yet, the social contact networks of Release group were considerably higher than this through the entire study. Looking across density, reciprocity, transitivity and component ratio metrics highlighted that Release group was more cohesive than the naturally forming kin related control groups of Diani both pre-release and for one year post-release. However, by the final six months of the study Release group levels of cohesion had reduced and displayed figures that were more representative of the wild group. Out of the three groups, Hotel group displayed considerably lower levels of cohesion in both their grooming and social contact network. As discussed in Chapter 4 and 5 Hotel group spent significantly less time in social activities than University or Release group and is likely to be a contributing factor to reduced group cohesion. Interestingly, Release group exhibited higher cohesion levels in their social contact network than grooming network, compared to the control groups where the reverse was the case. For the control groups, social contact appeared to require a higher level of tolerance towards an individual than grooming and was generally only observed between kin or individuals of similar ages.

Several authors have highlighted that group social structure and group cohesion, required to survive life in the wild, is strongly connected to kin relationships and life-long bonds (Borgeaud *et al.* 2016; Isbell and Young 1993b; Struhsaker 1967b). Therefore the control groups were predicted to display higher levels of cohesion than Release group, yet the reverse was true. The unexpectedly high levels of cohesion displayed by Release group may be attributed to their background and complete lack of traditional kin ties, resulting in the artificially structured Release group displaying greater levels of cohesion than naturally forming control groups. Kin recognition in primates is generally thought to be based on close association early in life

(Bernstein 1991; Walters 1987). In primate species that lack close association between males, females and their infants, kin recognition enables individuals to recognise maternal, but not paternal kin (Silk 2002). Studies of the independent effects of familiarity and kinship on interaction patterns among young monkeys (Erhart *et al.* 1997; Welker *et al.* 1987) indicated that monkeys display clear preferences for familiar conspecifics over unfamiliar conspecifics and did not discriminate among kin and non-kin when familiarity was held constant. Considering familiarity in Release group, at the time of release the group was artificially constructed of non-kin individuals that had been slowly formed over 39 months from mostly young orphaned individuals. If hand-rearing intervention was required very young infants were housed together, until of an age when they could feed themselves and were then housed with older infants (who did not need or no longer required human intervention) and young juveniles, eventually being integrated with older juveniles, sub-adults and adults. In these cases and with a lack of any kin relationships, infants associated with only unrelated individuals upon whom they solely relied for social and physical support, potentially forming bonds that replicate kinship. These bonds would not be primarily single generation matriarchal lines as recorded in wild vervet groups, but more inclusive, multi-generation 'web-like' networks. Additional support is added to this observation in the individual centrality values within each group; Release group displays far less variability in the values calculated for group members, than either of the control groups. Further exploration of the possibility of early association resulting in the replication of kinship ties in such artificially formed groups is required.

6.4.2 Hypothesis 2: Group Cohesion: Release Group Pre- and Post-Release

Vandenburg (1967) stated that 'without giving animals sufficient freedom to desert the group, social cohesiveness cannot be measured'. Due to the confinements of captivity enforcing proximity, food provisioning reducing foraging time and therefore promoting social activities, it was predicted that the highest levels of cohesion for Release group would be recorded during the captive pre-release period. Post-release it was predicted that cohesion levels would rapidly reduce (Ancrenaz 2001; Goossens *et al.* 2005; Guy *et al.* 2011; Humle *et al.* 2010; Kawai 1960; Vandenburg 1967; Wimberger *et al.* 2010b) and be lower than those produced by the wild groups. Conversely, cohesion levels increased immediately post-release (period 2). For a 14 week period (Period 2 and 3) post-release the group were supplementary fed as part of the soft release protocol, this food provisioning could account for continued group cohesion during this period. However, I do not believe this to be the case as the food was distributed over a larger area than was possible in the group's pre-release enclosure and therefore cohesion levels would still be expected to reduce.

There were also peaks in cohesion in period 4 (grooming and social proximity) and 5 (grooming), which corresponded with the first (5 months post-release) and second (7 months post-release) birth in the group. With these births came an increase in grooming behaviour largely directed at the mothers (FA and KT) as other group members tried to earn their chance to hold the infant (Henzi 2001; Muroyama 1994). Period 3 saw a dip in cohesion levels (grooming and social proximity) that could be attributed to the first wild male joining the group. Figure 6.1 highlights that during Period 3, FF (the immigrating adult male), contributed to the grooming network less than in subsequent periods. Prior to his arrival all nodes had participated in grooming activity with numerous group members. However, the addition of a new member only grooming two other group members, initially weakens the grooming network. There was another reduction in cohesion levels in the social proximity during period 5 and was likely linked to the death of the alpha male (HJ) and the subsequent arrival of a wild adult male (AL) during this period. During the initial arrival of the new male, existing group members did not permit the new male (AL) to approach them closely and as such the social proximity (within 3 meters), network was initially weakened. By 12 - 18 months post-release group cohesion levels of the social contact and grooming networks had reduced to levels that were more similar to the control groups. It is worth noting that the reduction in group cohesion levels recorded in period 6 is possibly linked to a smaller focal sample size during this period as compared to the previous research periods. Likewise, it increases in cohesion recorded immediately post-release may be related to a smaller focal sample size recorded pre-release compared to post-release.

There are two, interlinked reasons why Release group showed higher levels of cohesion than expected. Firstly, and in contrast to all other reported primate translocation projects there was no relocation of the group in the period directly before release. The transportation of individuals undergoing release is normally unavoidable, but is recognised as incredibly stressful and must be coordinated with care (IUCN/SSC 2013). Following transportation and where possible, groups are held in an *in-situ* pre-release enclosure to allow for adjustment to the new environment and reaffirmation of group bonds. In the case of wild translocated animals this captive environment is novel and likely to be stressful (Beck 2016), and for release animals familiar with captivity such temporary holding facilities are often comparatively small and do not promote reconciliation of group bonds (pers. obs). Due to these constraints, and the complexities of housing large primate groups, without incident, in field locations, groups are

often released within a few days of arrival (Guy 2013; Guy *et al.* 2011, 2012; Wimberger *et al.* 2010b) before full recovery of the disrupted social bonds, at an individual and group level, has occurred. This disruption in social bonds increases the chances of a group split up on release (Aguilar-Cucurachi *et al.* 2010; Kawai 1960; Richard-Hansen *et al.* 2000; Stanley-Price 1989; Vandenburg 1967). Capture and movement of primates for translocation has been reported to raise glucocorticoid levels indicating increased stress (Aguilar-Cucurachi *et al.* 2010). At the point of release individuals are already highly stressed and are heading in to another novel and stressful situation.

The vervet group in this study, were released directly from the enclosure where they had lived for their entire captive life, without a stressful recapture and transportation phase. They did not experience any highly stressful event that saw the group split in the weeks leading up to their release. Accordingly it is assumed that they had not undergone any disruption to their social bonds and were fully cohesive at the point of release. Secondly, increases in primate grooming activities have been recorded following stressful events including territory disputes, aggressive encounters and death (Aureli *et al.* 2002; Buhl *et al.* 2012). Translocations are known to be stressful for primates groups (Aguilar-Cucurachi *et al.* 2010) and therefore an increase in grooming behaviour would be reasonably expected in a cohesive group. An increase in grooming, social contact and social proximity (due to stress experienced from release), coupled with undisrupted social bonds (due to no pre-release capture and transportation) would account for the unusual increased cohesion levels post-release. The lower sample size of focal follows pre-release, compared to post-release, could also explain the lower than expected cohesion measures recorded pre-release.

6.4.3 Hypothesis 3: Central Individuals

An individual eigenvector centrality network position pre-release was predictive of their post-release eigenvector centrality network position. When considering eigenvector values, the same three individuals were the top three central individuals across three of the four time periods; FA and KT, the only two adult females in the group throughout most of the study and BA a sub adult male who's centrality was only surpassed in the last time period as DI developed in to an adult female. Knowledge of an individual's eigenvector centrality could be used to provide insight in to which individuals to consider for tracking devices when funds do not permit the collaring of every individual. Betweenness centrality was much more variable, however the same three individuals featured highly in all four time periods. Analysis revealed that the betweenness centrality network position of individuals pre-release was not an

indication of their network position post-release, but on a descriptive level comparisons can be drawn with eigenvector centrality, and recommendations made for tracking devices.

Highly central individuals (in terms of eigenvector and betweenness) were mainly adult females and/or individuals that had been with the group over a longer time frame pre-release. This trend corresponds to wild studies showing adult female vervets to be influential group individuals (Borgeaud *et al.* 2016; Struhsaker 1967b; van de Waal and Bshary 2011). Group dynamics of potential release groups is recognised as important (Wimberger *et al.* 2010b). This research supports recommendations regarding thorough consideration to group dynamics. Additionally it highlights that in social systems where females are central, adult females are an essential component to group stability and cohesion. These factors must be considered when the structure of release groups are formulated.

6.4.4 Hypothesis 4: Resilience Analysis

Resilience analysis revealed that Release group was very stable and the theoretical removal of even the most central individual did not cause the group to fragment. Small reductions in cohesion levels were recorded when the most central individuals were removed and a small increase was seen with the removal of the adult male. However, I do not consider this theoretical test to be a fair representation of 'real-life' events had one of these individuals been physically removed from the group. Firstly, while the removal of the adult male saw an increase in group cohesion this does not take into account other positives for group survival that he contributed, for example in predator awareness or the protective role he played during an early territory dispute. He played an important role in group survival, but one that is not represented by group cohesion. As for the three central individuals, their removal was purely theoretical and as they remained with the group in 'real-life' their influences on group cohesion remained. For example, KT was often the initiator of group grooming bouts. Theoretically removing her from the grooming network only removes her part in the recorded grooming bouts, but other group members are still recorded as grooming. Had she been physically removed from the group in real life it is possible that many of the group grooming bouts would not have occurred. Therefore, her real-life removal would have had a far greater impact than is demonstrated by her theoretical removal.

6.5 Conclusion

While this study focuses on social network analysis of vervet monkeys subject to a rehabilitation release the techniques are fully transferable to any group-living species subject to translocation. Group cohesion is critical for successful translocation of any group living animal. However, numerous primate translocation studies have reported a partial or complete breakdown in social structure of groups in the days, weeks and months following release (Ancrenaz 2001; Goossens *et al.* 2005; Guy *et al.* 2011; Humle *et al.* 2010; Kawai 1960; Vandenburg 1967; Wimberger *et al.* 2010b). Release group was exposed to all of these experiences and not only displayed levels of group cohesion comparable to those recorded in indigenous vervet groups, but increased their level of cohesion following initial release. I attribute this outcome to early-life associations between group members building kin-ship like bonds. In addition, analysis of individual centrality and the influence key monkeys have upon the group as a whole highlights that enabling the group to build bonds and relationships slowly over time and the presences of adult females may be key components in post-release success. Future release programmes should consider building release groups slowly, over many orphan seasons, gradually adding new generations in a way that replicates wild groups. A lack of pre-release transportation not disrupting social bonds has also been highlighted as influential in retaining group cohesion. This suggests that increased consideration should be given to the construction of more adequate in-situ holding facilities that will allow release groups to spend extended periods to recover and to re-group following transportation to the release site.

Chapter 7 General Discussion

IUCN/SSC/RSG specifies the need for scientific employment in all animal translocation programmes pre-, during- and post-release. In this thesis I aimed to follow and employ all guidelines as detailed by IUCN/SSC Reintroduction Specialist Group: Guidelines for Reintroduction and Other Conservation Translocations, in accordance with the Guidelines for Nonhuman Primate Reintroductions and where appropriate the IUCN/SSC Best Practice Guidelines for the Reintroduction of Great Apes for a rehabilitation release of vervet monkeys in Kenya. Additionally I aimed to provide measures of post-release success using verifiable indicators and criteria and report on the outcomes in scientific detail. This was achieved by comparing biological and behavioural measures of the released vervet group with indigenous vervet control groups inhabiting the same area, within the same time period. The purpose of this chapter is to review and evaluate the main findings of this study, discuss the potentially controversial release of vervet monkeys in to an anthropogenic habitat and within range of wild conspecifics, highlight interesting preliminary findings that warrant future research and conclude with recommendations for improving the management of future vervet rehabilitation releases and more generally primate translocations.

7.1 Release Site Selection

Translocations should only take place when the taxon's habitat requirements are satisfied and likely to be sustainable for the foreseeable future. If the taxon's basic habitat and ecological requirements cannot be determined, the animals should not be released (Baker 2002; Beck *et al.* 2007; IUCN/SSC 2013). Using preliminary home range data from indigenous control groups, habitat assessments were conducted within known vervet habitat. This data, combined with feeding ecology and sleeping site data provided an understanding of plant communities, biomass and structure that were important features in Diani vervet group habitat. This knowledge was used to inform on suitability of areas as potential release sites and the estimated vervet group size and home range area it would support. Monitoring of the release and control site continued through-out the post-release period, enabling a post-hoc investigation of the important relationship between biomass and how that translated to food availability. A replication of the habitat assessments was conducted 2 years post-release to assess the impact Release group had upon their environment and compare that to changes recorded at the control sites. Chapter 3 highlights that the presences of suitable plant

communities and biomass calculation alone are not an adequate indicator of release site viability. While this knowledge is important to highlight potential release areas that warrant further consideration, release site selection should not be based largely on this information. A minimum of one year phenological monitoring pre-release is recommended in order to understand seasonal fluctuations in food availability and to ensure that the plant communities flourish as expected.

7.2 Vervet Monkeys in an Anthropogenic Habitat as a Control Comparison

Vervet monkeys have one of the widest ecological tolerances of any primate species, ranging over a large geographical area covering most of sub-Sahara Africa (Wolfheim 1984). As generalists vervet monkeys are able to adapt to disturbed and marginal habitats such as secondary forests, farm and urban areas (Brennan *et al.* 1985; Saj *et al.* 1999; Wallace and Hill 2012). Animal behaviour, life history, movement patterns and habitat selection are influenced by anthropogenic activities (Cozzi *et al.* 2016; Sol *et al.* 2013; Widdows and Downs 2016). Chapter 4 revealed that the Diani vervet monkeys are not representative of other vervet populations (from natural or anthropogenically modified habitats) in terms of their feeding ecology and is most likely a reflection of resource availability and ease of access across different locations. However, their activity budgets and home range largely fall within, or close to, the expected ranges displayed in the limited number of vervet behaviours studies conducted in anthropogenically modified habitats. Finally, their day journey length was larger than expected for groups inhabiting an anthropogenic habitat and was more representative of vervet monkeys studied in natural environments.

In relation to translocation success, Strum (2005) stated that "Any claim made about primate translocation success must be both verifiable and broadly applicable. This requires 1) the use of measurable indicators of success, and 2) a way to evaluate them relative to an explicit performance target or control, since environmental conditions may affect success indicators independently." This statement is entirely applicable to this project and formed the basis of the baseline data collection of two indigenous wild groups to inform the release process both pre-release for release site selection and post-release to generate the most appropriate measures of success. The differences in behaviour and feeding ecology of the Diani vervet monkeys, compared to published literature from other locations, as presented in Chapter 4,

add weight to Strum's comment that environmental conditions may affect success indicators independently and validate the requirement of indigenous control group measures.

The survivorship of Release group was not significantly different to the control groups and at one year post-release was considerably higher than other reported vervet rehabilitation release studies. Only reintroduction programs of gorillas (King *et al.* 2011) and chimpanzees (Goossens *et al.* 2005; Humle *et al.* 2010) had higher survival rates. The home range of Release group (3.78ha) was substantially smaller than that of the control groups (19.7ha and 10.8ha) and was considered the result of the availability of additional anthropogenic food sources within the home range. The activity budget of Release group was largely representative of the control groups and fell within expected ranges. Social behaviour was the exception and was significantly higher in Release group than the control groups. This difference was attributed to the group experiencing novel exposure to infants born into the group post-release, resulting in increased levels of grooming and play, in addition to sub-adults being included in the analysis of Release group but not the control groups. Finally, the feeding ecology of Release group was very broadly representative of the control groups. The most significant difference was a considerably higher consumption of anthropogenic food by Release group and was entirely the result of access to food given to other captive monkeys undergoing rehabilitation within the release site. There was surprisingly little dietary overlap between any of the groups, but the greatest dietary overlap was between Release group and University. This low level of overlap was considered a result of differences in species abundance and availability between the three sites as a result of anthropogenic modification and management. Release group had a more diverse diet than the control groups, consuming a wider range of species. As their habitat was not considered to be more diverse than the control groups (Chapter 3) this difference in species consumption was deemed the result of exploration by food naive vervet monkeys as they learnt what species to consume.

Surprisingly, Release group displayed higher levels of cohesion than either of the control groups. Several authors have highlighted that group social structure and group cohesion, required to survive life in the wild, is strongly connected to kin relationships and life-long bonds (Borgeaud *et al.* 2016; Isbell and Young 1993b; Struhsaker 1967b). With a complete lack of kinship, the high levels of cohesion reported in Release group were attributed to kin-like recognition based on close association early in life (Bernstein 1991; Walters 1987). If this

assumption is correct it places emphasis on the importance of building pre-release groups slowly overtime and introducing orphaned infants as early as it is deemed safe to do so.

7.3 Release Success

This rehabilitation release project was considered a success. Release group displayed survival rates, day journey lengths, activity budgets and general feeding ecology that fell within the excepted ranges of the control groups. However, their home range was considerably smaller than the control groups and was likely the consequence of Release group having access to additional anthropogenic food sources, which meant they needed to range less to fulfil their nutritional requirements. The success of this release can be attributed to four main areas; adhering to IUCN guidelines, lengthy rehabilitation period, transportation to the release site and post-release monitoring with the presence of knowledgeable personnel.

IUCN Guidelines

Following the IUCN guidelines led to robust and careful planning. These guidelines were an invaluable source of information and promoted many interesting discussions and ideas from all members of the multi-disciplinary team put in place to oversee this rehabilitation release process. It is doubtful the release would have been successful without their guidance.

