people's trust for **endangered species**

Conservation and comparative behavioural ecology of the Bale monkey (*Chlorocebus djamdjamensis*) in southern Ethiopia

Adult male Bale monkey (left) and Adult female Bale monkey with infant (right)

Final Report

People's Trust for Endangered Species (PTES), UK

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Abstract

The Bale monkey (*Chlorocebus djamdjamensis*) is a little-known primate species endemic to the montane forests of southern Ethiopia. Until recently, Bale monkeys were believed to be confined to bamboo forest habitats, specializing on the young leaves of highland bamboo (*Arundinaria alpina*). However, recent surveys showed that Bale monkeys persist in several small and isolated forest fragments where bamboo was eradicated decades ago. In addition, the current study suggests that new populations of Bale monkeys were also discovered in the fragmented forests in the human dominated land scape of Sidamo. The population estimate data were collected in the intact bamboo forests of Shedem and Harenna where they encountered in the bamboo forest habitats suggesting that the species is able to prefer the bamboo forest than any other habitats. Furthermore, we aimed to assess the effect of habitat loss and degradation on Bale monkeys by comparing their behavioural ecology in continuous bamboo forest (Odobullu), fragmented bamboo forest (Kokosa), and fragmented forest where bamboo has been extirpated (Afursa). We found that both fragmented forest populations consumed relatively species-rich diets. Grass spp. and *Hagenia abyssinica* were the first and second most often consumed foods at Afursa accounting 27% and 25% of their overall diet, respectively. Bamboo and grass spp. were the first and second most often consumed foods at Kokosa contributing 48% and 18%, respectively. Bale monkeys at Odobullu Forest consumed a species-poor diet of only 5 plant species, of which bamboo and *Psychotria orohila* contributed 91% and 5%, respectively. Bale monkeys at fragmented habitats use relatively larger home range areas than monkeys in the intact forests. Monkeys in the intact bamboo forest are more arboreal than those living in the fragmented habitats. However, the postural behavior is similar in both intact and fragmented groups. The monkeys in the fragmented groups raid crops with intense conflict with the local community while those in the intact forests and far from the local people have no potential conflict with the local community. In general, these findings suggest that Bale monkeys are capable of extreme behavioural plasticity, adjusting their behaviour to the food species and available habitats in fragments. Despite this encouraging evidence of dietary, habitat and other behavioural plasticity, without longitudinal data on population trends, the long-term conservation prospects for Bale monkeys in forest fragments remain unclear.

Keywords: Activity time budget, Bale monkeys, behavioural plasticity, distribution, feeding ecology, human-monkey conflict, population estimate, ranging

1. Introduction

Many primate species today face a variety of anthropogenic threats including habitat loss and fragmentation, disease, hunting as a result of crop raiding, and climate change (Oates, 1996; Cowlishaw and Dunbar, 2000; Onderdonk and Chapman, 2000; Lee and Priston, 2005; Isabirye-Basuta and Lwanga, 2008; Dickman, 2010). Consequently, more than half of the world's primate species are currently threatened with extinction (Chapman and Peres, 2001, Wallis and Lonsdorf, 2010). The biggest threat for primate species is extensive conversion of their habitat into cultivated land for agriculture, human settlement and plantations (Lee and Priston, 2005; Isabirye-Basuta and Lwanga, 2008). Conversion of primate habitats into agricultural land, in particular, creates a potential conflict between hungry primates and local people (Oates, 1996; Cowlishaw and Dunbar, 2000; Campbell-Smith et al., 2010). Many primate species living in small fragmented forests adjacent to agricultural land are known to engage in crop raiding (Hill, 1997; Lee and Priston, 2005; Priston and Underdown, 2009; Campbell-Smith et al., 2010). Local communities are, therefore, likely to develop negative attitudes towards crop raiding primates resulting in conflict further endangering primates already at risk of extinction due to habitat destruction (Hill, 1997; Campbell-Smith et al., 2010; Meijaard et al., 2011). As a result, many primates are threatened because of hunting by humans due to their crop raiding behaviour (Oates, 1996; Cowlishaw and Dunbar, 2000; Campbell-Smith et al., 2011; Meijaard et al., 2011; Mekonnen et al., 2012).

Due to increasing habitat loss and degradation, primate populations are living in small fragments isolated by human dominated landscapes (Marsh, 2003; Cowlishaw and Dunbar, 2000; Onderdonk and Chapman, 2000; Mekonnen et al., 2012). Even today, many primates tend to occur in relatively small forest blocks (Cowlishaw and Dunbar, 2000). In small fragments, the quantity and quality of available forest habitat would be reduced, minimizing the carrying capacity of the fragment and eliminating suitable monkey habitats with subsequent reduction in quantity and quality of monkey food resources and sleeping trees (Arroyo-Rodríguez and Mandujano, 2006; Anderson et al., 2007; Baumgarten and Williamson, 2007; Dunn et al., 2009; Bonilla-Sánchez et al., 2010; Chapman et al., 2010; Chaves et al., 2012). Thus the distribution and abundance of monkeys would be severely affected, with the consequent reduction in population size (Fahrig, 2003; Mbora and Meikle, 2004; Baumgarten and Williamson, 2007).