Lengthy Rehabilitation

A lengthy rehabilitation period as part of the pre-release group, aided the ability to form strong group bonds that were beneficial to the individual. Chapter 5 highlighted that individuals that had spent longer in the pre-release had an increased survivorship, while Chapter 6 showed that an individual's length of time in the pre-release group increased their levels of centrality within the group. I attribute this outcome to early-life associations between group members building kin-ship like bonds facilitated by a longer period of rehabilitation, with individuals joining the group sporadically, over time. Similarly, Humle *et al.* (2010), reported on the benefits for post-release survival of a lengthy rehabilitation, of chimpanzees, in a group setting in an environment similar to the future release site.

Transportation to the Release Site

In contrast to all other reported primate translocation projects there was no relocation of the group in the period directly before release. Chapter 6 highlighted that due to this lack of transportation directly prior to release, Release group had not endured a highly stressful process that is documented to break down social bonds. This finding highlights the

requirement to make the transportation process as stress-free as possible. In addition I recommend for animals that are familiar with captivity, more emphasis needs to be given to facilitating pre-release groups with larger and more functional, in-situ pre-release enclosures. This would allow groups to spend prolonged periods of time recovering from the stresses of transportation, adapting to their new environment and reaffirming their group bonds, before being released.

Post-release Monitoring with the Presence of Knowledgeable Personnel

The presence of research assistances and later general Colobus Conservation staff members around the release site helped to reduce the risk of predators, negative wildlife interactions and human wildlife interactions either via direct intervention, mitigation and/or engagement of the local community through formal and informal meetings. During the supplementary feeding period all release related personnel were permitted to intervene as required, using protocol that did not put them at risk, to prevent dog and baboon attacks and also potential territory conflict with Hotel group. Over time, and via team meeting discussions, the response time to intervention was increased while the level of intervention was decreased. This approach allowed Release group to avoid serious conflict during early, naive interactions and for the release team to supplement the vervet monkeys pre-release training with post-release training. For example during their time in the pre-release enclosure the vervet monkeys were able to defend their food source from baboons due to the captive environment. Once released the adult and sub-adult male vervet monkeys continued to attempt to defend their supplementary food from baboons. Without the protection of the enclosure, conflict between baboons and vervet monkeys can be fatal to the vervet monkeys. Intervention in these cases involved 'herding' the release individuals away from food sources upon the arrival of baboons to a safer area, teaching Release group to sacrifice food to keep the group safe from baboons, a behaviour observed in the control groups. All vervet monkeys quickly learnt this response with the exception of the dominate male; however after a painful, but non-life threatening injury inflicted up on him by a baboon during a conflict over food he was observed actively leading the group to avoid baboon contact in subsequent visits. In addition to preventative intervention, medical intervention was also facilitated with consultation between release team and veterinary personnel. Any individual requiring intervention was removed from the group, via trapping, for examination and treatment, returning to the group once fit to do so. In some cases, individuals were only absent from the group for a matter of minutes, while others involved care for many days. No individual was removed from the group for longer than 10 days.

However, the rehabilitation release project was not without failings. The largest causes of concern were the low food availability in the release site during the dry season at the end of 2012 - early 2013 (Chapter 3). This failing could have been addressed by conducting a full one year analysis of the phenology of the release site prior to release rather than basing release site selection upon biomass calculations alone. In addition to this and in some ways related, was the access Release group had to enclosure food. Prior to release, measures had been put in place to safe guard the animal care staff from raiding by Release group during feeding times, but the ability of Release group to access this food supply once distributed within the enclosure and during cleaning periods had been thoroughly underestimated. Furthermore, the group were released with just three adult vervet monkeys within the group. While this number was within the ranges observed in the Diani vervet groups the loss of just one of these adults during the early release process could have been devastating to the overall success of the release. Finally, despite all efforts to prevent death of release individuals by human wildlife interactions, at least two group members suffered this fate. In the first case the groups dominate male was targeted by children within the local community with a catapult. The children responsible had not been subject to the extensive education programme that was conducted by Colobus Conservation pre- and post-release due to boarding school commitments, and on the day of the event they had been left home alone during the Christmas break while the adults attended church. In the second case an adult female was killed after being hit by a car while crossing the road. At this point the group was 17 months post-release and all members had extensive experience with crossing the road, however, the individual was in the late stages of pregnancy. Pregnant females are considered to be more vulnerable to negative human wildlife interactions due to the additional weight and cumbersome movements associated (pers. obs).

7.4 Rehabilitation Releases

The majority of primate translocations ultimately occur due to welfare related issues, including the release of wild-born captive individuals and the translocation of individuals (or groups) as a result of human wildlife interactions rather than purely for the conservation of the species (Beck 2016). However, rehabilitation releases are criticised by many translocation professionals due to the potential for ecological disruption, introduction of inappropriate genes, disease transmission and because the welfare of the individual is not always enhanced

(Beck 2016; Guy *et al.* 2014). The IUCN guidelines for conservation reintroductions and translocation of all animals consider rehabilitation release to be 'outside the scope of the guidelines' (IUCN/SSC 2013). Similarly the non-human primate reintroduction guidelines do not consider rehabilitation releases to be a reintroduction approach as they are motivated by goals other than conservation (Baker 2002). However, both sets of guidelines recommend that should rehabilitation releases occur they follow the procedures for conservation reintroductions (Baker 2002; IUCN/SSC 2013). Conversely, the guidelines for the reintroduction of great apes (Beck *et al.* 2007) acknowledges the necessity of rehabilitation release (termed welfare based reintroductions), under correct conditions, where there is evidence to indicate that their welfare would be improved and provided they are not conducted solely to dispose of surplus animals or relieve overcrowding.

Given the scope of primate sanctuaries, institutes and organisations across three continents that are conducting rehabilitation release, guidelines that target considerations and procedures relating to this would be beneficial (Beck 2016). The productions of welfare related guidelines would improve the quality of these projects, increasing the welfare of the individuals concerned and addressing potential risks more thoroughly. Rehabilitation releases that are thoroughly considered and well monitored, can also provide knowledge that is of benefit to other conservation translocations (Guy *et al.* 2014).

7.5 Vervet monkeys as a Rehabilitation Release Species

Most vervet monkey species are classified as least concern on the IUCN Red Data List and there is opinion that such species should not be released back to the wild as they were of little conservation value (Strum 2005). As discussed throughout this thesis, primate translocation is not a common event and success rates are often less than ideal. Methods to improve translocation success should be developed with the use of least concern and/or generalist species before exposing individuals from endangered and/or specialist species to this risky process. I was able to assess methods for release site selection, investigate the consequences of releasing naive vervet monkeys in to a novel environment and monitor their progress against indigenous, wild conspecifics, while gaining insight into the formation of a cohesive group from unrelated individuals. Furthermore, data exists regarding pre-release training methods, predator avoidance post-release and the impact of release group upon neighbour group. Therefore, this research provided an opportunity to document the rehabilitation release process fully and to evaluate the results for application to primate conservation more

generally (Strum 2005). If a generalist species such as vervet monkeys could not be successfully translocated, then more specialised primates would be unlikely candidates for translocation (Strum 2005).

The IUCN require that all translocation programs make a positive contribution to the conservation of the species concerned. Translocations can contribute to conservation in ways not directly related to species numbers including attracting publicity, promoting conservation ideals, raising public awareness and educating the public (Cheyne *et al.* 2012; Cowlishaw and Dunbar 2000; Kleiman *et al.* 1991; Tutin *et al.* 2003; Yeager 1997). Conservation has be dedicated to mitigating human wildlife interactions within the Diani environment for six primate species for 20 years; with this rehabilitation release being just one of many programmes. Additionally, the location of this project enabled local, national and international visitors to engage with Colobus Conservation, exploring the release site (under close supervision from trained tour guides) and witness first hand a rehabilitation release programme in progress. Therefore, this rehabilitation release programme has made a positive contribution to the conservation of six primate species within the Diani environment via publicity, promoting conservation ideals, raising awareness and educating the public.

7.6 Translocation in an Anthropogenic Habitat

I understand that vervet monkeys released into an area of human habitation is not supported by IUCN. Nevertheless, it is important to recognise that in this scenario the individuals were being returned back to the environment from which they originated. Potential conflicts arising from release in to an anthropogenic environment were mitigated by extensive education of the human population surrounding the release site, intensive post-release data collection that allowed for potential conflicts to be anticipated and mitigated quickly and efficiently, and ultimately the termination of the release programme was always a consideration if any situation became unmanageable. Tropical forests continue to disappear at a phenomenal rate leading to increasing incidences of human/wildlife interactions (Cowlishaw and Dunbar 2000; Wallace and Hill 2012). The numbers of displaced, injured and ex-pet primates being kept in captivity will only increase as their natural environment continues to disappear. Rehabilitation in conjunction with human/wildlife mitigation and intensive and continued education may make it possible to release smaller bodied primates back to wild habitats even in proximity to human habitation, provided a strict series of criteria are adhered to.

This project shows that primates can be released in to human modified areas with minimal negative impact upon humans or animals. However, just because something can be done does not mean it should be done. Diani is a fairly unique location where the human population has established a residential area and the primate inhabitants have continued to survive, and even thrive in some cases. The predominant local industry is tourism, and primates are generally considered of benefit this trade. There is little agricultural land, commercial or subsistence, an industry that would consider primates to be pests due to crop raiding. In areas on the outskirts of Diani, with increased levels of subsistence farming the primate population is largely absent (pers.obs), most likely due to lack of suitable habitat and persecution from human inhabitants. In situations like this project, where individuals are being returned back to the area from which they were taken or rescued, that happens to be anthropogenic but direct conflict with humans can be reduced, releases can be justified provided thorough planning, post-release monitoring and mitigation can be supported for the life of the release individuals and future generations. However, I would not advocate anthropogenic environments to be considered as release areas if they completely lack any form of natural habitat, have the presence of agricultural lands or the release animals did not originate from that environment. In addition, larger bodied primates that have been reported to, or have the ability to, inflict life threatening injuries up on humans should not be considered for translocation in close proximity to humans.

7.7 Impact on Neighbouring Groups

In the thesis I investigated the consequences of a rehabilitation release process upon the release group of vervet monkeys (Chapter 5 and 6) and superficially upon the habitat (Chapter 3). There is concern about the impact of translocations up on indigenous communities and is a commonly cited reason for not releasing animals in to areas already occupied by wild conspecifics. One major concern is disease transfer. In this study, all release individuals were given a comprehensive medical examination and the individuals tested for all diseases of concern, provided the facility to do so was available in country. The ability to test for simian HIV was not possible within the limits of clinics within country. As most of the release vervet monkeys had been within the facility for many months and years it was reasonable to assume that signs of illness would have been spotted due to poor condition or repeated illness of individuals. Even in cases where this may not be true the release individuals were returning to an environment from which they came, and therefore would not be introducing new illnesses

in to the primate community as they must have been contracted from the community originally.

The second concern is competition between existing population and release groups. There is some indicatory evidence of competition between Hotel and Release group in terms of habitat use. Figure 7.1 shows Hotel groups home range in Year 1 (December 2011 - November 2012) and Year 2 (December 2012 - November 2013) of data collection, and the home range of Release group within the same time periods. Release occurred in May 2012, half way through the Year 1 map. The two groups met on three recorded occasions in June 2012; territory disputes were recorded but no injuries to either group were inflicted. After these interactions Hotel group did not enter Release groups home range again until June 2015 during which time a new male joined the group (Chapter 5, Table 5.4,). While the home range location of Hotel group clearly changed between the two years, the size of the home range remained unchanged at 19.1 ha. To the contrary, the home range of University group did not alter as dramatically in the same time period (Figure 7.2). Superficially, comparing difference between the data calculated in Chapter 4 and Chapter 5, there appears to be little change to the activity budget of Hotel group after Release group were released. However, differences in feeding ecology are notable. Similar changes in feeding ecology are also noted in University group, and therefore these differences could be the result of environmental influences rather than competition with Release group. Adaptation to life in the wild presents many obstacles for the translocated individuals and one of these should not be excessive food competition through poor selection of the release site, nor should the wildlife already occupying the release site be compromised by this competition.

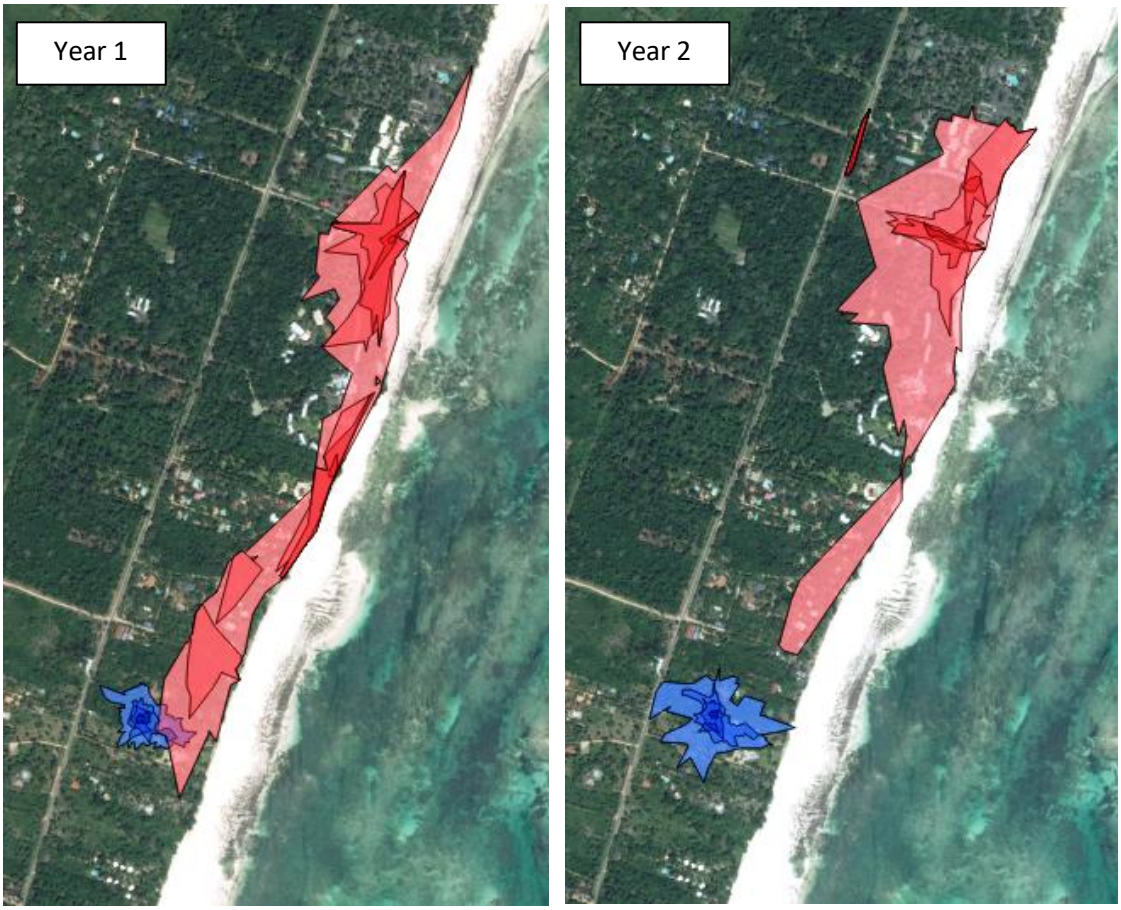


Figure 7.1 LoCoH utilisation distribution for home range of Hotel group in pink and Release group in blue. Year 1 displays Hotel groups home range from December 2011 - November 2012 and Release groups home range from May 2012 - November 2012. Year 2 displays both groups home range from December 2012 - November 2013. Shading indicates level of use by each group, light and transparent areas represent lower levels and darker and opaque areas higher levels of use. Scale 1:15,000 ©2016 DigitalGlobe ©2016 GeoEye Earthstar Geographics SIO ©Microsoft Corporation

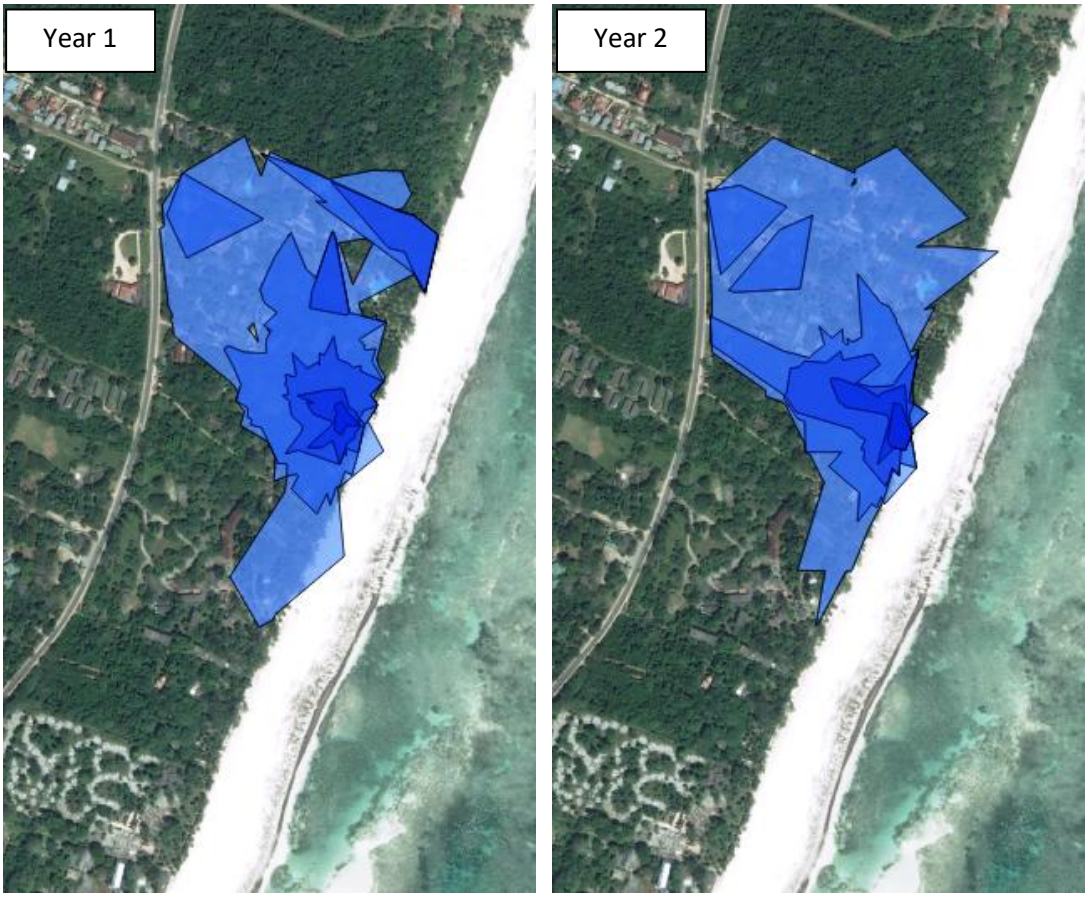


Figure 7.2 LoCoH utilisation distribution for home range of University group. Year 1 displays home range from December 2011 - November 2012. Year 2 displays home range from December 2012 - November 2013. Shading indicates level of use by each group, light and transparent areas represent lower levels and darker and opaque areas higher levels of use. Scale 1:8,000 ©2016 DigitalGlobe ©2016 GeoEye Earthstar Geographics SIO ©Microsoft Corporation

7.8 Limitations

In hindsight there are a range of improvements I would have made to my data collection and analysis.