For forest dwelling arboreal folivore primates, however, habitat fragmentation could have a negative influence on habitat quality within fragments (Anderson et al., 2007; Arroyo-Rodríguez and Mandujano, 2006) by affecting feeding ecology (Dunn et al., 2009; Chaves et al., 2012), habitat use, activity patterns (Chaves et al., 2011; González-Zamora et al., 2011) and ranging ecology (Irwin, 2008). As a consequence, the persistence of such primates in small fragmented forests depends on their ability to cope with changes (Onderdonk and Chapman, 2000; Chaves et al., 2012). Studies suggest that some primates can persist in fragmented forests based on their ability to feed on available food species and items (Dunn et al., 2009; Chaves et al., 2012), adjust their activity pattern to the new modified habitats (Boyle et al., 2009; Dunn et al., 2009; Boyle and Smith, 2010; Chaves et al., 2011) and to use smaller home ranges (Onderdonk and Chapman, 2000; Irwin, 2008). However, several other factors may also influence the activity patterns and ranging ecology of monkeys including food availability, season, group size, age and social rank, human disturbance and scramble competition (Vasey, 2005; Fan et al., 2008; Mekonnen et al., 2010a; Chaves et al., 2012).

Over the past few decades, mammals and other fauna of the Ethiopian highlands have become increasingly threatened due to increasing habitat loss and degradation and also hunting caused by the ever increasing human population of Ethiopia. One of the species which is severely affected by the habitat loss and hunting is the Bale monkey (Butynski *et al.,* 2008; Mekonnen *et al*., 2010a, 2010b, 2012). Bale monkey is an arboreal endemic primate species restricted to southern Ethiopian highlands and classified as Vulnerable in the IUCN Red List (Butynski et al., 2008; Mekonnen et al., 2010a, 2010b). It is the least known and most range-restricted among other savannah monkeys (*Chlorocebus* spp.) containing the six species (Groves, 2005). Other members of the genus containing Bale monkeys, *Chlorocebus,* such as grivet (*C. aethiops)* and vervets (*C. pygerythrus),* are generalists that inhabit a variety of savannah/ woodland habitat types and feed on a wide array of food sources (Kingdon, 1997; Zinner *et al*., 2002; Enstam and Isbell, 2007). However, unlike the other sister taxa, Bale monkeys primarily inhabit bamboo forest and are described as bamboo forest habitat specialists with a high dietary specialization on young bamboo leaves, which account for 73% of their diet (Mekonnen et al., 2010a, 2010b). Given the general principal that the more specialized a primate's diet, the greater is its risk of extinction (Harcourt et al., 2002) because of habitat loss and fragmentation, in particular destruction of bamboo forest (Mekonnen et al., 2010a). Interestingly, a very recent survey revealed that Bale monkeys continue to survive in the human dominated landscape where bamboo was eradicated several years ago (Mekonnen et al., 2012). Furthermore, the total population size of Bale monkeys has never been estimated and their distribution pattern has never been thoroughly mapped (Mekonnen et al, 2012). The only population estimate so far has been carried out in Odobullu Forest (Mekonnen et al., 2010b). Otherwise, Bale monkeys have been documented in the Bale Mountains National Park, Harenna Forest (Carpaneto and Gippoliti, 1994; Kingdon, 1997; Butynski, *et al.*, 2013) and 23 km north-west of Dodolla and in the Djam-Djam Mountains near Abera area, east of Lake Abaya at 3,000 m asl (Carpaneto and Gippoliti, 1994; Butynski *et al*., 2013). In the recent surveys, Bale monkeys were discovered in less than 40% of the Bale Mountains, in continuous bamboo forests (Mekonnen et al., 2010b) and in small forest fragments within the human dominated landscape of Sidamo where 35% of the fragments did not have bamboo which was eradicated decades ago (Mekonnen et al., 2012). Such surveys, however, did not cover the whole range of the species in southern Ethiopian highlands including the Bale Mountains.

Studies on the response of the Bale monkey to habitat loss and fragmentation are a critical first step for understanding ecological adaptations and to make informed conservation management plan (Isabirye-Basuta and Lwanga, 2008; Bracebridge et al., 2012; Chaves et al., 2012). Data on the basic quantitative natural history of primate species is imperative for developing successful conservation management strategies (Caro, 2007; Fashing et al., 2007; Mekonnen *et al*., 2010a). The main aim of this study was to assess how bamboo habitat loss and degradation is affecting the species in Sidamo by comparing its natural biology in the undisturbed habitats of the remote areas of the Bale Mountains. The main objectives of this study were to: (1) determine the conservation status and map the entire distribution pattern of Bale monkeys in southern Ethiopia, (2) study the comparative behavioural ecology of Bale monkeys in both intact bamboo forest and fragmented forests, and (3) examine levels of conflict between Bale monkeys with humans in southern Ethiopian Highlands.

2. Objectives

The main objectives of the present study were to

1. determine the entire distribution pattern and population size of the Bale monkey and to determine its appropriate IUCN conservation status.
2. develop a habitat suitability map for Bale monkeys to delineate priority areas for the conservation of the species.
3. examine the differences in diet, foraging behaviour, activity and ranging patterns in both continuous and fragmented forests.
4. examine the locomotor and postural behavior of Bale monkeys in both continuous and fragmented forests.
5. assess the level of human wildlife conflict that exists between the Bale monkey populations in both continuous and fragmented forests.
6. suggest management actions for the conservation of Bale monkeys in different habitat types.

3. Study Areas

The distributional survey area is located in southern Ethiopian highlands both in the Oromia and SNNP Regions covering about 18,000 km^2 (Fig. 1). It includes intact forests in protected areas, and several fragmented and isolated forests outside protected areas in human dominated landscapes.

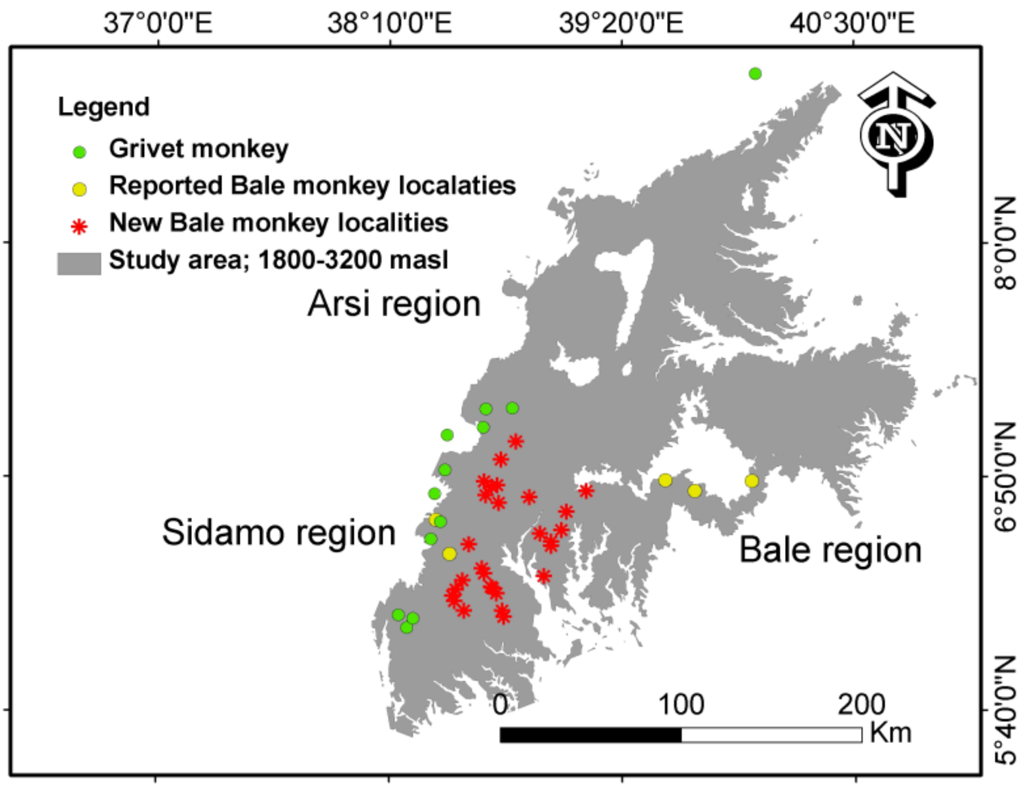

Fig. 1. Study areas for distribution, population estimate and habitat suitability modelling of Bale monkeys in southern Ethiopia.

The behavioural ecology was studied in four groups in two different habitats: two groups in the intact/continuous forest at Odobullu Forest (Plate 1), which lies east of the Bale Mountains National Park and two groups in the small fragmented forests at Kokosa (Plate 2) and Afursa Forests (Plate 3). The intact and fragmented forest habitats are separated by 160 km. The continuous Odobullu Forest is surrounded by tree dominated forest partially protected under Ethiopian Rift Valley Safaris, a private company. The two fragmented forests, Kokosa (c 0.84 km^2, 84 ha) and Afursa forests (c 0.34 km^2, 34 ha), are not protected and separated by 10 km where these fragments are surrounded by an anthropogenic matrix which includes cultivated lands, pastures, and human settlements.

Plate 1. Odobullu bamboo forest facing north to the tree dominated forest

Plate 2. View of Kokosa fragmented forest with human settlement and grazing land

Plate 3. View of Afursa fragmented forest surrounded by human settlement and grazing land

Fig 1. Map of the study fragmented forests (Afursa and Kokosa forest fragments) and the intact Odobullu Forest in southern Ethiopia.

4. Methods

Field organization, camping and site and study group selection

Preliminary survey were conducted to select study groups at each study site: Odobullu continuous bamboo forest habitat (2 study groups), fragmented forest with degraded bamboo (Kokosa fragment, 1 group) and fragmented forest with nearly eradicated bamboo (Afursa fragment, 1 group). The field team travel every month to the intact Odobullu Forest which takes three days using vehicle, on foot and horseback (Plate 4) while the fragmented study sites have a better access. Then the field team camp there in the intact forest habitat for several days (Plate 5).

Plates 4. Partial view of field team travelling to Odobullu Forest.

Plates 5. Field camping at the intact Odobullu Forest and partial view of the team.

Habituation of monkeys: The four study groups were habituated to human observers before the period of actual data collection (Plate 6). This helped the observers become familiar with the terrain and increased habituation of the monkeys. The focal groups were identified by natural markings, sizes, coat colour, body size, facial features and other distinguishing marks of members of each group (Mekonnen et al., 2010a; Chaves et al., 2011). Each study group was observed from dawn to dusk for 5-6 consecutive days per month.

Climatic Data

The rainfall and maximum and minimum daily temperatures data were measured using Oregon wireless rain gauge with indoor/ outdoor thermometer placed at each of the research camp sites (Plate 7). In addition, the maximum and minimum daily temperature data were recorded using a Taylor digital waterproof maximum/minimum thermometer. The average mean monthly rainfall and maximum and minimum temperature were calculated from the data recorded.

Plates 6. View of Bale monkey habituated group and behavioural ecology data collection by the PI.