Human Food Availability

A more detailed measure for human food availability should have been devised. For this thesis I used visitor numbers to Colobus Conservation as a proxy for human food availability. However, obtaining individual occupancies rates of each hotel and guest house within the range of all research groups would have provided are more reliable, and site specific indication of human food fluctuations. Additional information including monitoring of garbage pits and rating pest primate management techniques would have provided further information on the

ease of access the research groups had to the human food. In turn, this more detailed information would have better advised on the availability of human food specific to each research site.

Modified Whittaker Plots

An increase in the number of modified Whittaker Plots conducted per control group home range and within Release site would have been beneficial. Due to the heterogeneous mix of indigenous and exotic plants it is possible that a true reflection of the range of plant species present has not been gained, especially in relationship to Hotel group.

Identification of Grass Species

It was not until the analysis of the data that I became aware of how important grass was within the diet of all three vervet groups. Due to anthropogenic habitat modifications including the introduction of various exotic salt resistance species for manicured lawns, and the regular cutting of the grass in these areas, it was not possible to reliably identify all grass to species level. In areas where grass was naturally occurring and allowed to grow, species identification was possible. However, for data collection purposes grass was not identified to species level in the same way all other natural plant items were.

Access Permissions

Access to the home range of all groups proved problematic at some point during the data collection period due to numerous private landowners in each location. The most common problem across all three groups was access to areas that were secured with locked gates overnight from 6pm-7am meaning that following Research group to their sleeping site and connecting with them before they left the following morning was not always possible or occurred from a distance greater than was desirable.

7.9 Future Research

This research and subsequent analysis, has highlighted many areas of future research that would be of interest.

Continued Analysis on Rehabilitation Releases within Diani

A much larger range of data than is presented in this thesis was collected during the field period. Pre-release these included life-skills training, predator and electricity awareness training, and post-release data includes group proximity, wildlife interactions, predator avoidance and sleeping site use. In addition an entire replication of this research was also

conducted on two indigenous groups of Sykes monkeys and an attempted integration of four rehabilitated Sykes individuals in to an indigenous wild group, which was in part successful. However, division of my work commitments and time restraints of the write up period limited the analysis to what is presented here. There is valuable data and information contained within this research and analyses to fully understand its implications are required.

Detailed Investigation of Dietary Overlap and Competition in the Diani Primate Population

Adaptation to life in the wild presents many obstacles for the translocated individuals and one of these should not be excessive food competition through poor selection of the release site, nor should the wildlife already occupying the release site be compromised by this competition. Therefore, feeding requirements of the existing wildlife need to be identified and quantified. Data on feeding rates of Sykes monkeys in all three study sites has already been collected and for colobus at the release site. Future analysis of this data to understand dietary overlap and competition between the release vervets and other primate populations is recommended. In addition a yearlong comprehensive data collection of the feeding rates of baboons within the Diani environment is also be recommended, before embarking on further vervet releases in this area.

Further Detailed Rehabilitation Release Research in Other Locations

While this project has assessed and reported on many aspects of the rehabilitation release of the vervet species, I do not feel it is a complete project. I would encourage further and future translocations of vervet monkeys, provided a stringent and robust methodology is planned and followed and the outcomes reported on scientifically. As discussed in section 7.3 this project was not without failing and all of these areas can be improved upon to establish more robust methodology. Additionally, the location for this project was a fairly unique environment and the outcomes may not be replicated in a more natural habitat. Predator awareness training against species that actively hunt vervet monkeys, such as leopards, are likely to be more complex (pers.obs) and experimentation of these methods is required. I would advocate the replication of this study translocating vervet monkeys or other semi-terrestrial primates in to a more natural environment.

Kinship Ties in Artificially Formed Groups

Social network analysis revealed that Release group displayed higher levels of cohesion than the naturally formed wild groups. This led to the suggest that their group cohesion could be attributed to orphaned infants associating with only unrelated individuals upon whom they

solely relied for social and physical support, potentially forming bonds that replicate kinship. These bonds would not be primarily single generation matriarchal lines as recorded in wild vervet groups, but more inclusive, multi-generation 'web-like' networks. Further exploration of the possibility of early association resulting in the replication of kinship ties in such artificially formed groups is required to enhance understanding of group formation and bonding in groups scheduled for any form of translocation.

7.10 Conclusion

As habitats continue to become fragmented, increasing extinction risks of primates the importance of translocation programmes will increase (Cowlishaw and Dunbar 2000). Knowledge that wild-born, rehabilitated monkeys can be successfully returned to the wild, in close proximity to wild conspecifics has implications for the conservation of wild and captive populations in terms of translocation programmes, both conservation and welfare orientated. Guy and Curnoe (2013) made a basic decision tree and series of recommendation, based on survey results, literature and IUCN guidelines, for rehabilitation releases of primates. Within these recommendations they highlighted that assessment is a key component of rehabilitation, both pre- and post-release. An initial minimum quarantine of 31 days for primates is recommended during which time thorough medical checks for disease and parasites must be conducted, alongside behavioural assessments to ensure the animals are suitable for rehabilitation (Guy *et al.* 2014). Social group formation should match wild groups and an environment that promotes the development of natural behaviours and skills, i.e. bonding, predator avoidance.

This study presents data that supports all of these recommendations and provides areas for further consideration. Chapter 3 highlights the need to not only conduct a thorough habitat assessment but to ensure the habitat is continuously monitored for a minimum one year period before being deemed a suitable release location. Chapter 5 and 6 both highlight that extended periods of rehabilitation related captivity, where new infant individuals are introduced over time, replicating wild group formation benefit group cohesion and ultimately post-release survival. The desire to form groups and release them quickly to prevent the development of stereotypic behaviour may actually contribute to low levels of success reported in rehabilitation releases. In addition a lack of pre-release transportation was deemed to be highly beneficial to reducing pre-release stress that impacts upon group bonding. As transportation is generally unavoidable it is recommended that more emphasis

needs to be given to facilitating pre-release groups with larger and more functional, in-situ, pre-release enclosures. This would allow groups to spend prolonged periods of time recovering from the stresses of transportation, adapting to their new environment and reaffirming their group bonds, before being released. Finally this study presented an assessment for translocation success not traditionally used. Using data collected from indigenous wild populations within the same time frame as the post-release monitoring as a baseline for comparing biological and behavioural measures of the released animals. It is hoped that future translocations will follow a similar process. The comparison of biological and behavioural measure between indigenous control groups and a newly released group can provide information that is crucial for understanding factors contributing to rehabilitation release success and assist in success evaluations (Pinter-Wollman 2009; Strum 2005). Future translocation can benefit from the knowledge gained during this rehabilitation release and each new monitored and reported translocation will add vital information to the developing primate translocation model.

Appendix 1 Pre- and Post-release Protocol

Advisory Note
This document merges, and references, protocol developed by Colobus Conservation since it was established in 1997, with pre- and post-release protocol developed for the 2011 vervet rehabilitation release project. The protocol presented here is the protocol followed for the release reported in this thesis, and therefore protocol detailing transportation to the release site is not included. In addition, analysis and lessons learnt from this rehabilitation release will result in a number of recommended improvements and additions to this protocol for future releases. Some of these recommendations are outlined in the discussion chapter (Chapter 7).

Through-out this document 'personnel' refers to all Colobus Conservation staff members, researchers and volunteers. Whenever possible post-release monitoring will be conducted by a dedicated release team in the way outlined in this document. When personnel numbers do not allow this a minimum of twice daily census and health checks must be performed by staff members and supplementary food distributed as required.

1.0 Rescue

In animal welfare cases where animals are found, or brought to Colobus Conservation that cannot survive in the wild, they enter Colobus Conservations rehabilitation and release program. Methods for rescuing primates are outlined in Colobus Conservation Field Methods Manual.

1.1 Incident Report Form

Each individual brought to Colobus Conservation is recorded using the Incident Report Sheet and are assigned their own individual reference code. See section 8.1 of Appendix 1 for an example of an Incident Report Sheet.

If a veterinarian is required to assess a case, they must fill in the appropriate section of the Incident Report Sheet, sign and stamp their comments. All veterinarians attending to cases on behalf of Colobus Conservation must be registered with the Kenyan Veterinary Board.

1.2 Reporting to KWS

All animal welfare cases that involve the handling of a live animal are to be reported to the KWS Head Veterinarian and scans of the Incident Report Sheet e-mailed. Major changes to the treatment of animals, release of an animal following recovery, or death of an animal is also to be reported as soon as possible after the incident.

Euthanasia

If euthanasia is recommended by the attending veterinarian, a phone call or email to the KWS Head Veterinarian is necessary prior to the administration of the drug. If circumstances of the incident to not facilitate this, a report must be filed as soon as possible after the case is concluded.

2.0 Rehabilitation

Individuals that are brought into Colobus Conservation's care, go through rehabilitation and are released back into their home environment. Individuals may require relatively short-term, medical rehabilitation, while others, such as orphans or ex-pets, required long-term rehabilitation, including pre-release training before release.

Please note that the procedures developed are different for each species rehabilitated at Colobus Conservation. The remainder of this document focus' on procedures used for vervet monkey rehabilitation.

Upon admission to Colobus Conservation all individuals are given a full health check, treated medically as required, and enter either short-term or long-term captive care. All captive care is conducted using the policies, procedures and methods outlined in additional manuals: Field Methods, Veterinary Care, Captive Care of Weaned Primates and Enclosure Enrichment.

All policies, procedures and methods adhere to national and international standards of animal care and welfare, in accordance with KWS, PASA and GFAS.

2.1 Short-Term Care

Individuals in short term care are housed alone in the veterinary clinic or quarantine until they have regained their health and can be released back to their home group. Individuals in short-term care are normally treated and returned to their group within a few days, to 6 weeks, depending on the nature of their injury.

If the home group is unknown given the circumstances of the animal welfare incident, the individual must be released at the location it was found, making allowances for proximity to roads, electricity cables and other notable dangers.

2.2 Long-Term Care

Long-term care occurs in incidents of orphaned infants, immature individuals without a known provenance, or ex-pets of any age. Individuals under these circumstances enter Colobus Conservations long-term captive care program. The program has been designed to develop skills that will eventually allow for a wild release as part of an artificially formed group.

Individuals in long-term care are quarantined either individually, in human care or as part of a small group, for a minimum of thirty days. During this period they undergo a thorough health check by a KVB registered veterinarian. This health assessment includes a clinical examination, faecal screening for parasites, haematology and serum biochemistry to aid disease detection, serological testing to detect infectious diseases and microbial culture to isolate and identify causes of the disease, and subsequent treatment and/or vaccination (see medical form in section 8.4 of Appendix 1). Once medically healthy, individuals less than a year old began rehabilitation in orphan care and the nursery enclosure, before being transferred to the pre-release enclosure. Older individuals are integrated directly into the pre-release enclosure.

3.0 Pre-release Protocol

3.2.1 Habitat Assessment and Release Site Selection

The most important criterion upon which a release site needs to be assessed is its ability to provide sufficient nutrition and predator safe sleeping sites throughout the year to support released animals (Britt, *et al*. 2004), without detrimental impact up on fauna and flora already inhabiting the area. Ideally, this requires detailed knowledge of the natural diet and sleeping site selection of the species to be released (Britt, *et al.* 2004). This base line data has been collected for the vervet populations.

When selecting a release site consideration must be given to the future plans of the area. Diani is entirely in private ownership, divided into numerous sub-plots that are owned by commercial traders and local residents. Once potential release sites have been identified, discussions with the relevant land owner(s) will occur to investigate the future plans for the site. If a site is due for development or sale at any point in the future it will be ruled out as an area for release site consideration.

Population Assessment

A detailed population survey and assessment of a proposed release site must be conducted prior to any translocation. The assessment must determine whether any population of the species to be released persists in the area, and if so details of population status and biology must be recorded. In addition, an assessment of other species that may be directly or indirectly impacted by the proposed translocation must be made. Release sites with resident populations of the species to be translocated require different considerations to those without resident populations. For example, if population reinforcement is not required for long-term viability of the resident population, translocation should not occur in the area as the potential risks outweigh the potential benefits. In addition, both sites with and without existing populations, require assessments to determine whether translocations can establish/maintain a viable population into the long-term. Locating suitable release sites without an existing resident population can be achieved by matching distribution data with data from habitat surveys (see Habitat Assessment below). Finally, an assessment of potential carrying capacity must be conducted. This will require data on both habitat availability and species home range requirements, ideally from an assessment at the release site or by using data from wild conspecifics or closely related heterospecifics in similar habitats (e.g. similar latitude, altitude, forest structure, floristic composition etc.).

Habitat Assessment

The aim of habitat assessments is to determine whether sufficient resources are available to support the translocated population. It is essential that the release habitat resembles the natural habitat for the species as closely as possible. In cases where the site has an existing population, or one that has only recently become locally extinct, a comprehensive assessment is still required to ensure that there have been no significant changes in habitat quality. Long-term habitat assessment, both before and after release, can help increase the probable success of a translocation programme (Cheyne 2006; Cheyne *et al.* 2012). The structure and composition of the habitat in the potential release site requires assessment, with areas of existing and potential fragmentation identified. The availability of suitable food, water and adequate sleeping and refuge sites from predators are all essential requirements for assessment (Abbott 2000; Britt *et al.* 2004; Cheyne *et al.* 2006; Cheyne *et al.* 2013; Isbell 1990; Nakagawa 1999). Finally, in areas with significant seasonal food availability, surveys should be conducted over a period of time that allows a complete cyclical/annual assessment of food availability. This should be assessed in parallel with existing knowledge of the ecology of the species to be translocated.

For tropical forests, modified Whittaker plots have been proposed for multi-scale sampling (Stohlgren and Chong; 1997, Ganzhorn, 2003). Nested subplots of different sizes within a larger plot allow the development of species to area curves and estimation of the number of species in a larger un-sampled area. Data sheets used for habitat assessments are detailed in section 8.2 of Appendix 1.

Selected at random, each modified Whitaker plot surveys four levels of the habitat:

- A: one 50m x 20m (1000m^2) plot detailed all trees $\geq$ 30cm diameter at breast height (DBH) recording species, percentage of canopy cover, crown width, tree height, DBH and bole height.

Within plot A, a further twelve rectangular plots with side ratios of 1:2 were surveyed at varying sizes reflecting different vegetation stratums of the habitat.

- B: Two plots of 7.07m x 14.14m (100m^2) were surveyed and all trees <30cm $\geq$ 10cm DBH recorded, noting species, percentage of canopy cover, crown width, tree height, DBH and bole height.
- C: Four plots of 2.24m x 4.47m (10m^2) were surveyed and record all bushes, shrubs and trees $\leq$10cm DBH, noting species, percentage of canopy cover for the trees or percentage of ground cover for the shrubs and bushes, tree height and DBH.
- D: Six plots of 0.71m x 1.41m (2m^2) were surveyed and record the herbaceous vegetation, noting species and percentage of ground cover (Figure A1.1).

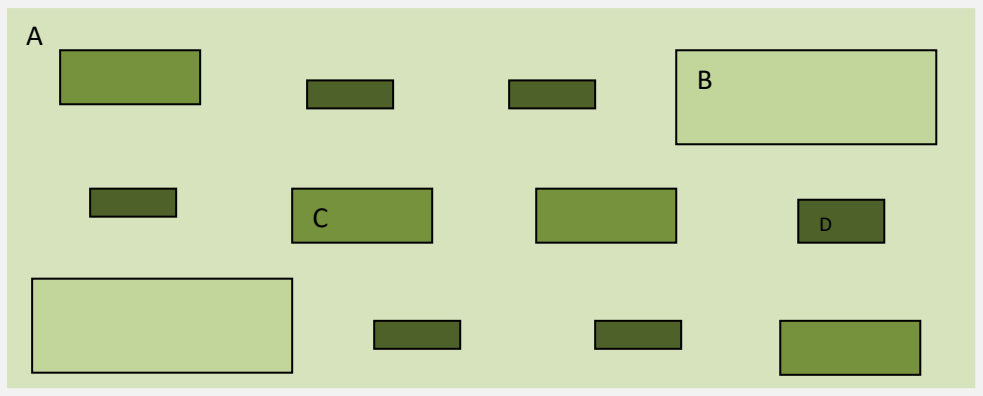


Figure A1.1 Modified Whittaker Plots, consisting of nested subplots (Strohlgren and Chong 1997). A, B, C, D and associated colour coding indicate subplots of different size as detailed in the text.

This habitat survey is repeated, in the same month, using the same plots, one year post-release. Results from the two surveys are compared to indicate what impact the release group has had up on the environment and to monitor any detrimental effect this may have up on other species at the site. In addition to increasing understanding of the sites carrying capacity.

3.2.2 Rehabilitation of Release Animals

Animals brought into captivity as juveniles or infants will not have had the opportunity to learn the skills that they need to survive in the wild (Tutin *et al.* 2003). It is important for rehabilitation projects to provide training environments to allow these skills to be developed (Earnhardt 2010).

Preparation of the release group occurs daily and throughout the entirety of their captive care and the following points must be adhered to:

- From the moment an individual is integrated in to the pre-release enclosure, a strict 'hands off' policy is implemented.
- Life skills' training includes environmental enrichment to encourage natural foraging behaviour and daily exposure to wild foods.
- Care is taken not to encourage pest behaviours and therefore no 'crop' food or enrichment involving human food packaging is presented.
- Once in the pre-release enclosure direct hand feeding never occurs unless medically required.
- In the months directly prior to release, the release group undergo predator and electricity awareness training to ensure they have appropriate responses to location specific dangers.
- Only individuals displaying appropriate predator awareness skills, consuming wild foods and recorded sleeping high in the enclosure are considered viable for release.

Colobus Conservations Primate Captive Care and Enclosure Enrichment manuals detail further these processes and include a recommended daily enrichment schedule for life skills training.

3.2.2.1 Predator Awareness Training

The primates subject to release into the Diani environment need to be aware of, and able to respond appropriately to, four main predators: snakes, dogs, baboons and humans. All predator awareness training is conducted in the three months directly prior to release, to ensure that any learning is retained and that habituation does not occur from repeated

exposure. The release group is exposed to a maximum of three predator awareness training sessions per model to prevent over exposure and habitation to the danger. However, once the individuals, and group as a whole, respond correctly to training session no further sessions are required. The duration of each training session should be no longer than a few minutes. Predators do not move slowly, or wait to be seen by their prey, therefore the release group need to be responding to the danger in the instant it is first encountered. Research assistants will monitor each of these interactions from the viewing windows. All individuals are scored simultaneously, it is therefore necessary to ensure there are enough researchers to accomplish this task. Each researcher should be assigned specific individuals to monitor. In addition, it is recommended that predator awareness training exposures are video recorded to enable playback of the event in case an individual's response is missed. Observed responses of the focal animals will be ranked from 0 – 5, where:

0 - Predator seen and individual approaches and/or attempts to initiate contact with predator
1 - No response (continuation of current behaviour / change to another non-predation related behaviour)
2 - Curiosity towards predator, including visual attentiveness
3 - Alarm calling and/or appropriate positioning in response to other members of the release group alarm calling and moving to an appropriate position
4 - Alarm calling and/or appropriate positioning in direct response to the predator
5 - Initiate alarm calling and moving to appropriate position

An example of a data sheet used for predator awareness training is shown in section 8.3.1 of Appendix 1

These rankings are then used to rate the group as a whole for predator awareness, by taking a mean. Individual rankings of 3-5 will be considered satisfactory, if combined with an overall group ranking of 4-5 for each predator presented. If the pre-release group all respond satisfactorily on the first exposure no further training will be provided. If a few individuals do not respond satisfactorily to the first exposure the training can be repeated not less than one week later, for a maximum of three exposures.

Where an individual or groups response to a model predator is deemed repeatedly unsatisfactory, its presentation is to be paired with the appropriate alarm call. Vervet monkeys

have species-specific alarm calls and responses. Any playback of alarm calls that is required will incorporate the correct call for the model predator presented, ensuring that the response displayed is also species-specific. Playback exposures are to be repeated until the individuals display the desired response, at a minimum of one week intervals, for a maximum of three exposures. If individuals are not displaying correct responses after these six exposures their suitability for release must be reviewed.

Note: Playback experiments are not required if the initial exposure illicit the correct response as detailed above

Snake Awareness Training

A segmented, wooden model snake is presented to the pre-release group, hidden within their enclosure during the morning cleaning routine. It is important to ensure that the 'set-up' used for the training is constructed out of view of the monkeys, and put in the enclosure as a finished product.

- A hollow structure that the monkeys are familiar with, for example a log or plastic piping, is used to conceal the model snake.
- With a length of fishing line (or other non-visible line) tied around the neck of the model snake, insert the model in the hollow structure. The model snake can now be manipulated and moved by personnel from outside the enclosure (Figure A1.2).
- During enclosure cleaning, place the hollow structure inside the enclosure, with the fishing line trailing from inside the structure, leading out from underneath the enclosure door.
- Once the monkeys are allowed access in to the enclosure a research assistant can begin to pull the model snake out of the hollow structure, across the enclosure and out underneath the enclosure door (Figure A1.3). This exposure should begin soon after the monkeys are allowed access to the enclosure to prevent self discovery of the model and potentially reduce its effect. However, it is also important to ensure that the majority of the group are within sight of the model.
- This model was tested on a wild Sykes group, prior to exposing the captive pre-release group to ensure it was a viable training model.

Figure A1.2 Example of how a model snake can be manipulated from a safe distance by a researcher for the purpose of snake awareness training.

Figure A1.3 Model snake being remotely manipulated to move through the pre-release enclosure for the purpose of snake awareness training.

Dog Awareness Training

In separate training events the pre-release group is exposed to two live dogs, one large and one small. The dogs are walked around the outside of enclosure on a lead by a researcher. Due to enclosure design, the dog cannot come in to direct contact with any of the monkeys, limiting the chance of attack or disease transmission.

It is expected that the monkeys respond to the dogs in the same manner regardless of size. In the Diani environment, small dogs can be equally as dangerous as the large dogs, especially to infants and juveniles.

Baboon Awareness Training

Due to the regular, and unpredictable nature of wild baboons visiting the pre-release enclosure, this exposure cannot be classed as training. However, during visits by the wild baboons, the pre-release monkeys will be observed and scored, as above, for the appropriate predator response.

Wild monkeys in Diani, generally vacate the area when baboons enter, moving to a different section of their range. If once released, the release group do not show appropriate reactions when wild baboons are encountered, researchers will herd the monkeys from the area, as quickly and quietly as possible in an aim to recreate how wild vervet monkeys in Diani respond to approaching baboons.

Human Awareness Training

The primary concern for human/primate contact is association of humans with food which potentially may lead to release primates approaching and threatening humans who are carrying food. This may ultimately result in euthanasia due to negative human/wildlife interactions. From the moment the rehabilitation monkeys enter the pre-release enclosure all direct contact with humans is stopped. During feeding periods, any monkey that attempts to take food directly from the carer is sprayed with water, which is an effective aversion technique.

Each enclosure is fitted with an anti-cage. Anti-cages are designed to facilitate human entry into an enclosure while preventing animal escape via a double door action. A person enters through the first door and locks it behind themselves; with the second door remaining locked, they are effectively in a small, adjacent cage to the main enclosure. Figure A1.4 shows an anti-cage. Ordinarily, and in accordance with Colobus Conservation protocol, people only enter the

anti-cage once the main enclosure has already been cleared of monkeys. Therefore entering the anti-cage while the monkeys remain in the main enclosure will be unusual. In order to instil a general level of human avoidance, selected humans will enter the anti-cage of the enclosure (the person is therefore kept protected from attack). Care will be taken to expose the monkeys to humans from a range of ethnic origins, ages and both genders. If the monkeys approach the anti-cage, the human will shout, bang and chase the monkeys away, with assistance from researchers on the outside of the enclosure. As with baboon exposure, training to avoid humans may need to be continued during post-release monitoring.

3.2.2.2 Anthropogenic Dangers

Due to the anthropogenic nature of Diani, the release group will come in to contact with dangers not experienced in more natural environments. The most frequently encountered and deadly of these are moving vehicles and uninsulated electricity cables.

Vehicles

Training the pre-release group to avoid moving vehicles within the enclosure is not possible. However, Colobus Conservation use two mitigation techniques to reduce wildlife-vehicle collisions within the Diani region; canopy bridges (colobridges) or speed bumps in areas where the habitat is not suitable for canopy bridges. However, speed bumps need local government approval and are generally only installed in areas where human life is at risk from road traffic accidents. In order to reduce the release groups risk of wildlife-vehicle collision, canopy bridges are installed in high risk areas within the release site and speed bumps requested if required. Additionally, each pre-release enclosure is fitted with a canopy bridge so the monkeys become familiar and comfortable with the structure (Figure A1.4).

Figure A1.4 An example of a canopy bridge installed within a pre-release enclosure.

Electricity Awareness Training

The second largest cause of fatalities among the Diani primate population is electrocution on uninsulated domestic and commercial power lines. It is therefore essential that electricity awareness training is part of any release groups, pre-release training. The ethics of conducting this training are carefully considered and the following points addressed:

- The electricity is generated by Fi-Shock Electric Fence Energizer, a battery powered, light-duty energizer designed for small garden animals and pets. The voltage of electricity the group is exposed to during training is 3.5KV +/-20%, a voltage in line with that used in electric fencing of primate sanctuaries (pers. obs.).
- Importantly, the flow of electricity used in the training is pulsed, not constant. Electricity flow for domestic and commercial used is a constant flow, meaning that once a monkey grasps a cable, the muscles contract in the hand or foot, and they are unable to let go of the cable. However, with a pulsed source, there is an interruption in the source of electricity. A pulse of electricity is emitted once every 3 seconds, this

allows ample time for the monkeys, to let go of the wire between electricity pulses, preventing prolonged exposure.

- The monkeys are observed at all times by two researchers during each training bout.
- The entire area below the cables is fitted out with hammocks, branches and a thick leaf litter floor, in order to break any fall, in the very unlikely event that any individual is stunned following contact with the training electricity cables. In addition, veterinarian personnel are to be on site for the duration.

The physical installation of this training device is also carefully considered;

- Electricity cables that are an exact replica of the cables used within the release site are required. Contact the local energy supplier for off cuts or spares.
- In order to receive a shock from live electricity cables, contact need to be made with two cables simultaneously and therefore, the model must also involve the same requirement (Figure A1.5 and A1.6).
- If the enclosure where the training is being conducted is metal, ensure there is sufficient insulation at any contact points between the cables and the enclosure to prevent the entire enclosure being electrified (Figure A1.6).
- Do not allow the monkeys access to an enclosure with live wires without an observer being present. Additionally do not allow the monkey access to the enclosure if the wires are installed but they are not live, otherwise the monkeys will learn that the cables can sometimes be touched safely.

Figure A1.5 An example of the set up for Electricity Awareness Training, note two parallel cables high in the enclosure, with hammocks, branches and leaf litter distributed directly below.

Figure A1.6 An example of insulation between the training electricity cable and the metal enclosure.

As with predator awareness training, electricity awareness training is conducted in the three months directly prior to release, to ensure that any learning is retained and that habituation does not occur from repeated exposure. The release group is exposed to a maximum of three electricity awareness training sessions to prevent over exposure and habitation to the danger. However, once the individuals, and group as a whole, respond correctly to electricity training sessions, no further sessions are required. The duration of each training session should be long enough to ensure that each individual has had the opportunity to approach the cables. The minimum exposure duration recommended is 4 hours, but longer exposures should be conducted whenever possible. The longer a monkey avoids the electricity cables the greater the enforcement that they understand the cables are dangerous and should not be touched. Research assistants will monitor each of these interactions from the viewing windows.

Data collected on individuals undergoing Electricity Awareness Training is all occurrence sampling, comprising of individual focal notes detailing proximity to the cables, shocks received, latency of the shock, how the individual responds to be shocked or seeing group members being shocked, alarm call etc. There is no scoring system for the exposure and complete avoidance of the cable by all group members is the desired outcome. It is expected on the first exposure all group members will receive a shock or see a group member receive a shock within the first hour. After this initial exposure the time between subsequent shocks should reduce. On the second exposure, it is expected that only a few individuals will receive a shock and thereby enforce the memory that these cables are dangerous. By the third exposure it is hoped that no individual approaches or touches the cables as the group have learnt that these are dangerous and need to be avoided. Provided at all group members have either been shocked themselves or observed a group member receiving a shock. If the group do not approach the cables at all during the second exposure, a third exposure is not required.

An example of the electricity awareness training data sheet can be seen in section 8.3.2 of Appendix 1.

3.2.2.3 Wild Foods

Pre-release monkeys will be encouraged to begin foraging on naturally occurring resources, via specifically selected environmental enrichment and provisioning of wild leaves, fruits and flowers, from the day they enter the rehabilitation enclosures. Ensuring they have an adequate knowledge of edible plants within the release site. Prior to release, close monitoring will occur from the research team, noting individuals' reactions to the wild food provided, which

individuals are eating the food and the individuals that are relying solely on human provisioned food. This information will be particularly important when introducing the animals to fallback foods which the species rely upon during periods of food scarcity, as it is essential that all individuals feed from this source.

The pre-release group will be monitored daily during the distribution of wild foods and each individuals response to the wild food will be scored, as follows:

1 – No interest in wild foods when presented

2 – Notices wild foods distributed but do not ingest – if individual lacks access due to ranking or not enough food, make note

3 – Shows interest in wild food, ingests a few mouthfuls, plays with food. Losses interest when other monkeys stop eating wild foods

4 – Very interested in wild foods, carries away or guards their own portion. Stops eating wild foods before it is all gone, or turns to provisioned foods (if the only wild food remaining is guarded by another individual than score as number 5)

5 – Dominates wild food supply, continues to ingest until all wild foods are gone.

These rankings are then used to rate the group as a whole for wild food consumption, by taking a mean. Individual rankings of 3-5 will be considered satisfactory, if combined with an overall group ranking of 4+.

An example of the wild food monitoring data sheet is in section 8.3.3 of Appendix 1

3.2.2.4 Sleeping Location

In order to increase an individual's post-release survival, it is essential that they adopt a sleeping position that is considered normal for wild con-specific. Wild vervet monkeys are recorded to sleep in small groups, high in the tree canopy.

Prior to release, the pre-release group will be visited after dark, twice a week and their sleeping location recorded using the following scores:

1 – On the ground alone

2 – On the ground with another monkey(s)

3 – Mid enclosure alone

4 – Mid enclosure with another monkey(s)

5 – Top of enclosure alone

6 – Top of enclosure with another monkey(s)

These rankings are then used to rate the group as a whole for sleeping location, by taking a mean. Individual rankings of 4-6 will be considered satisfactory, if combined with an overall group ranking of 4+.

An example of the sleeping location data sheet is in section 8.3.4.

3.2.2.5 Group Cohesion

Three months prior to release, the release groups composition will be finalised (subject to removal of any individuals deemed to be unsuitable following pre-release training) and no additional individuals will be introduced. Group cohesion will be assessed using wild social dynamics as a representative baseline, taking in to account limitations enforced due to the confinements of the pre-release enclosure. Social networks will be created, based on grooming, social contact and proximity, recorded as described in the post-release protocol (section 5.1 of Appendix 1). Each pre-release enclosure allows individuals to be more than 5 meters away from the focal animal and still be in visual contact. Individuals will also be able to move into neighbouring enclosures, increasing this distance further and has the addition of visual barriers.

3.2.3 Pre-release Assessment

In the months prior to release each individual, as well as the group as a whole, will be assessed for their suitability to be included in the release program. The assessment is based on medical health and behavioural suitability. Section 8.4 of Appendix details the individual assessment form. Individuals who are not suitable for release will be removed from the group for continued rehabilitation and hopeful inclusion on future releases.

Health assessment

Prior to release day each monkey will be given a second health check, identical to the health check they received during their quarantine period. Animals kept in captivity are susceptible to parasite infections and human diseases that may be alien to the wild population (Cunningham 1996). Failing to carry out pre-release medical checks can result in disease transmission to wild populations, both conspecifics and other species (Viggers *et al.* 1993).

In order to be considered suitable for release an individual must not have any ailment or condition that will compromise their survival, group survival or negatively impact on animals living within the release site.

Behavioural Assessment

In order to qualify for release individuals are required to display appropriate responses to all life skills training, including predator awareness, electricity awareness, wild food foraging and sleeping position. In addition, for three months prior to release daily activity budgets, including proximity data will be collected, using the same methods and data collection sheets as designed for the post-release monitoring (section 5.1) to confirm suitability for release. This systematic assessment of behaviour will highlight any individual who is seeking human contact or displaying stereotypic behaviour, both of which will affect post-release survival. Finally, this data will allow for comparison of time budgets pre- and post-release and changes in hierarchy.

In order to be considered viable for release an individual must have adequate scores relating to all aspects of pre-release training, display normal behaviour for the species as appropriate within a captive environment and is a cohesive group member.

3.2.4 Tracking Device

Tracking devices such as radio- or GPS-collars are vital to monitoring. Radio-collars have been used for several releases of vervet monkeys (Guy *et al.* 2011; Wimberger *et al.* 2010a). Where funding allows each release individual should be fitted with a radio collar to ensure knowledge of each individuals outcome is guaranteed. If this is not possible, selection for collars will be based on those individuals noted as integral to the group with high centrality or high vulnerability, .e.g. low ranking members, as calculated from social network analysis. GPS collars are recommended whenever finances permit as they allow remote data collection when animals cannot be physically located.

It is vital that any tracking device used does not negatively impact up on the survival of an individual. Therefore the weight of an individual's tracking device must not exceed a maximum 5% of an individual body mass (Animal Care and Use Committee 1998).

In this release each individual will be radio collared using collars supplied by Advance Telemetry Systems, Model number: M1555 - mammal zip tie collar, weighing 20g with a battery life of 502-897 days.

4.0 Release

Release day will be scheduled for a period that offers optimal resources and minimal resource competition for the monkeys being released. Therefore, release is anticipated to occur in May, one month after the on-set of the long rains when numerous trees are in full fruit and flower, insect numbers are high and plentiful water is available.

Released primates will be monitored for a one-year period, ensuring that the research team can monitor the animals through the toughest point of the year (January-March dry season) when fallback foods are most important. This will enable assessment as to whether wild food pre-release exposure could be improved. Supplementary feeding will be provided for the first four-eight weeks post-release, with quantities given reduced weekly to slowly wean the release group off provisioned food. Intervention in the case of illness or injury and support from predators will be given, when required, throughout the year. After this time they are subject to the same assessment by Colobus Conservation as all wild primates involved in a welfare event.