Plate 7. View of rain gauge set up at the intact forest habitat.

Vegetation sampling and Phenology

Vegetation composition

The vegetation composition of the study areas were examined from randomly selected vegetation transects crossing the home range of each of the study groups. A total 3-4 with 300-700 m long and 5 m wide vegetation transects from the centre were laid out to adequately sample the diversity of big trees ≥ 10 cm DBH (i.e, 30 cm GBH) (Plate 8). All big trees with DBH ≥ 10 cm were recorded and identified along with species identity, number, DBH, height, canopy layer (lower, middle and upper), canopy size (m in diameter) and percentage of canopy cover. To sample all plant species ≥2 m height including bamboo, a total of at least 6 50 m x 10 m vegetation enumeration quadrats were laid randomly from the vegetation transects in the home range areas of the study groups. All plant species ≥2 m height within each quadrat were counted and identified along with species identity. Unidentified plant species recorded in the transects and quadrats were collected using plant press and identified to species level by professional botanists at the National Herbarium, Addis Ababa University.

The vegetation quadrats and transects were used to quantify the overall vegetation composition of the study areas and differences in forest composition between the study group home ranges and habitat types. The density of each plant species were calculated by dividing the total number of individuals species recorded with the total number of all plant species sampled per hectare in the home range of Bale monkeys. Plant species diversity in the study areas were calculated using the Shannon-Wiener index, H' of diversity and evenness were assessed using the evenness index, J (Krebs, 1999).

Plate 8. Vegetation transect lay out and vegetation sampling

The basal area (BA) of tree species was calculated from the measured DBH to estimate the biomass of each tree within the home range of monkeys (Fashing, 2001b; Felton et al., 2008). BA per hectare was used to estimate the biomass of each tree species in the home range of each study group (Kool, 1989).

Forest phenology

Phenological assessment of the trees in the home range of Bale monkey study groups was carried out to evaluate monthly changes in the availability of potential food resources. Phenological data on plant parts were collected monthly from randomly selected trees from or near the vegetation transects during the study period. Trees with a diameter at breast height (DBH) ≥ 10 cm were marked and identified for phenological monitoring including lianas with DBH ≥ 5 cm sometimes ≥ 2 cm. Bamboo (*Arundinaria alpina*) ≥ 5 cm DBH was included for phonological observation (Irwin, 2008) as it is a major component of the intact forest and diet of Bale monkeys (Mekonnen et al., 2010a). Data were collected at least from 3-10 potential food tree/shrub/lianas species in each of the home range of the study groups with 10-15 individuals per species depending on the habitat and diet of Bale monkeys. The availability of food items from the marked trees, lianas and bamboo was inspected monthly for 1 or 2 days after completing the group dietary data collection. Each marked tree, liana and bamboo was assessed for the relative abundance score of potential food resources (mature leaves, young leaves, flowers, ripe or unripe fruits, and others) by visual inspection and using binoculars with a relative abundance score ranging from 0 to 8 at intervals of 1. A value of 0 corresponds to a complete absence of that plant part, and a value of 8 when it encompassed >87.5% of the crown (Twinomugisha and Chapman, 2008; Vandercone et al., 2012).

Food availability was analysed from the average availability scores of food item categories of each marked tree species. The monthly phenology scores of young leaves, mature leaves, fruits, flowers and others were averaged for each plant species as well as for all plant species in each study group. Food availability index (FAI) (units per hectare) for young leaves, mature leaves, fruits, flowers, and others were obtained from the monthly average phenology scores and the basal area per hectare value for trees in the vegetation transects and quadrats in the home range of the study groups (Dasilva, 1994). The most frequently consumed plant species by Bale monkeys were selected for FAI analysis.

i) Distribution, population estimate, and habitat suitability

Distribution*:* Since 2008, we have been conducting surveys to establish the Bale monkey's distribution across several localities in the Bale Mountains (Mekonnen *et al*., 2010b) and Sidamo regions (Mekonnen *et al*., 2012) (Fig 1). The current survey areas will cover the remaining parts of the highlands which we have not reached yet. The distributional survey of Bale monkeys was carried out using presence/absence surveys through direct observations and interviews with the local people (Davenport *et al*., 2008). Based on the bamboo habitat preference of Bale monkeys, the bamboo forest within the elevation range between 2,200–3,400 m asl was identified from 2 m resolution satellite imagery and a 90 m Digital Elevation Model by using Erdas Imagine and ArcMap 10.0 (Irwin *et al.,* 2005). Additionally, people were asked to recognize photographs of the *Chlorocebus* species that occur in their areas (Baumgarten and Williamson, 2007; Davenport *et al*., 2008, Mekonnen *et al.,* 2010b). In addition, historical sites reported in the literature were also surveyed.

Habitat suitability map: A GIS-based habitat suitability map for Bale monkeys will be developed within the Bale Mountains and Sidamo highlands of Ethiopia, covering about 18,000 km^2 (Fig 1). The model will be developed based on important geographical and ecological variables including elevation, slope (determined from a Digital Elevation Model), and habitat types including tree-dominated forest, homogenous bamboo forest, mixed bamboo forest, human settlement and agriculture, bushland, and grassland which will be derived from 5 m resolution satellite imagery obtained from Planet Action Fund (http://www.planet-action.org/web/85-project-detail.php?projectID=10369).