Over the course of the first year post-release the contact time the research team will spend with the release group will gradually reduce with the aim to create a self-sustaining group over a gradual process of reduced support.

4.1 Release Day

- Release day should be planned for four weeks after the start of the short or long rains (April or November)
- The release should take place on a Sunday as this is a day with reduced human traffic through the property
- It is likely that wild primates will be on the property at the time of the release but if possible, release when they are not present. Baboons should not be present when the monkeys are released
- Final visual checks of individual health condition are to be conducted in the morning by the release team
- After the monkeys have been fed and watered, the group will be released by one person, quietly opening the enclosure door
- No fuss or cheering is to be made. Only members of the release team are to be present at the time of release. Human numbers are to be kept to an absolute minimum

- A door of the rehabilitation enclosure is to be left open in case any individual(s) choose to return and use the enclosure as a safe refuge. The door needs to be loosely tied to prevent the door opening fully and allowing baboon access. A gap sufficient for the largest release animal is the maximum that is required (Figure A1.7)
- Researchers are to follow the monkeys throughout the day and leave them only as they are settling down for the night in their sleeping site. Full research monitoring protocol is to be conducted throughout the day

Figure A1.7 Illustration of the enclosure door fixed in a partially open position. The door is secured with a rope tie, but wedged open with a large stone. This allows the release group access to the pre-release enclosure, while keeping the area safe from baboons.

5.0. Post-release

5.1 Monitoring

Ideally, the release group should be monitored for minimum of 12 months post-release, initially visited daily by two researchers according to the schedule below. This schedule can be adjusted according to the conditions of the release group, as not all groups will adapt in the same manner, some requiring more monitoring time and others requiring less monitoring time. Group and individual acclimation to the wild will be monitored very closely in the beginning stages of the release to determine when is an appropriate time for the research team to begin reducing the monitoring.

Months 1-3: The release group will be monitored daily from dawn until dusk, comprising of a morning and evening census, two focal sessions (morning and afternoon), collecting data on behaviour, feeding ecology, day and home range, proximity, wildlife interactions and sleeping site use.

Month 4: The release group will be monitored for five full days, conducting the research as detailed above, and two half days of monitoring, conducting the research as detailed above, but with only one focal session. These partial days allow the monkeys to acclimate to, and interact with, their environment on their own, slowly decreasing their dependence on the human research team.

Month 5: The release group will be monitored for three full days, and four half days of monitoring, conducting the research as detailed above.

Month 6: The release group will be monitored for seven half days, conducting the research as detailed above.

Month 7-9: The release group will be monitored for five, reducing to 3 half days per week, conducting the research as detailed above.

Month 10-12: The release group will be monitored for two half days per week (one morning and one afternoon) to allow focal follows and feeding ecology during the dry season to occur, with an additional one contact per week for the purpose of conducting only the census, conducting the research as detailed above.

Full days are dawn until dusk and half days are dawn until midday, or midday until dusk.

Ideally, a primate release should only be conducted when an adequate research and release team is in place for post-release monitoring. However, minimum post-release monitoring is set at twice daily census and health checks, to be conducted by trained staff members for the first three months, reducing in intensity as per the monthly schedule above.

Daily Census

A census of the group is taken at the beginning and/or end of each research period as the group descends from or ascends to their sleeping site. Each known group member is recorded as present or absent. Infants born to group females are immediately classed as group members, immigrating individuals were classed as group members after a consistent presence of two weeks, emigrating individuals are recorded as such only if seen alive, either alone or with another group, after a two-week absence from the group. Individuals are recorded as dead only when their death is witnessed or an identifiable body discovered. Individuals absent from the group, but with no confirmed outcome are classed as missing.

The second part of the census is a once weekly, visual health score index for each individual, where:

1 - in poor health or condition, has server wounds or emaciated

2 - in below average condition, under weight, dull eyes and patchy coat

3 - in adequate condition and adequate weight

4 - in above average condition, good body weight and thick coat

5 - in excellent condition, good body weight, thick glossy coat with no patches, foraging and feeding on wild foods

Any individual scoring two or below will be assessed for intervention requirements and where possible treated within the group, allowing it to remain wild.

An example of the census data sheet is in section 8.5 of Appendix 1.

Behavioural Data Collection

Instantaneous focal sampling (Altmann 1974) will be used to gain detailed information on specific classes of individuals. Focal individuals are selected using random sampling; rotating according to a fixed, randomly selected schedule, through all individuals (Altmann 1974). This method prevents prominent individuals from being studied more frequently than non-prominent individuals and ensures that different age and sex classes of monkeys are studied at different times of the day, reducing bias in possible time associated behaviours such as feeding behaviour and species eaten.

Focal follows occur continuously throughout each research period. Each individual focal is 20 minutes in length with instantaneous sampling occurring every minute, followed by a ten

minute period to collect and order any plant samples for later identification. Up to twelve focal sessions are to be completed during each morning and afternoon study period, with a different focal animal being sampled in each 20-minute session.

Behaviours are classified as one of 25 categories. For behaviours where individuals other than the focal individual are involved, the ID of the additional individual(s) is recorded. Finally, details of food items consumed are recorded detailing food type (fruit, flower, seed, leaf, grass, animal matter, human and other) and the species. Unidentified species are collected for later taxonomic identification. Due to the anthropogenic environment, groups are able to access human food. Human food items ranges from fresh produce, cooked goods, garbage and with very rare occurrence crop raiding. Human food is located both within and outside of buildings. All food items accessed from a human source are recorded as human food, including fruits that grow naturally in the wild environment i.e. mango (*Mangifera indica*) and coconut (*Cocos nucifera*). When human food is recorded as being consumed additional information on how it was accessed is also recorded.
An example of the focal data sheet is in section 8.6, focal and feeding ethograms are detailed in section 8.7 of Appendix.

Range Data

At the beginning of each 20 minute focal follow, starting and ending with the groups sleeping site, the geographical location of the focal individual will be recorded via a handheld Garmin GPS unit. Day range length will be determined for each group based on the shortest point-to-point movements of the group between consecutive GPS locations during full-day follows from 0600 h to 18.30 h.

Proximity data collection

Proximity data is collected using scan sampling (Altmann 1974) of adult, sub-adult, juvenile and infant individuals. Scan sampling is conducted at 10 minute intervals in conjunction with the focal follow. At minutes 0, 10 and 20 of the focal follow a scan sample records all group members that are in contact, $\leq$1 meter, >1$\leq$3m, >3$\leq$5 m and >5 meters from the focal subject.

An example of the proximity data sheet is in section 8.8 of Appendix

Wildlife Interactions

All wildlife interactions will be recorded using all occurrence sampling, A wildlife interaction is any interaction, peaceful or aggressive, with any other animal i.e. baboons, Sykes monkeys, a

different vervet group, dogs, snakes etc. An interaction may last just a few minutes to many hours and each interaction is recorded as one event.

An example of the wildlife interaction data sheet is in section 8.9 of Appendix 1

Phenology

To produce a quantitative measure of natural food availability, a range of plant species will require phenological monitoring. A species qualifies for phenological monitoring when one or more of its plant parts contributes >5% to any months dietary consumption. New species can be added to the list for the entirety of the study. Ten mature individuals of each species will be selected for monitoring and their GPS coordinates recorded. If ten mature specimens are not available for a specific species, phenological monitoring is conducted on all known individuals recorded within the appropriate groups home range. Once a month the relative abundance of five phenophases (young leaves, mature leaves, flowers, whole fruits and seeds) will be determined. Each phenophase is assessed separately and given a score between 0 (none present) to 10 (full canopy) at intervals of 1, with each interval representing 10% of the canopy.

An example of a data sheet for phenological monitoring can be seen in section 8.10 of Appendix 1

Sleeping Site Use

Analysis of the tree species and the associated structure of the sleeping sites selected by wild and release groups will make an important contribution to the habitat assessment and post-release monitoring. The tree species selected for sleeping sites may not be prominent food trees and therefore would not be included as a requirement in the habitat assessments based on feeding ecology data alone. However, trees and their related structure that are favoured for sleeping or refuge sites are equally important to consider in habitat selection to increase survivorship of the release group. Each sleeping site will be named numerically in accordance to when first located by the field team and surveyed for the 13 habitat features detailed in Table A1.1

Table A1.1 Eleven variables each sleeping site will be surveyed for (Bernard et al 2010, Ganzhorn 2003, Wang et al 2011)

Habitat Feature	Habitat Feature Description
G.P.S.	G.P.S. position of the sleeping site
Location	Verbal description of site, i.e. centre or edge of forest, stand alone tree, residential property
Number of trees	The number of trees occupied by the group while sleeping
Tree Species	The species of all trees that are slept in
Food Abundance	Number of food trees within a 10m radius of the sleeping site
DBH	Diameter (cm) at breast height
Canopy density	Canopy density, recorded as a percentage, of the tree(s) slept in
Ground density	Vegetation density, recorded as a percentage, at ground level measured within a circular radius of 20m from the tree trunk
Distance	Distance, recorded in meters from the main Diani Road
Height	Height of tree (m)
Branch height	Height (m) of bottom most branch
Number of branches	Number of main branches
Connectivity	Arboreal connectivity with neighbouring trees ranked according to a scale of 0–4, with 0 indicating that the tree was completely isolated and 4 that it overlapped completely with surrounding trees

All length variables will be measured using a standard measuring tape (cm or m), except height which will be calculated using a clinometer. Visual judgment will be used to estimate canopy and ground density. Every sleeping site encountered throughout the year will be recorded in order to highlight if there are seasonal preference to trees according to canopy and ground density or food availability.

Example of a sleeping site data sheet can be seen in section 8.11 of Appendix 1

5.2 Supplementary Feeding

Supplementary feeding is designed to ease the transmission of captive to wild life. As such the amount given needs to be gradually reduced, so to wean the monkeys off the dependent feeding routine that they have been used to.

Week 1 - For the first week post-release all monkeys should be supplementary fed once daily and watered provided if appropriate – food supplied at 75% the captive quantities
Week 2 - Provide 50% of captive quantities of food once daily and water as appropriate
Week 3 - Provide 50% of captive quantities of food every second day and water as appropriate
Week 4 - Provide 25% of captive quantities of food every second day and water as appropriate
Week 5 - Provide 25% captive quantities of food twice a week and water as appropriate
Week 6 - Distribute sunflower seeds widely around the home range, twice a week, at a quantity of 50g per monkey
Week 7 onwards – Terminate supplementary feeding, monitor individual's conditions, ensure that sufficient wild foods are available and the monkeys are feeding for themselves adequately in the wild. If this is not the case, supplementary feeding should continue until such time that the monkeys are coping sufficiently in the wild.

Dependency on supplementary feeding should not be created, so care must be taken.

- Daily Animal Care staff (not volunteers) are responsible for distribution of supplementary food. Coordinate feeding times and locations with the release team or management in the absence of researchers.
- Supplementary food must not contain highly desired fruits, such as banana, mango, and papaya. The aim is that the release monkeys only access this support if required. Therefore, by making the food less appealing only those individuals that need a 'top up' will eat. Supplementary food can consist of vegetables including cabbage, squash, spinach, green beans, cassava, sunflower seeds etc.
- Supplementary food must be cut into the smallest possible sizes (no large chucks). This will allow the food to be scattered more widely, reducing competition between release group individuals and increasing equal access regardless of an individual's group status.

The environment is also a factor to be considered in the reduction of supplementary food. The monkeys must be weaned off the supplementary before the dry season begins to take effect on the vegetation, otherwise the monkeys will have no supplementary food and little wild food to counter balance this.

The timing and method of supplemental feeding should take into account the following:

- Feed at different times and different locations each day to prevent a routine forming.

- During the first week feed at the release site (in the vicinity of the pre-release enclosure), so the monkeys view the enclosure as a safe place. This will allow for greater ease in trapping an individual if intervention is required
- As soon as it is apparent that the monkeys move in and out of the cage without fear, begin feeding them farther away from the release site
- Scatter food over a wide area to avoid fights and intra group aggression
- Scatter food in sheltered areas, such as the nature trail or tree covered garden area, to protect monkeys from predators whilst feeding
- DO NOT feed when any wild groups are present. Even if it means feeding does not occur that day
- STRICTLY NO HAND FEEDING
- DO NOT allow the monkeys to see staff distributing the food. Scatter the food quickly, discretely, and in a location out of view of the monkeys, to prevent association and food aggression towards personnel
- DO NOT feed the monkeys close to any house

5.3 Behaviour of Humans in Proximity to the Release Group

At NO TIME (except in intervention – see below) should there be any form of contact between Colobus Conservation personnel and monkeys. If a monkey approaches a researcher, staff or volunteer it should be firmly and efficiently chased away. Some effective methods:

- Using a spray bottle to spray the monkey with chilli water
- Using a stick or piping to scare away monkeys without contact
- Threatening to throw small stones at the individual - no stone should ever be aimed and thrown at a monkey

All personnel must be especially careful not to leave food lying around in non-monkey proofed areas. Areas of particular problem are:

- The veranda – no food, snacks or orphan meals to be left anywhere on the veranda. All items must be returned to their correct storage place immediately
- The monkey kitchen – the monkey kitchen and vet clinic door must be kept locked at all times to prevent the release group gaining access to the area
- The burn pile - no food waste is to be placed on burn pile until it is due to be burnt. In between 'burn days', food waste is stored in the garbage area in the designated bins

Under no circumstance should:

- Any release animal be given food to distract them while captive monkeys are fed or food delivered to site. If there is a problem monkey, alert management
- Any individual be allowed to enter the house. All on site personnel are responsible for the prevention of this

Personnel must be aware of their proximity to the release group:

- A minimum distance of 3m must be adhered to at all time, increasing to 5m by 6 months post-release
- If a release individual approaches a researcher within this distance it is the researchers responsibility to reposition themselves to a 3m distance
- It is appreciated that during times of dispute or fast movement this will be difficult, however, every effort must be made
- Tour guides are responsible for ensuring correct behaviour of eco-tourists around the monkeys during their visits

Personnel must be aware of the affect their actions have upon the group:

- As a researcher it is essential that you do not bias the behaviour or movement of the group. It is therefore recommend that the above minimum distances are adhered to
- In addition make every attempt to move alongside the group rather than in front (leading) or behind (herding)
- By moving alongside the group it will allow the group to turn and flee, without coming into close contact with the researchers.

5.4 Control Group Monitoring

Measures of translocation success must be both verifiable and broadly applicable, with indicators evaluated relative to a detailed performance target or controls groups (Strum 2005). Environmental factors within a release location may affect food supply; and close monitoring of the indigenous populations and release groups provides a more detailed understanding of successes and failures (Strum 2005). As such, the post-release monitoring outlined above will be replicated on two wild control groups living within the same anthropogenically modified habitat as the release group, within the same time frame.

6.0 Intervention

6.1 Intervention

Staff and researchers should only intervene in life threatening circumstances, and should not intervene in natural inter-group or intra-group interaction unless fights become life-threatening. Intervention is justified in emergencies, including:

- Predators – intervention is required if predators are near the release monkeys and they are not showing the appropriate response, this includes cars and electricity cables – the research team should play the appropriate alarm call and/or actively herd the group away from the danger
- Conspecifics - in the first four weeks post-release physical intervention between the release group and wild monkey groups is acceptable, if required. However, by one month post-release this intervention needs to reduce unless an interactions escalates to attack and individuals are physically injured
- Severe loss of fitness/injury – any individual that is badly injured or suffering from a severe lack of fitness (malnourishment, dehydration, etc.), is to be captured and returned to Colobus Conservation for care
- If the individual is fit and healthy within a reasonable time frame, they may be released back to their group, if recovery takes a longer period they will be retained and prepared for later release
- Close monitoring of any re-release individual is required to ensure they are still cohesive with the group. If not recapture will be considered

No primate should be release on its own. In the case when one or more individuals are returned to captive care, upon re-release, they must be returned back to the original group rather than released alone, or as a second group

The aim of the soft release is to slowly wean the release group from human care. By four months post-release the group is left for one morning and one afternoon period per week. The group need to know how to respond to wildlife interactions without the researchers or staff assistance so they are prepared for unmonitored wildlife interactions.

6.2. Group Split

- If the group splits – a researcher must follow each group

- If not possible, the group with the most individuals or more vulnerable individuals (i.e. infants, juveniles) should be followed
- The situation must be monitored and assessed

6.3. Individual Split

- Researchers and staff should make every attempt possible to locate and reunite lost individuals with the rest of group. Leading the lost individual back to the group by foot
- If an individual continually becomes lost from the group (3 or more times), it should be assessed if the individual needs to be removed from the release and returned to Colobus Conservation. If removed, every attempt should be made to integrate the monkeys into another group to be released at a later date, where he/she may form a stronger group bond
- If an individual(s) is separate from its group, but in proximity to wild conspecifics give the individual(s) a few days and observe whether he/she (they) are trying to integrate into the wild group. In this case do not try to re-unite the individual(s) with its release group, as they are likely not lost, but trying to emigrate into another group. Data collection of these individuals(s) needs to be continued.

7.0 Other Considerations

- All eco-tours must be informed of the release and the proximity of the release group BEFORE leaving the information centre.
- The release group is NOT part of the eco-tour experience and you must not promise the tour the chance to see the release group. Neither should you actively seek out the release group during a tour. However, if the release group is in the area normally used by an eco-tour then the tour may observe them at an appropriate distance.
- Eco-tours must be informed that under no circumstances are they to approach or solicit contact with the individuals nor do they run away from the group if they approach – both actions could lead to attack
- All tours are guided and each guide must carry their water spray and act as the defence between the release group and the tourists, as required and within the limits of personal safety
- Tour guides and tourists can carry 1m lengths of conduit piping to be used to deter individuals if they try to approach too closely. The piping is held out by the human to

create a barrier between themselves and the monkey while constantly moving backwards. The monkey should not be hit with the piping

- The research team will also be present and aid in this process, but the behaviour of the tourists is for the tour guide to control

8.0 Data Sheets

8.1 Incident Report Sheet

INCIDENT REPORT SHEET

Incident
- ○ Electrocution
- ○ Road Traffic Accident
- ○ Snare
- ○ Dog bite
- ○ Poisoning
- ○ Pet
- ○ Pest behavior
- ○ Natural – fighting
- ○ Natural – illness
- ○ Infanticide
- ○ Unknown
- ○ Other (specify)_____
- ○ Reported, not found

Standard Information
Date reported (dd/mm/yy)_____
Time reported_____
Approx date and time of incident_____
_____
Rescue team departure time_____
Rescue team members_____
_____
Date captured_____
Time captured_____

Informant_____
Tel_____
Staff recording_____

Animal Description
Species_____
Reference No_____
Sex:
○ Male ○ Female
Pregnant Yes No Unknown

Age:
○ Adult ○ Sub adult
○ Juvenile ○ Infant

Colobus infant (less than one year)
○ White ○ Grey ○ Black and White

Baboon infant (less than two years)
○ Black ○ Brown

Incident Location Details
Location of incident_____
G.P.S. Location S04._____E39._____
Habitat in immediate vicinity of incident:
Tick all appropriate for each direction at the incident location

	North	South	East	West
Dense forest				
Scattered trees				
Isolated trees				
Indigenous				
Exotic				
Bush				
Open grass				
Residential				
Holiday cottages				
Hotel				
Commercial				
Road				
Other (describe below)				

Other_____
_____
_____

Capture method used
○ Trapping ○ Manual restraint ○ Darting (by vet)

Chemical Restraint
Xylazine_____% _____ml Ketamin_____% _____ml

Detailed Incident Description
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Measurements (cm) for all primates
(See file for instructions)

Head length		Torso circumference	
Head circumference		Hip-knee length	
Neck circumference		Knee-ankle length	
Body length		Foot (sole) length	
Shoulder-elbow length		3rd toe length	
Elbow to wrist length		Tail length	
Hand (palm) length		Ear length	
2nd finger length		Weight (kg)	

Colobus only

Epaulets length			
White tail length 1		White tail length 2	

Animal Condition/Symptoms - superficial assessment
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Case Conclusion Date (dd/mm/yy)_____

- ○ Dead
- ○ Alive not captured
- ○ Euthanized
- ○ Died at CC
- ○ Treated and released
- ○ Treated and entered rehab
- ○ Released after rehab

8.2 Habitat Assessment

Habitat Assessment Data - A Plots

Study Group: _____ *Recorders:* _____ *Date:* _____ *Ref No:*_____

Total percentage of canopy cover:_____ Height at eye level of clinometer recorder_____

PLOT A.1 – 50m x 20m (1000m^2)

G.P.S. Co-ordinates: NW:_____ NE:_____

SW:_____ SE:_____

Record all trees ≥30cm DBH or ≥94cm CBH

Ref number	G.P.S.	Species	CBH (cm) (each multi stem and trunk where needed)	% canopy cover	Tree height (degrees/cm) 7m from tree	Average Crown Spread (90 degree angle) in cm		Bole Height (cm)
						Longest	Shortest	

Percentage of canopy cover of trees surveyed in plot A: _____

Habitat Assessment Data - B Plots

Study Group: _____ *Recorders:* _____ *Date:* _____ *Ref No:*_____

PLOT B.1, B.2 - 7.07m x 14.14m (100m^2)

G.P.S. Co-ordinates: NW:_____ **NE:**_____

SW:_____ **SE:**_____

Record all trees <30cm >10cm DBH or <94cm >31cm CBH

Ref number	G.P.S.	Species	CBH (cm) (each multi stem and trunk where needed)	% canopy cover	Tree height (degrees/cm) 7m from tree	Average Crown Spread (90 degree angle) in cm		Bole Height (cm)
						Longest	Shortest	

Total % of canopy cover of Plot B.1:_____

Percentage of canopy cover of trees surveyed in plot B.1: _____

Habitat Assessment Data - C Plots

Study Group: _____ *Recorders:* _____ *Date:* _____ *Ref No:* _____

PLOT C.1, C.2, C.3, C.4 – 2.24m x 4.47m (10m^2)

G.P.S. Co-ordinates: NW: _____ **NE:** _____

SW: _____ **SE:** _____

Record all trees, shrubs and bushes <10cm DBH or <31cm CBH

Ref #	G.P.S.	Species	CBH (cm) (each multi stem and trunk where needed)	% canopy cover (trees)	% ground cover (shrubs)	Tree height (degree/cm) 7m from tree	Average Crown Spread (90 degree angle) cm		Bole Height (cm)
							Longest	Shortest	

Total percentage of canopy cover of plot C.1: _____

Percentage of canopy cover of trees, shrubs and bushes surveyed in plot C.1: _____

Percentage of ground cover of trees, shrubs and bushes surveyed in plot C.1: _____

Habitat Assessment Data - D Plots

Study Group: _____ *Recorders:* _____ *Date:* _____ *Ref No:* _____

PLOT D.1 – 0.71m x 1.41m ($2m^2$) – herbaceous level
G.P.S. Co-ordinates:
_____

Species	% Ground cover
Total canopy cover of Plot D.1	

PLOT D.2 – 0.71m x 1.41m ($2m^2$) – herbaceous level
G.P.S. Co-ordinates:
_____

Species	% Ground cover
Total canopy cover of Plot D.2	

PLOT D.3 – 0.71m x 1.41m ($2m^2$) – herbaceous level
G.P.S. Co-ordinates:
_____

Species	% Ground cover
Total canopy cover of Plot D.3	

PLOT D.4 – 0.71m x 1.41m ($2m^2$) – herbaceous level
G.P.S. Co-ordinates:
_____

Species	% Ground cover
Total canopy cover of Plot D.4	

PLOT D.5 – 0.71m x 1.41m ($2m^2$) – herbaceous level
G.P.S. Co-ordinates:
_____

Species	% Ground cover
Total canopy cover of Plot D.5	

PLOT D.6 – 0.71m x 1.41m ($2m^2$) – herbaceous level
G.P.S. Co-ordinates:
_____

Species	% Ground cover
Total canopy cover of Plot D.6	

8.3 Pre-release Training Data Sheet

8.3.1 Predator Awareness

Pre-release Predator Awareness Training

Observers: _____

Date: _____ **Start Time**: _____ **Finish Time:**_____

Predator: Baboon ☐ Snake ☐ Dog ☐ Human ☐ Other ☐ **Event:** Model ☐ Live ☐ Ad hoc ☐ Pre-planned ☐

Description of Predator Training: _____

_____

_____

_____

_____

Distance when first observed: _____ **Distance when first call sounded (if different):**_____

Numbers of predators present: _____ **Overall group reaction:** _____

Response of predator: _____

ID	P/A	SCORE	NOTES

A/P: 0 = Absent 1 = Present

Score:
0 – Predator seen and individual approaches and attempts to initiate contact with predator
1 – No response (continuation of current behaviour / change to another non-predation related behaviour)
2 – Curiosity towards predator, including visual attentiveness
3 – Alarm calling and/or appropriate positioning in response to other's doing so
4 – Alarm calling and/or appropriate positioning in direct response to the predator
5 - Initiate alarm calling and moving to appropriate position

Notes: Anything note worthy. Who calls first? Is this linked to dominance? Do monkeys respond to subordinates or dominant calls differently?

8.3.2 Electricity Awareness Training

Pre-release Electricity Awareness Training

Observers: _____

Date: _____ **Start Time**: _____ **Finish Time:**_____

Description of Electricity Training: _____

_____

ID	P/A	TIME	NOTES

A/P: 0 = Absent 1 = Present

Notes: Ad hoc all occurrence. Approach wire (within 30cm), touch wire, if a shock is received, response of individual shocked, response of individuals who observe the shock, alarm calls.

Pre-release Electricity Awareness Training

Observers: _____

Date: _____ **Start Time**: _____ **Finish Time:**_____

Description of Electricity Training: _____

_____

ID	P/A	TIME	NOTES

A/P: 0 = Absent 1 = Present

Notes: Ad hoc all occurrence. Approach wire (within 30cm), touch wire, if a shock is received, response of individual shocked, response of individuals who observe the shock, alarm calls.

8.3.3 Wild Food Consumption

Pre-release Primates Wild Food Daily Monitoring

Observers: _____ **Date:** _____ **Start Time**: _____ **Finish Time:**_____

Time since last fruit bowl:_____ **Time since last scatter feed:**_____

ID	P/A	SCORE	NOTES

A/P: 0 = Absent 1 = Present

Score:
1 – No interest in wild foods when presented
2 – Notices wild foods distributed but does not ingest – if individual lacks access due to ranking or not enough food, make note
3 – Shows interest in wild food, ingests a few mouthfuls, plays with food. Losses interest when other monkeys stop eating wild foods
4 – Very interested in wild foods, carries away or guards their own portion. Stops eating wild foods before it is all gone, or turns to provisioned foods (if the only wild food remaining is guarded by another individual than score as number 5)
5 – Dominates wild food supply, continues to ingest until all wild foods are gone.

Notes: Anything note worthy. Who eats first? Is this linked to dominance or food preference? Do monkeys steal wild leaves from each other, if so which ones (food type and monkey)?

8.3.4 Sleeping Location

Pre-release Primates Weekly Sleeping Location Check

Observers: _____ **Date:** _____ **Start Time**: _____ **Finish Time:**_____

ID CODE	P/A	SLEEP LOCATION	NOTES

A/P: 0 = Absent 1 = Present

Condition:
1 – On the ground alone
2 – On the ground with another monkey(s)
3 – Mid enclosure alone
4 – Mid enclosure with another monkey(s)
5 – Top of enclosure alone
6 – Top of enclosure with another monkey(s)

Notes: Which portion of enclosure and which other monkey(s) sleeping with

8.4 Individual Assessment for Release Suitability

PRE RELEASE HEALTH CHECK AND ASSESMENT

Animal I.D.

Name:_____ Reference no:_____

Species:_____ Sex: ☐Male ☐Female Age: ☐Adult ☐Sub-adult ☐Juvenile ☐Infant

Approx date of birth (dd/mm/yy):_____ Date of release:_____

Unique physical traits: _____

Ear tags	**Radio collar**
Color combination:	Frequency:
Location:	Date fitted:

Pictures

Colobus Conservation Ltd, P.O. Box 5380-80401, Diani, Kenya
www.colobusconservation.org +254 (0)711 479453 enquiries@colobusconservation.org

Clinical examination

1 – Visual observation (with the monkey awake in the home cage, without entering the enclosure)

1.1 - Skin and fur condition:

☐Normal ☐Abnormal _____

1.2 - Body condition (rough estimate):

☐1 ☐2 ☐3 ☐4 ☐5

1.3 - Ability to use all 4 limbs (without signs of lameness or imbalance):

☐Normal ☐Abnormal _____

1.4 - Head and eye movements:

☐Normal ☐Abnormal _____

1.5 - Front teeth and nostrils (abnormal discharges, unevenness or swellings):

☐Normal ☐Abnormal _____

2 – Clinical observation (with the monkey sedated)

2.1 - Weight:

_____ Kg

2.2 - Body condition (palpate the monkey over its thoracic and lumbar vertebrae):

☐1 ☐2 ☐3 ☐4 ☐5

2.3 - Eyes (straight, with no discharges, pupils even):

☐Normal ☐Abnormal _____

2.4 - Ears (clean, with no discharges, pinna not swollen) :

☐Normal ☐Abnormal _____

2.5 - Nostrils (clean, even in size) :

☐Normal ☐Abnormal _____

2.6 – Mouth (1 - just lifting up the lips: color of the gums, condition of the incisor and canine teeth; 2 – opened: examine premolar and molar teeth, check the cheek pouches and the back of the throat) :

☐Normal ☐Abnormal _____

2.7 - Jaw and throat (no swelling, check content in the cheek pouches) :

☐Normal ☐Abnormal _____

2.8 - Arms and legs (run hands down each arm and leg simultaneously checking for evenness in length and thickness of joints) :

☐Normal ☐Abnormal _____

2.9 - Fingers and toes:

☐Normal ☐Abnormal _____

2.10 - Abdomen (observe respiratory movements (respiratory rate/min: 30 – 70 min) and palpate the abdomen) :

☐Normal ☐Abnormal _____

2.11 - Thoracic auscultation (heart rate/min: 120 – 180 min) :

☐Normal ☐Abnormal _____

2.12 - External genitalia, anal and urethral orifices :

☐Normal ☐Abnormal _____

2.13 - Rectal temperature :

_____ ºC

2.14 - Tail :

☐Normal ☐Abnormal _____

2.15 – Body measurements

Head length		Shoulder-elbow length		Hip-knee length		Torso circumference	
Head circumference		Elbow to wrist length		Knee-ankle length		Tail length	
Neck circumference		Hand (palm) length		Foot (sole) length		Weight (kg)	
Body length		2nd finger length		3rd toe length		Ear length	

2.16 – Overall condition rating (1-5 as per census records). Explain: _____

_____

_____

Screening tests

Samples collected: ☐Feces ☐Blood ☐Urine ☐Hair ☐Other _____

Hematology

Hemogram

WBC (mm3) _____ ☐

NEU (%) _____ ☐

LYM (%) _____ ☐

MON (%) _____ ☐

RBC (M/mm3) _____ ☐

HGB (g/dl) _____ ☐

HCT (%) _____ ☐

MCV (fl) _____ ☐

MCHC (g/dl) _____ ☐

MCH (pg) _____ ☐

PLT (m/mm3) _____ ☐

Biochemistry

Renal profile

Urea (mmol/l) _____ ☐

Creatinine (umol/l) _____ ☐

Liver function

AST (U/L) _____ ☐

ALT (U/L) _____ ☐

Glucose (mmol/l) _____ ☐

Observations:_____

_____

_____

_____

Fecal test

Parasitology

Number of eggs _____ EPG

Parasites: _____

Treatment: _____

_____

TB test

Date: _____/_____/_____ Time of injection: _____

Eyelid: ☐ Right ☐ Left

Blood after injection: ☐ Present ☐ Not present

Reaction observed:

24h	48h	72h
☐ Grade 0	☐ Grade 0	☐ Grade 0
☐ Grade 1	☐ Grade 1	☐ Grade 1
☐ Grade 2	☐ Grade 2	☐ Grade 2
☐ Grade 3	☐ Grade 3	☐ Grade 3
☐ Grade 4	☐ Grade 4	☐ Grade 4
☐ Grade 5	☐ Grade 5	☐ Grade 5

Grade 0 – No reaction observed
Grade 1 – Bruise with extravasation of blood in the eyelid associated with the injection of tuberculin (considered negative)
Grade 2 – Varying degrees of erythema without swelling (considered negative)
Grade 3 – Varying degrees of erythema, minimum swelling or slight swelling without erythema (considered questionable)
Grade 4 – Obvious swelling, drooping of the eyelid, with varying degrees of erythema (considered positive)
Grade 5 – Swelling and/or necrosis with eyelid closed (strong positive)

Final result: ☐ Positive for TB

☐ Negative for TB

Other tests

_____

_____

_____

_____

Vaccines

Vaccines administered: _____

_____

_____

Side effects or adverse reactions: _____

_____

_____

Behavioural Assessment

1 – History

– Length of time at Colobus Conservation: _____

– Length of time in captivity prior to being at Colobus Conservation: _____

– Length of time in the wild: _____

– Location of wild living: _____

– Circumstances that lead to individual being in rehab: _____

_____

_____

2 – Group cohesion

– Current rank within the troop, has this changed recently? Explain: _____

_____

_____

– Which other troop members does this individual associate with most? _____

_____

– Is this individual often observed alone?: _____

_____

3 – Predator Awareness

– How did the individual rank on predator awareness training:

Snake: _____

Dog: _____

Baboon: _____

Human: _____

– What is this individuals level of attachment to humans (1 – no attachment – 10 – highly attached). Explain:

_____

_____

_____

_____

4 – Survival Techniques

– Use of colobridge: _____

_____

– Response to electricity training: _____

_____

_____

5 – Wild Food Selection

– Does the individual respond to wild food placed in the enclosure or do they rely solely on food provided by the Trust? _____

_____

6 – Sleep positioning

– Does the individual correctly position itself for sleep? Explain: _____

_____

_____

_____

– Does the individual sleep with other individuals? Explain: _____

_____

_____

_____

7 - General Behaviour

– Does the individual display any unusual or repetitive behavior? Explain: _____

_____

_____

_____

– Is the individual aggressive? Explain: _____

_____

_____

_____

Release Suitability

Do any of the above condition(s) prevent or hinder this individual (or the troops) survivability? Explain: _____
_____
_____
_____

From this review and personal knowledge of the individual does this individual have the skills required to survive in the wild? Explain: _____
_____
_____
_____

Approval

Is this individual approved for release? ☐Yes ☐No
Release Group Name: _____
Release Date (dd/mm/yy): _____

Signed:
Conservation Manager: _____ Veterinarian: _____
Date (dd/mm/yy): _____ Date (dd/mm/yy): _____

8.5 Daily Census Data Sheet

Primate Census Data Sheets
Focal Reference: RV_____.