Population estimate and habitat preference: In the extended and intact forests, population density and habitat preference were determined by using line transect survey techniques designed for forest primates (Plumptre, 2000; Lacher, 2003, Peres, 1999). In addition, total count method were employed in small isolated and fragmented localities (Plumptre and Cox, 2006; Davenport *et al*., 2008). In Harenna and Shedem intact forests in the Bale Mountains, transects were established based on a stratified random sampling approach within different habitat types (Plumptre, 2000; Lacher, 2003) and were censused 16-20 times both in wet and dry season in 2012 (Mekonnen *et al.,* 2010b). Censuses were conducted on transects from 06:30-06:45 to 10:30-10:45 in the morning and from 14:00 to 18:00 in the afternoon (Peres, 1999). During transect walks, when Bale monkeys and other primates are encountered, the observer recorded the dominant habitat type where the group is spotted, along with the GPS location, time, group size, group spread, animal-observer distance, sighting angle, perpendicular distance from the transect to the first animal seen, and the height of the animal on the tree when first detected (Chiarello, 2000; Fashing and Cords, 2000).

Encounter rates of groups per km were calculated for each habitat type (Bobadilla and Ferrari, 2000), and sightings were summarized as the total number of groups and individuals observed in each habitat type (Anderson *et al*., 2007). Both the DISTANCE method (Buckland *et al.,* 2010; Ferrari *et al.,* 2010) and the animal-observer distance method to the first animal seen will be used for the density estimation of Bale monkeys (Fashing and Cords, 2000; Marshall *et al.*, 2008; Mekonnen *et al.,* 2010b).

ii) Comparative Activity and Ranging Ecology of the Bale monkeys

Activity patterns

Activity time budgets will be collected for the selected study groups in both populations (continuous and fragmented forest) using the instantaneous scan sampling method (Altmann, 1974) for 5-6 consecutive days per month from each study group covering both wet and dry season. During activity scan sampling, the activities of monkeys were recorded at 15 minute intervals for up to 5 minutes duration from 0700 to 1730 (Fashing, 2001a; Wong and Sicotte, 2007). During scans, data were collected for the first 5 adults, sub-adults or juveniles (Mekonnen *et al*., 2010a) (Plate 9). The identity of the scanned individual was recorded and assigned to one of the following age/sex classes: adult male, adult female, sub-adult male and sub-adult female, juvenile male and juvenile female. During scans, individuals were recorded as performing one of the following behaviors on the standardized data sheet: feeding, moving, resting, playing, aggression, grooming, sexual activity, or other (Fashing, 2001a, Mekonnen *et al*., 2010a).

Plate 9. Behavioral observation of study groups Kokosa and Odobullu sites by the PI.

Percent time spent in different activities was calculated by dividing the proportion of the number of behavioral records for each activity category by the total number of activity records. The behavioral records of the troop will then be used to calculate the activity budgets for each day and averaged within each month to construct monthly as well as overall activity budgets.

Ranging patterns

During scan sampling, the location of the geographic center of the study group has been recorded at 15-minute intervals. Day range lengths were calculated using the Hawths tools extension in Arc GIS (Fashing *et al*., 2007). The minimum convex polygon method (MCP) and fixed kernel methods were used to determine the home range sizes of Bale monkeys using GIS software (ArcGIS version 10) (Fashing *et al.*, 2007; Wong and Sicotte, 2007; Mekonnen *et al.,* 2010a). To estimate home range size, all day ranges were combined to generate 95% and 100% MCPs in ArcGIS 10.

Habitat use and density

The habitat types occupied by the study group were recorded during scan sampling or activity time budget study every 15 minutes as the group moved from point to point in their home ranges (Vié et al., 2001; Zabala et al., 2005; Wallace, 2006; Mekonnen, 2008). The habitat use of the study groups was analyzed by the proportion of the use of areas with respect to the availability of habitat types (Zabala et al., 2005; Wallace, 2006). Thus, the habitat use of monkeys was calculated by the proportion of the number of scans where the group spend with the available habitats in its home range (Vié et al., 2001; Wallace, 2006; Tesfaye, 2013). The proportion of the habitat use of the monkeys was compared between the study groups living with similar habitat types and also between fragmented and continuous forest habitat types. The density of the study groups was calculated by the total number Bale monkeys in the focal study group divided by its home range per km square (Boyle et al., 2009; Boyle and Smith, 2010).

iii) Comparative feeding ecology of Bale monkeys

For the selected study groups (continuous and fragmented forest), dietary data have been collected using instantaneous scan sampling at 15-minute intervals on members of the study groups (Altmann, 1974). During scan sampling, when a monkey is observed feeding, the type of food item as well as the species consumed was recorded on a standardized data sheet. The food items were recorded as young leaves, mature leaves, root, stem, flower, fruit, seeds, shoot, grass, herb or animal prey (Mekonnen *et al*., 2010a). The species consumed by the monkeys were noted in the field if possible while unidentified species will be collected for later taxonomic identification in the National Herbarium, Addis Ababa University.