Observers:_____ Date:_____ Start/Finish Time:_____

AM Sleeping site:_____ PM Sleeping site:_____

AM Sleeping site GPS:_____ PM Sleeping site GPS:_____

ID	Census		Condition	Notes
	AM	PM		

Colum name	Recorded	Codes
Census	AM and PM	0 = Absent 1 = Present
Condition	Daily	1 = in poor health or condition, has server wounds or emaciated 2 = in below average condition, under weight, dull eyes and patchy coat 3 = in adequate condition and adequate weight 4 = in above average condition, good body weight and thick coat 5 = in excellent condition, good body weight, thick glossy coat with no patches, foraging and feeding on wild foods
Notes	Ad hoc	Detail injuries, loss of condition/weight, births, deaths, late arrivals, unusual behaviour, anything different or interesting

8.6 Focal Follow Data Sheet

<u>Primate Focal Study Data Sheet</u>

Study Group*:** _________________________ ***Observer: _________________________ ***Date:*** _________________ ***Focal Ref No:***______________________

Research Period: Morning ☐1 Afternoon ☐2

Focal _ Start Time	**Individual I.D.**							**Sex:**			**Age:**			**G.P.S.: S04.**							**Notes**
	Weather:							**Focal Interval/minutes**						**E039.**							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Behaviour																					
Association																					
Food Type																					
Position in Canopy																					
Focal _ Start Time	**Individual I.D.**							**Sex:**			**Age:**			**G.P.S.: S04.**							**Notes**
	Weather:							**Focal Interval/minutes**						**E039.**							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Behaviour																					
Association																					
Food Type																					
Position in Canopy																					
Focal _ Start Time	**Individual I.D.**							**Sex:**			**Age:**			**G.P.S.: S04.**							**Notes**
	Weather:							**Focal Interval/minutes**						**E039.**							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Behaviour																					
Association																					
Food Type																					
Position in Canopy																					
Focal _ Start Time	**Individual I.D.**							**Sex:**			**Age:**			**G.P.S.: S04.**							**Notes**
	Weather:							**Focal Interval/minutes**						**E039.**							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Behaviour																					
Association																					
Food Type																					
Position in Canopy																					
Focal _ Start Time	**Individual I.D.**							**Sex:**			**Age:**			**G.P.S.: S04.**							**Notes**
	Weather:							**Focal Interval/minutes**						**E039.**							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Behaviour																					
Association																					
Food Type																					
Position in Canopy																					

8.7 Ethograms

8.7.1 Example of Focal Follow Behavioural Ethogram

Behaviour	Description	Additional recording
Aggression +	Acting aggressively towards another individual	ID of individual(s) involved
Aggression -	The recipient of an aggressive encounter	ID of individual(s) involved
Contact	Two or more individuals touching when the behaviour does not require contact	ID of individual(s) involved
Clinging	Infant clinging to another individual	ID of individual involved
Feeding	The act of eating a food item i.e. biting, chewing and storing in cheek pouch	Record food type and species
Foraging	The act of preparing a food item to be ingested i.e. locating, picking, smelling and rolling.	Record species and type of food involved
Grooming +	Being the recipient of grooming	ID of individual(s) involved
Grooming -	Grooming another individual	ID of individual(s) involved
Locomotion	Any distance travelled, vertical, horizontal, on the ground, in the trees or on buildings	
Mating	Copulation	ID of individual involved
Mounting +	One individual mounting another without copulation	ID of individual involved
Mounting -	One individual being mounted by another without copulation	ID of individual involved
Nursing	Mother breast feeding infant	ID of individual involved
Other	Any behaviour that does not fall within the other descriptions	Describe the behaviour and ID of individual involved
Out of Sight	When individual cannot be clearly seen and behaviour accurately described	
Play	Playing	ID of individual(s) involved
Predator Avoidance	Actively avoiding predators or alarm calling	Complete wildlife interaction data sheet
Presenting +	Being presented to by another individual	ID of individual involved
Presenting -	Presenting itself to another individual	ID of individual involved
Resting	Sitting or lying with eyes closed	
Scratching	Scratching own body	
Self Grooming	Grooming own body	
Suckling	Infants or juveniles breast feeding from mother	ID of individual involved
Vigilance	Eyes open, aware of environment. Can be standing, seated or lying	

8.7.2 Example of Human Food Ethogram

Code	Description	Code	Description
1	Garbage pile/scattered waste food	9	Taken directly from a person
2	Rubbish bin	10	Given directly from a person
3	Hotel/guest room	11	Crop raiding
4	Hotel dining table	12	Fruit or vegetable from monkey enclosures
5	Buffet table	13	Other animal food (poultry, cat, dog)
6	Bag (shopping, backpack, handbag)	14	Wild leaves from monkey enclosure
7	Kitchen	15	Roadside shop
8	House dining area		

8.8 Proximity Data Sheet

Primate Proximity Data Sheet

***Study Troop*: ________________________ *Observer:* ________________________ *Date:* ________________ *Focal Ref No:*_____________________**

Research Period: Morning ☐1 Afternoon ☐2

Focal _ **Start Time_**	**Individual I.D.**		**Sex:**	**Age:**	**G.P.S.: S04.**
	Weather:		**Distance from Focal Individual**		**E039.**
Focal Minute	Contact	<1m	1 – 3m	3 – 5m	>5m
0 minute					
10 minute					
20 minute					
Focal _ **Start Time_**	**Individual I.D.**		**Sex:**	**Age:**	**G.P.S.: S04.**
	Weather:		**Distance from Focal Individual**		**E039.**
Focal Minute	Contact	<1m	1 – 3m	3 – 5m	>5m
0 minute					
10 minute					
20 minute					
Focal _ **Start Time_**	**Individual I.D.**		**Sex:**	**Age:**	**G.P.S.: S04.**
	Weather:		**Distance from Focal Individual**		**E039.**
Focal Minute	Contact	<1m	1 – 3m	3 – 5m	>5m
0 minute					
10 minute					
20 minute					
Focal _ **Start Time_**	**Individual I.D.**		**Sex:**	**Age:**	**G.P.S.: S04.**
	Weather:		**Distance from Focal Individual**		**E039.**
Focal Minute	Contact	<1m	1 – 3m	3 – 5m	>5m
0 minute					
10 minute					
20 minute					
Focal _ **Start Time_**	**Individual I.D.**		**Sex:**	**Age:**	**G.P.S.: S04.**
	Weather:		**Distance from Focal Individual**		**E039.**
Focal Minute	Contact	<1m	1 – 3m	3 – 5m	>5m
0 minute					
10 minute					
20 minute					

8.9 Wildlife Interaction Data Sheet

Wildlife Interactions Data Sheet

Study Troop:_____ **Observers:**_____ **Date (dd/mm/yy):**_____ **Focal Ref:** _____
Start time:_____ **End time:** _____ **G.P.S.** _____

Question	Result
Distance (m) when other animals first observed by study troop	
Distance (m) between the study troop and the other animal(s) at closest contact	
Species and number of individuals	
Description of interaction site	
If contact, who initiated it? (which group and/or individual)	
Reaction of the focal troop: use the ratings and give a verbal description to highlight how different troop members react.	
Reaction of the other troop/animals: use the ratings and give a verbal description to highlight how different individuals react.	
Injury: Document any injuries sustained by the focal troop	
Injury: Document any injuries sustained by the other troop/animals	
Details: give details of the contact, territory aggression, predation, food competition, mating competition, non aggressive, sleeping together, intimidation tactics used, vocalizations made, include details of individuals involved or natural barriers that limited the interaction	
Outcome: Document who withdrew first/ended interaction and why (if known). Any focal individuals missing/dead/left with new primate troop. New members joined?	

Reaction of focal/other troop
0 – no reaction, 1 – look at approaching animals, 2 – vocalisation, 3 – retreat to trees, 4 – move away, 5 – chase after animals, 6 – come to ground, 7 – vocalise and chase animals away, 8 – vocalise and move away, 9 – play, 10 – remain but vigilant, 11 – remain but display, 12 – approach animals, 13 - approach and display,14 – peaceful/ignore, 15 – peaceful/intermingle,

8.10 Phenology Data Sheet

Phenology Study Data

Study Group: _____ ***Observer:*** _____ ***Date:*** _____ ***Phenology Ref No:*** _____

Species	Code	Abundance Score					
		LB	YL	ML	FL	FR	SE
Azadirachta indica	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						

Species	Code	Abundance Score					
		LB	YL	ML	FL	FR	SE
Delonix regia	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						

Species	Code	Abundance Score					
		LB	YL	ML	FL	FR	SE
Dictyospermum album	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						

Species	Code	Abundance Score					
		LB	YL	ML	FL	FR	SE
Ficus benjamina	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						

	Code	Abundance Score					
		LB	YL	ML	FL	FR	SE
Ficus lingua	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						

Species	Code	Abundance Score					
		LB	YL	ML	FL	FR	SE
Ficus sycomorus	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						

Species	Code	Abundance Score					
		LB	YL	ML	FL	FR	SE
Lecaniodiscus fraxinifolius	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						

Species	Code	Abundance Score					
		LB	YL	ML	FL	FR	SE
Lannea weltswischi	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						

Species	Code	Abundance Score					
		LB	YL	ML	FL	FR	SE
Mangifera indica	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						

LB – Leaf bud	**YL** – Young leaf	**ML** – Mature Leaf	**FL** – Flower/flower bud	**FR** – Whole Fruit	**SE** - Seed

Score abundance on a scale from 0 – 10, where 0 represents none present and 10 represents greatest abundance for that food type

8.11 Sleeping Site Date Sheet

Primate Sleeping Site Data Sheet
General Analysis of Whole Sleeping Site

Sleeping Site Ref No: _____ ***Study Group:*** _____ ***Observer:*** _____ ***Date:*** _____ ***Focal Ref No:***_____

Habitat Feature	Habitat Feature Description	Results
G.P.S.	G.P.S. position of the sleeping site (at the most central point of the sleeping site)	
Location	Verbal description of site, i.e. centre or edge of forest, stand alone tree, residential property	
Food Abundance	Number of food trees or plants within a 10m radius of the sleeping site Listing each species and number	
Canopy density	Canopy density, recorded as a percentage, of the tree(s) slept in. Be as accurate as possible but can use ranges if unsure i.e. 0-25%, 25-50%, 50-75% or 75-100%	
Ground density	Vegetation density, recorded as a percentage, at ground/herb level measured within a circular radius of 20m from the tree trunk. Take particular note of any food species present (unlikely for colobus)	
Distance	Distance, recorded in meters from the centre of the sleeping site to the main Diani Road and to the beach (if beach side of road)	Distance to road - Distance to beach -
Connectivity	Arboreal connectivity with neighbouring trees ranked according to a scale of 0–4, with 0 indicating that the tree was completely isolated and 4 that it overlapped completely with surrounding trees. Make a not if the connectivity is man made	

Primate Sleeping Site Data Sheet - Detailed Analysis of each individual Sleeping Tree

Sleeping Site Ref No: _____ ***Study Group:*** _____ ***Observer:*** _____ ***Date:*** _____ ***Focal Ref No:***_____

Number of trees occupied by the troop while sleeping:_____

Tree number	Species	Circumference (cm) at breast height	Height of tree (m) Using clinometer	Height (m) of bottom branch	Number of main branches	Crown Spread
1			Eye level (H2) - Distance (B) - Degree (A1) -	Height - Eye level (H2) - Distance (B) - Degree (A1) -		Longest - Shortest -
2			Eye level (H2) - Distance (B) - Degree (A1) -	Height - Eye level (H2) - Distance (B) - Degree (A1) -		Longest - Shortest -
3			Eye level (H2) - Distance (B) - Degree (A1) -	Height - Eye level (H2) - Distance (B) - Degree (A1) -		Longest - Shortest -
4			Eye level (H2) - Distance (B) - Degree (A1) -	Height - Eye level (H2) - Distance (B) - Degree (A1) -		Longest - Shortest -
5			Eye level (H2) - Distance (B) - Degree (A1) -	Height - Eye level (H2) - Distance (B) - Degree (A1) -		Longest - Shortest -
6			Eye level (H2) - Distance (B) - Degree (A1) -	Height - Eye level (H2) - Distance (B) - Degree (A1) -		Longest - Shortest -
7			Eye level (H2) - Distance (B) - Degree (A1) -	Height - Eye level (H2) - Distance (B) - Degree (A1) -		Longest - Shortest -
8			Eye level (H2) - Distance (B) - Degree (A1) -	Height - Eye level (H2) - Distance (B) - Degree (A1) -		Longest - Shortest -
9			Eye level (H2) - Distance (B) - Degree (A1) -	Height - Eye level (H2) - Distance (B) - Degree (A1) -		Longest - Shortest -

Appendix 2 List of Consumed Plant Species

Latin Name	Plant type	Status	Hotel					University					Release				
			Fruit	Seed	Flower	Leaf	Other	Fruit	Seed	Flower	Leaf	Other	Fruit	Seed	Flower	Leaf	Other
Acacia zanzibarica	Tree	I														x	
Acalypha species	Shrub	E											x			x	x
Adansonia digitata	Tree	I			x		x	x			x		x		x		
Adenanthera pavonina	Tree	E											x				x
Adenia gummifera	Climber	I			x												
Afzelia quauzensis	Tree	I										x					
Alchornea laxiflora	Shrub	I											x			x	x
Allophylus pervillei	Shrub	I						x					x			x	x
Asystasia gangetica	Herb	I				x				x					x	x	
Azadirachta indica	Tree	E	x		x	x		x		x	x		x		x	x	x
Bambusa vulgaris	Bamboo	E															x
Bauhinia species	Tree	E													x	x	
Bidens species	Herb	?													x	x	
Bougainvillea spectabilis	Shrub	E			x					x	x				x	x	x
Bridelia cathartica	Shrub	I											x			x	x
Cactus species	Cactus	?									x						
Calliandra surinamensis	Shrub	E													x	x	
Carpodiptera africana	Shrub	I				x				x						x	x
Cascabela thevetia	Shrub	E									x		x		x	x	x
Cassia singueana	Tree	I							x							x	
Casuarina equisetifolia	Tree	E							x		x						X
Coccinia species	Herb	I														x	

Latin Name	Plant type	Status	Hotel					University					Release				
			Fruit	Seed	Flower	Leaf	Other	Fruit	Seed	Flower	Leaf	Other	Fruit	Seed	Flower	Leaf	Other
Cocos nucifera	Palm	E						x					x			x	
Codiaeum variegatum	Shrub	E													x	x	
Combretum schumannii	Tree	I					x						x			x	
Commelina benghalensis	Herb	I													x	x	
Commiphora lindensis	Tree	I													x		
Cordia goetzei	Tree	I						x									
Cordia monoica	Tree	I														x	
Cyphostemma adenocaula	Herb	I											x				
Delonix regia	Tree	E		x	x	x			x	x	x			x	x	x	x
Dictyospermum album	Palm	E	x					x									
Diospyros consolatae	Tree	I						x		x	x						
Diospyros kabuyena	Tree	I													x		
Dovyalis macrocalyx	Tree	E											x				x
Drypetes reticulata	Tree	I						x									
Encephalartos hildebrandtii	Cycad	I						x									
Feretia apodanthera	Shrub	I														x	
Fernandoa magnifica	Tree	I													x	x	x
Ficus benjamina	Tree	E	x					x			x		x		x	x	x
Ficus bubu	Tree	I											x				
Ficus bussei	Tree	I						x									
Ficus lingua	Tree	I	x					x			x		x				
Ficus polita	Tree	I											x				

Latin Name	Plant type	Status	Hotel					University					Release				
			Fruit	Seed	Flower	Leaf	Other	Fruit	Seed	Flower	Leaf	Other	Fruit	Seed	Flower	Leaf	Other
Ficus sur	Tree	I						x									
Ficus sycomorus	Tree	I	x					x			x		x			x	x
Flueggea virosa	Shrub	I	x								x		x		x	x	x
Grandidiera boivinii	Tree	I														x	
Graptophyllum pictum	Shrub	E													x		
Grass	Herb	I		x	x	x	x		x	x	x	x		x	x	x	x
Grewia glandulosa	Shrub	I						x									
Grewia plagiophylla	Shrub	I						x		x			x		x	x	x
Grewia vaughanii	Shrub	I						x		x	x		x		x	x	x
Haplocoelum inopleum	Shrub	I														x	
Heliconia sp	Herb	E												x		x	
Hibiscus rosa-sinensis	Shrub	E			x	x				x	x				x	x	x
Hoslundia opposita	Shrub	E									x						
Hunteria zeylanica	Tree	I											x			x	x
Julbernardia magnistipulata	Tree	I									x						
Kalanchoe obtuse	Succulent	?															x
Lannea schweinfurthianum	Tree	I						x					x			x	
Lannea welwitschii	Tree	I	x										x			x	x
Lantana camara	Shrub	E						x							x	x	
Lecaniodiscus fraxinifolius	Tree	I	x			x		x			x						
Leucaena leucocephala	Tree	E												x		x	
Lianas	Liana	I	x					x		x	x		x				

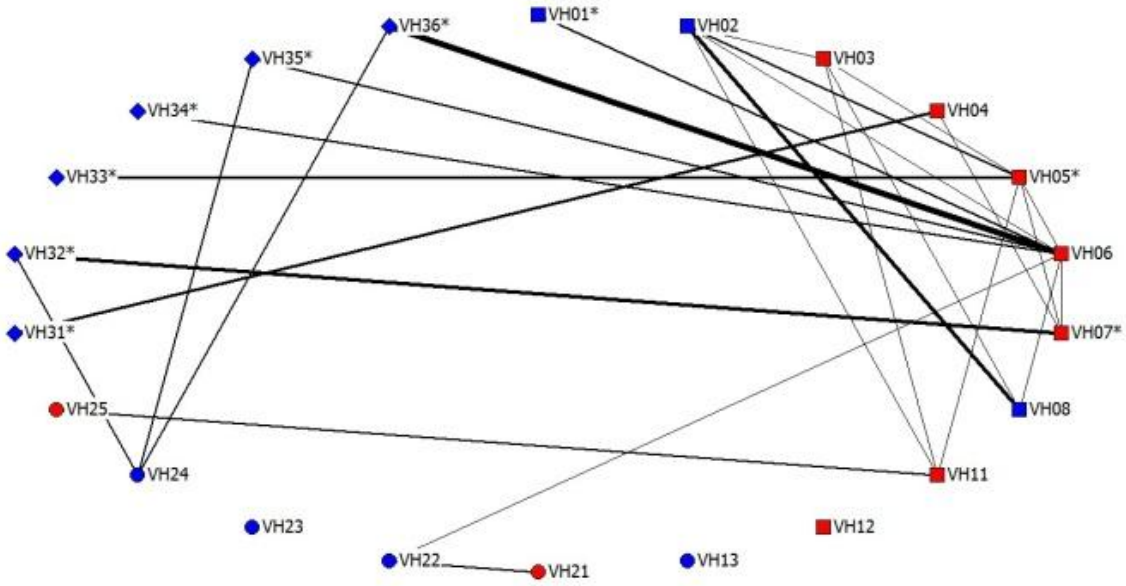
Latin Name	Plant type	Status	Hotel					University					Release				
			Fruit	Seed	Flower	Leaf	Other	Fruit	Seed	Flower	Leaf	Other	Fruit	Seed	Flower	Leaf	Other
Ludia mauritiana	Tree	I														x	x
Majidea zanguebarica	Tree	I						x									
Mallotus oppositifolius	Tree	I											x			x	x
Mangifera indica	Tree	E	x					x					x		x	x	x
Markhamia zanzibarica	Tree	I	x			x	x	x									
Melanthera biflora	Herb	E								x	x						
Melia azedarach	Tree	E											x				x
Mildbraedia carpinifolia	Tree	I														x	
Millettia usaramensis	Shrub	E															x
Mimusops obtusifolia	Tree	I								x							
Mkilua fragrans	Tree	I														x	
Monodora grandidiera	Tree	I						x									
Musa paradisiaca	Herb	E														x	
Oxalis species	Herb	?									x						
Palm species	Palm	?											x			x	
Pandanus kirkii	Tree	I	x					x				x	x				
Pemphis acidula	Bush	I	x			x											
Phyllanthus ovalifolius	Shrub	I														x	
Pithecellobium dulce	Tree	E														x	
Plectranthus tenuiflorus	Succulent	?													x		
Plumeria rubra ·	Tree	E								x					x	x	x
Polyscias balfouriana	Shrub	E									x					x	