Diet composition was evaluated by determining the proportion of different food items and species consumed by the monkeys. Diet selection by the study group was determined from the relative proportions of the number of scans spent feeding on different food items and plant species in the diet. Specifically, dietary selection ratio for food species in the diets of the study groups were calculated using two methods based on the stem densities and basal area (BA) of different tree species. To assess dietary diversity over the study period, the Shannon-Wiener index of diversity was used to examine potential differences in diet (over time) by species (Krebs, 1989). Dietary diversity was measured via the Shannon-Wiener index, H,' and dietary evenness was assessed by the evenness index, J (Krebs, 1989). Dietary preference for different food species by the study group will be calculated as the proportion of time spent feeding on a certain species *i* divided by the density of that species *i* in the study group's home range (Fashing, 2001a). The annual overlap of dietary species (fruit, leave species, etc) in diet between continuous forest and fragments were calculated using the Morisita–Horn's index (C) (Krebs, 1999).

iv) Comparative locomotor and postural behaviour of Bale monkeys

Positional behavior (locomotor & posture) data for Bale monkeys were collected using an instantaneous scan sampling technique (Altmann, 1974) at 15 min intervals as the study groups are not likely to be consistently visible enough in their forested habitats to enable focal sampling to be used. Data were collected from dawn to dusk for 5-6 days per month at each study site. On every 15 min time point, the following variables were recorded on a standardized data sheet for up to the first 5 visible individuals: (a) behaviour/activity, (b) positional (locomotor or postural) mode, (c) substrate use (d) support type, (e) support size, (f) support inclination, (g) number of supports and (h) forest layer, along with the date, time, and age-sex class of the individual (Hunt et al., 1996; McGraw, 2000; Bitty and McGraw, 2007; Youlatos et al., 2008; Youlatos, 2009; Iurck et al., 2013).

Locomotor maintenance activities associated with positional behaviour were recorded in the following four categories: feeding, travelling, resting and socializing (McGraw, 2000; Chatani, 2003; Bitty et al., 2007). Locomotor modes (movements involving positional changes) were recorded as *climb, descend*, *leap*, *walk*, *run/gallop*, *bridge*, and *others* (McGraw, 2000; Garber, 2007; Prates and Bicca-Marques, 2008). Postural behaviours during feeding and resting were recorded based on body shape and limb position as *sit*, *quadru/tripedal stand*, *bipedal stand*, *lie* and *others* (McGraw, 2000; Garber, 2007; Prates and Bicca-Marques, 2008). For every 15 min scan, *support use* was recorded as terrestrial or arboreal, *support type* was recorded as ground, vertical trunk, bough, branch, twig, liana, or other; *support size* as small (< 2 cm), medium (2 - 10 cm), large (10 - 20 cm) or very large (>20 cm in diameter), and *support inclination* was recorded as horizontal (0±22.5), oblique (between the vertical and horizontal classes) or vertical (> 67.5) (McGraw, 2000; Bitty et al., 2007; Youlatos et al., 2008; Youlatos, 2009; Iurck et al., 2013). Furthermore, *forest layer* was recorded as ground, shrub layer (<5 m), small trees and bamboo stratum (5-15 m), middle canopy tree stratum (16-25 m), and upper canopy layer (>25 m).

The percentage contribution of each locomotor maintenance activity was calculated by dividing the number of locomotor maintenance activity records for each activity category by the total number of locomotor maintenance activities recorded. The percentage contribution of each locomotor (climb, descend, leap, walk, run, bridge, and others) and postural mode (sit, quadru/tripedal stand, bipedal stand, lie and others) were calculated by dividing the number of locomotor behaviour records for each locomotor and postural mode by the total number of locomotor/postural modes recorded, respectively. The habitat utilization of monkeys was calculated by the percentage contribution of each category of forest layer, support type, support size and support inclination used by the monkeys divided by their total contribution.

v) Human-wildlife conflict of Bale monkeys with the local community

Human monkey conflict was studied from questionnaire surveys in localities of the Sidamo region where Bale monkeys reside in close vicinity to human villages and in the more remote Bale Mountains region from Sept 2012 – Dec 2012. One adult individual from each family was interviewed. Semi-structured and open-ended questions were asked that include describing (1) problematic wildlife in their area in decreasing order of cost of damage, (2) whether the Bale monkeys cause damage to their crops and fruits, (3) what particular crop types or species Bale monkeys cause damage to, (4) what measures they take to prevent the damage, (5) whether they ever kill Bale monkeys for crop raiding, (6) any trends over the past 5 years in the extent of damage caused by Bale monkeys, (7) their suggestions as to what potential options there are for mitigating human–wildlife conflicts with Bale monkeys, (8) whether they believe that catching/hunting Bale monkeys is legal or illegal, and (9) whether they are aware that the Bale monkey is legally protected (Okello, 2005; Lee and Priston, 2005; Campbell-Smith, 2010).

5. Results to date and outputs

The preliminary data has been analysed while the whole project result has been under review and analyses. Thus, I have presented here the preliminary results analysed.

Climate data

Climatic data on the rainfall and temperature has been collected at Odobullu and Kokosa camp sites where the Kokosa campsite is about 8 km far from the other nearby fragment study site, Afursa with similar altitude that would have similar rainfall pattern. So, the rainfall and temperature data is available for both continuous and fragmented habitats. However, the preliminary result for four months is presented in Fig 2.

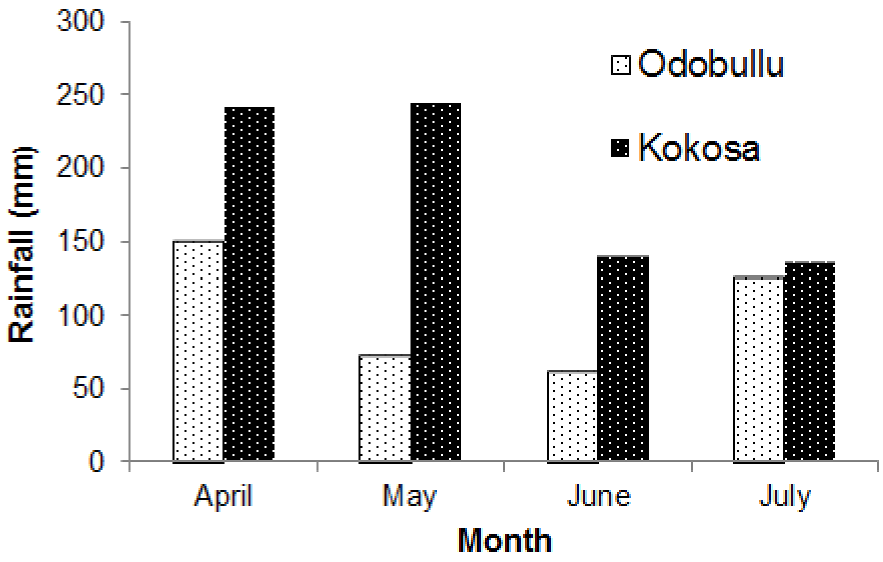

Fig. 2. Monthly changes in rainfall at Odobullu intact bamboo forest and Kokosa fragmented forest habitat camp sites.

Vegetation composition and phenology

The vegetation composition for the continuous bamboo forest habitat (Odobullu) and the fragmented forest habitats (Kokosa and Afursa) have been collected, identified to species level (Plate 9) and the density and composition were analysed. Based on the availability and density of bamboo culms, the dominant food species of monkeys, the habitat types are divided into three: Afursa – non-bamboo fragment containing 1.8% bamboo stem density, Kokosa – degraded bamboo containing 49.2% and Odobullu intact bamboo forest containing 85.7% of bamboo stem density. The plant species diversity, dominance and evenness are presented in Table 1.

Table 1. Plant species diversity (>2 m tall) in the vegetation transects at each study site

Habitat type	Study site (N=no of plant species > 2m tall)	Dominance _D	Shannon-Wiener diversity index, *H´*	Evenness index, J
No-bamboo	Afursa (40)	0,11	2,82	0,42
Degraded bamboo	Kokosa (33)	0,28	1,87	0,20
Intact bamboo forest	Odobullu (19)	0,74	0,75	0,11

Basal areas of trees ≥ 10 cm DBH were calculated in each habitat types. The *Ilex mitis* was dominant in the basal area of trees at the fragmented study sites while *Psychotria orohila* was the first at the Odobullu intact bamboo forest. The phenology data has been collected from each study group from the food species consumed by the monkeys dominantly in the study period and will be analyzed in the coming few months.

i) Distribution, population estimate, and habitat suitability

The distribution data were collected from sites that were not surveyed before and discovered 8 new sites in the Bale Mountains and Sidamo areas of Southern Highlands of Ethiopia. The population estimate data were collected from the continuous forests of the Harenna Forest and Shedem Forests covering largest forests of southern Ethiopia with the strongholds of Bale monkey populations. Total count was used to estimate the population in the fragmented habitats. The GPS location data for habitat suitability modelling were collected from different habitat types in the study areas and will be used for the analyses. Satellite image was supported from Planet Action Fund for the habitat suitability modelling of Bale monkeys (http://www.planet-action.org/web/85-project-detail.php?projectID=10369). The results are now in preparation for publication.

ii) Comparative feeding ecology of Bale monkeys

Data for the preliminary studies is available while the whole data will be summarized and analyzed in the coming several months. The preliminary data indicates that Bale monkeys showed extreme dietary plasticity between the intact bamboo forest habitat (Odobullu Forest) and fragmented Forests (Kokosa – degraded bamboo and Afursa – no bamboo). We found that Bale monkeys at Afursa and Kokosa fragmented forests consumed relatively diverse plant species with 18 and 24, respectively. Grass sp. and *Hagenia abyssinica* were the first and the second highly consumed plant species by Afursa Group accounting 26.6% at and 24.9% of their diet, respectively. While bamboo and grass sp. were the first and the second highly consumed species by Kokosa Group contributing 48% and 17.8%, respectively. On the contrary, Bale monkeys at Odobullu Forest consumed only 5 plant species, of which, bamboo (*Arundinaria alpina*) and *Psychotria orohila* contributed (90.7%) and (4.7%), respectively. Bale monkeys at Odobullu forest consumed dominantly bamboo

Plates 10. Bale monkey consumed young leaves (Left) and shoot of bamboo (Right).

Plate 11. Bale monkeys feeding on grass and herbs in the farmer's grazing land at Kokosa.

NB: The result of this study will be summarized, analyzed and submitted for publication. The abstract of this study has already submitted to the International Society of Primatologists/ IPS conference that will be held in August 2014 at Hanoi, Vietnam.

iii). Comparative Activity and Ranging Ecology of the Bale monkeys

The preliminary studies showed that the activity time budget for the three study sites for bamboo forest habitat (Odobullu Forest – intact bamboo, Kokosa fragment – degraded bamboo and Afursa fragment – no bamboo are given below in Table XX. Bale monkeys at each study site spend most of their time for feeding. Non bamboo forest habitat spends less time for resting than other habitat types.