Latin Name	Plant type	Status	Hotel					University					Release				
			Fruit	Seed	Flower	Leaf	Other	Fruit	Seed	Flower	Leaf	Other	Fruit	Seed	Flower	Leaf	Other
Premna hildebrandtii	Tree	I														x	x
Pseuderanthemum sp.	Herb	?						x			x						
Punice granatum	Shrub	E													x		
Pycnocoma littoralis	Tree	I														x	
Ricinus communi	Shrub	E														x	x
Sideroxylon inerme	Tree	I	x			x		x			x		x				x
Sterculia rhynchocarpa	Tree	I											x				
Tamarindus indica	Tree	I		x	x	x			x	x	x						
Terminalia catappa	Tree	E	x				x	x			x		x				x
Transcadentia spartapca	Herb	E													x		
Tridax procumbens	Shrub	I													x	x	
Turraea floribunda	Tree	I														x	x
Turraea nilotica	Tree	I				x		x								x	
Uvaria acuminate	Shrub	I														x	
Uvaria lucida	Shrub	I														x	
Variegatum pictum	Tree	E									x				x	x	
Xylopia parviflora	Tree	I															x
Zanthoxylum chalybeum	Tree	I									x		x				
Ziziphus muctonata	Tree	E											x				

Appendix 3 Social Contact Graphs

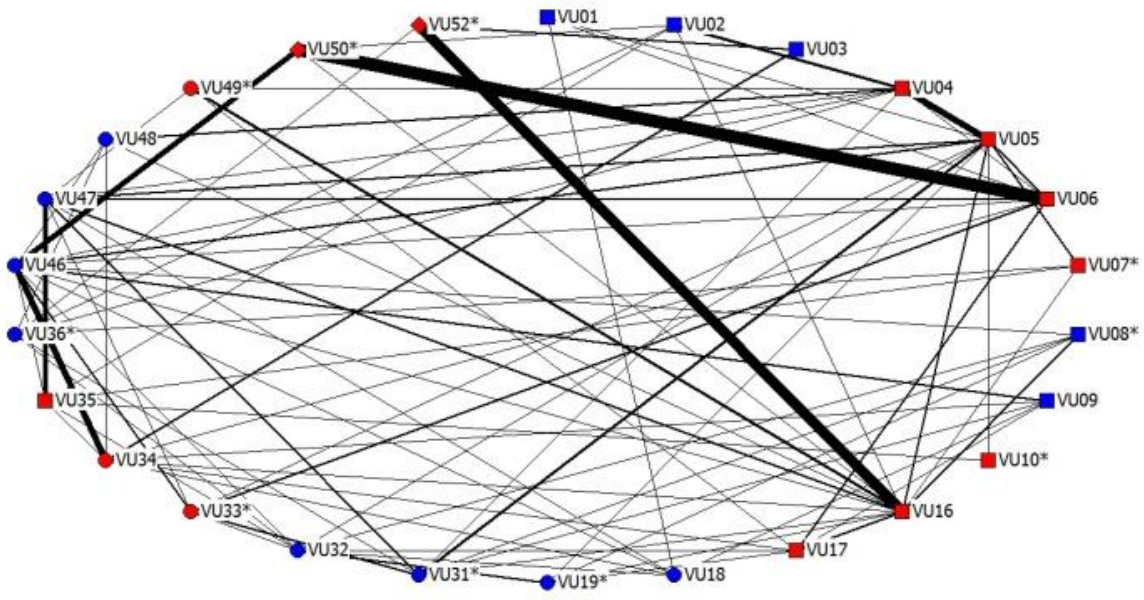
Social Contact networks

Hotel Group - 22 Nodes



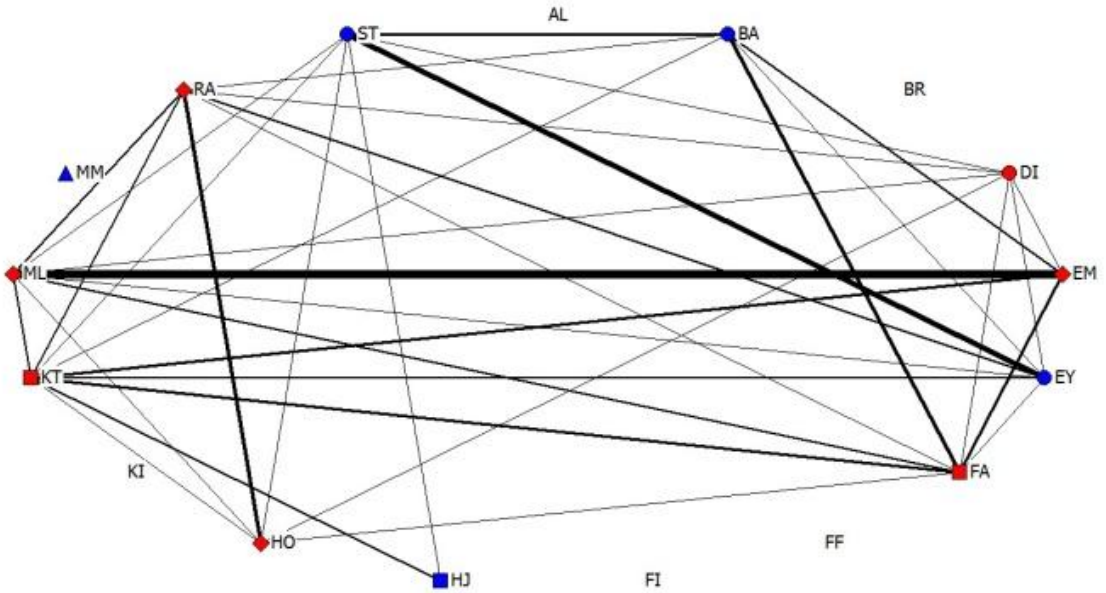
N=96, Density=0.09, Component ratio=0.39, Connectedness=0.45

University Group - 26 Nodes



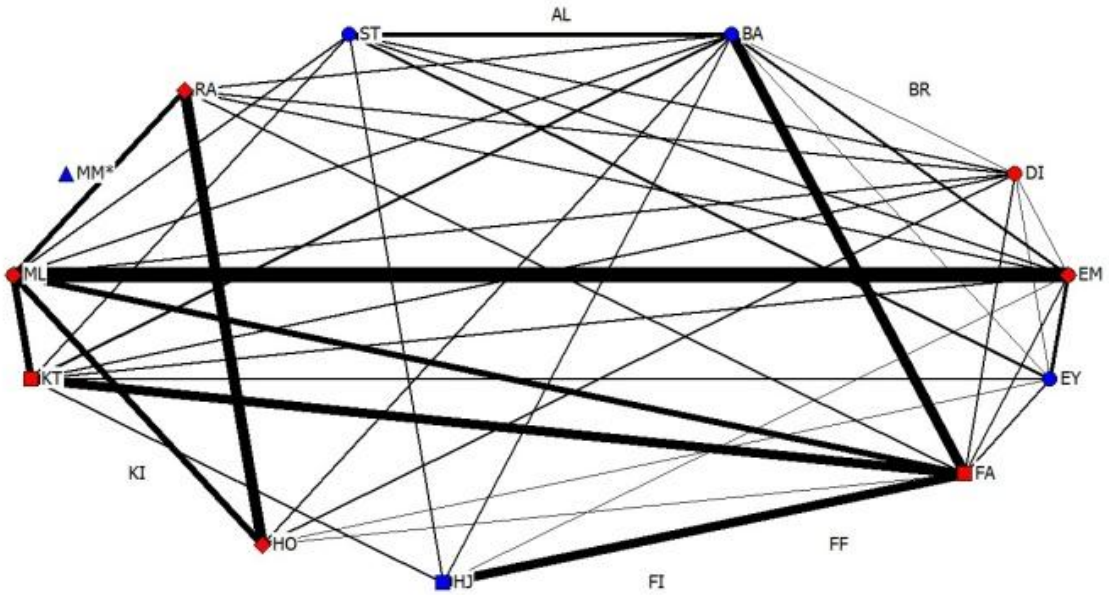
N=208, Density=0.15, Component ratio=0.88, Connectedness=0.89

Release Group - Period 1: 11 Nodes



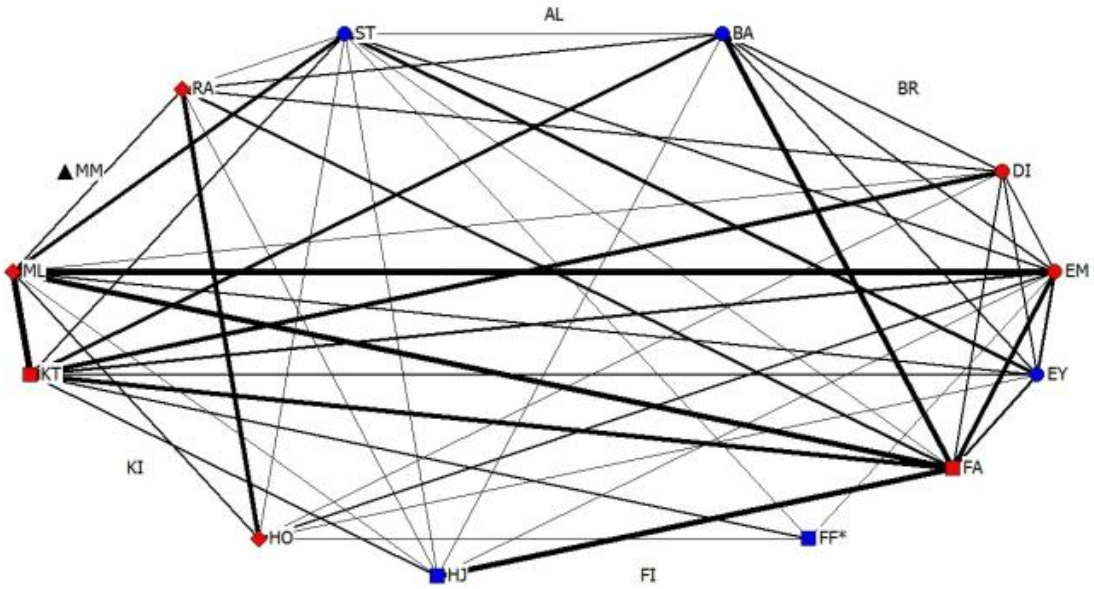
N=184, Density=0.51, Component ratio=0.90, Connectedness=0.91

Release Group - Period 2: 11 Nodes



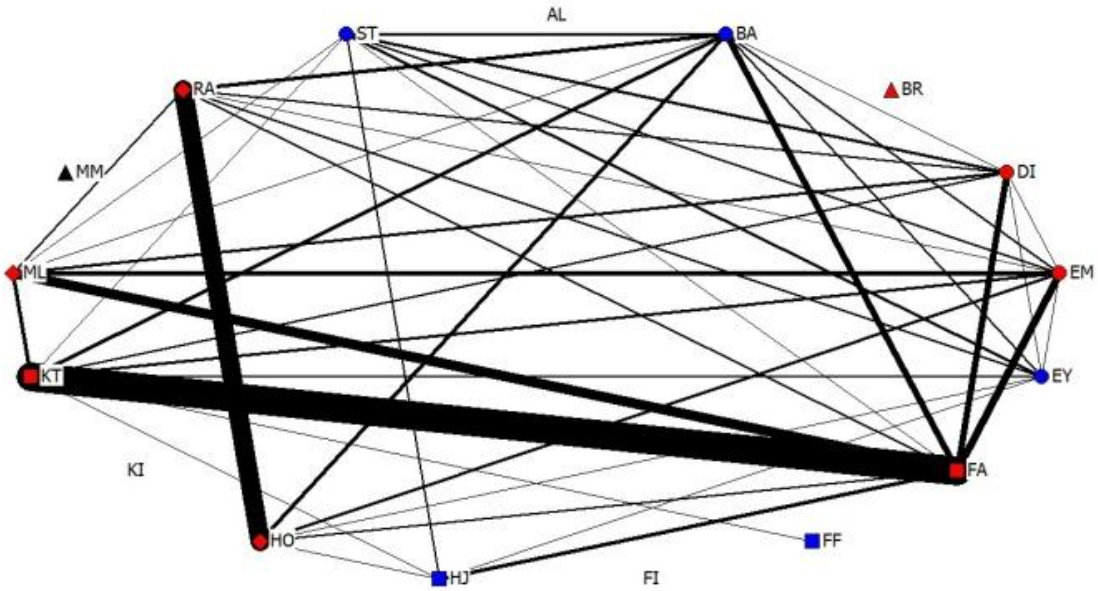
N=393, Density=0.66, Component ratio=1, Connectedness=1

Release Group - Period 3: 12 Nodes



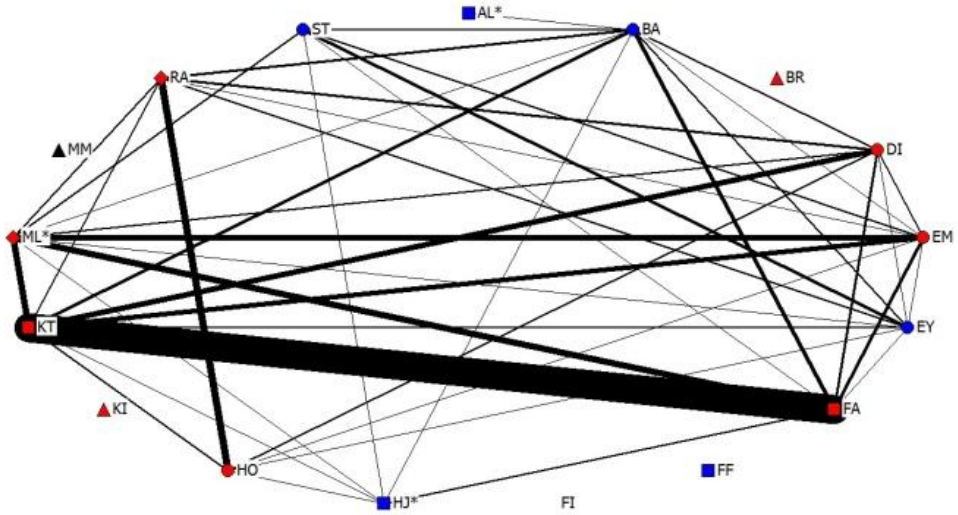
N=284, Density=0.56, Component ratio=1, Connectedness=1

Release Group - Period 4: 12 Nodes



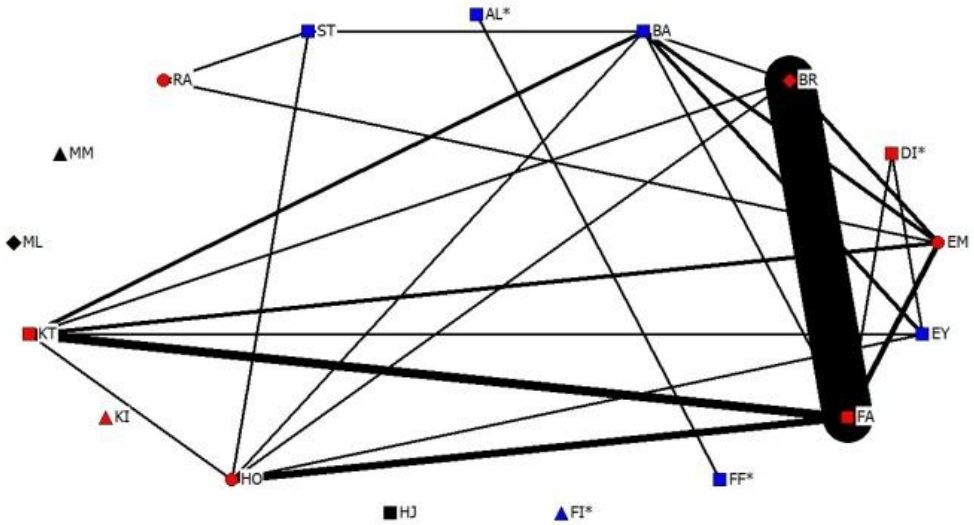
N=502, Density=0.50, Component ratio=0.91, Connectedness=0.92

Release Group - Period 5: 13 Nodes



N=489, Density=0.51, Component ratio=0.91, Connectedness=0.92

Release Group - Period 6: 12 Nodes



N=97, Density=0.27, Component ratio=0.8, Connectedness=0.83

Figure A3.1 Graph representation of social contact events recorded in the control groups for the entire 24 month research period and Release group across six time periods defined within the 20 months research period. Nodes coloured blue indicate males, red indicates females and black indicate individuals that have died. Square nodes represent adults, circle nodes represent sub-adults, diamonds represent juveniles, triangles represent infants* and the absences of a shape indicate individuals that have not yet joined the group. Thickness of edge represents the strength of association. * infants are not analysed in the data set and included in the graphs for representative purposes only.

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