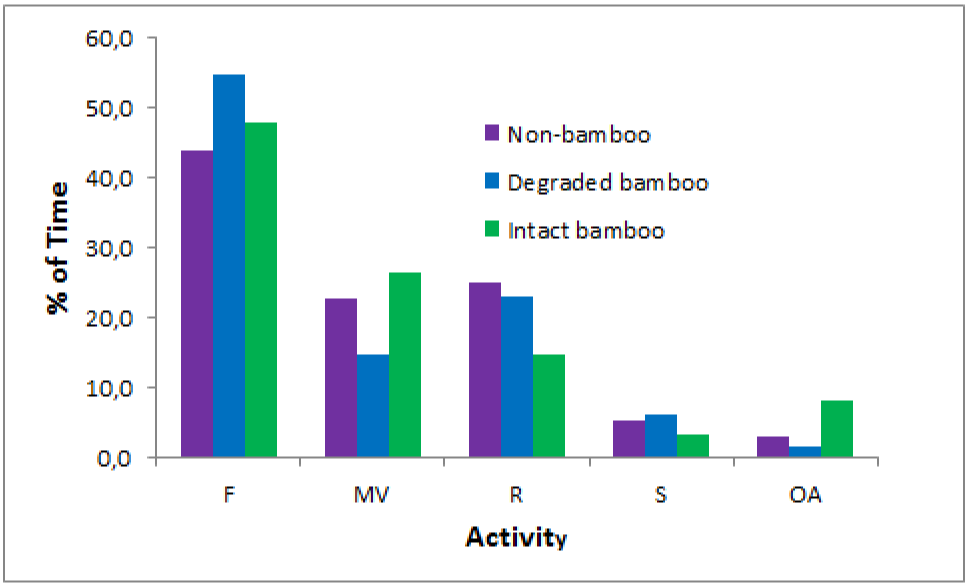

Fig 3. The overall activity time budget of Bale monkeys in the three habitat types.

Ranging patterns

Bale monkeys living at the Kokosa fragmented forest use larger home range areas than Odobullu and the Afursa Fragment habitat (Table 2). Bale monkeys at the fragmented forest habitats travel relatively short distances per day than groups living at the intact bamboo forest habitat.

Table 2. Mean daily travel distance and home range size of Bale monkey groups in different habitat types using Minimum Convex Polygon (MCP) (n=3 months).

Habitat type	Group	Mean daily travel distance (m),				Home range area (ha)
		Mean (N)	SE	Std. Dev.	Range	
Non-bamboo forest	Afursa	863 (15)	92,7	359,2	421-1604	28
Degraded bamboo	Kokosa	910 (13)	73,6	265,4	555-1285	60,8
Intact bamboo forest	Odobullu GA	1093 (9)	94,5	283,4	768-1473	32,9
	Odobullu GB	1051 (8)	125	353,7	535-1399	21,3

Habitat use

Bale monkeys use different habitat types depending on the available habitats in the fragments while the bamboo and mixed bamboo forest habitat at the intact bamboo forest (Fig. 4).

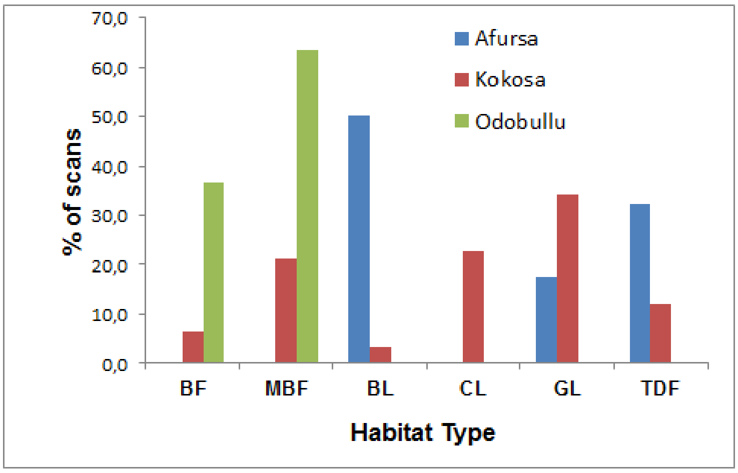

Fig 4. Variation in the habitat use of Bale monkeys in different habitat types during the course of the preliminary research (n= 3 mo). Habitat types: BF = Bamboo forest; MBF = Mixed bamboo forest; BL= Bushland; CL = Cultivated land; GL= Grassland: TDF =Tree-dominated forest

v) Locomotor and postural behaviour of Bale monkeys

Postural behavior: *Feeding posture*

Bale monkeys prefer primarily sitting as feeding posture regardless of the variation in the habitat types as shown in Table 3.

Table 3. The overall frequencies of feeding posture at the three different habitat types.

Habitat type	Study site	% of postural mode				
		S	TS	BS	QS	Total
Non-bamboo	Afursa	92,4	7,4	0,3	0,0	100,0
Degraded bamboo	Kokosa	96,3	3,6	0,1	0,0	100,0
Intact bamboo	Odobullu	94,9	4,7	0,2	0,2	100,0

S = Sit; TS = Tripedal stand; BS = Bipedal stand; QS = Quadrupedal stand

Resting posture

Bale monkeys prefer predominantly sitting posture during resting regardless of the variation in the habitat types as shown in Table 4.

Table 4. The overall frequencies of resting posture at the three different habitat types.

Habitat type	Study site	% of resting posture				
		S	TS	BS	QS	Total
Non-bamboo	Afursa	99,5			0,5	100,0
Degraded bamboo	Kokosa	100,0				100,0
Intact bamboo	Odobullu	99,6			0,4	100,0

S = Sit; TS = Tripedal stand; BS = Bipedal stand; QS = Quadrupedal stand

Locomotion

The locomotor behavior of Bale monkeys is variable depending on the variation in the habitat types as shown in Table 5.

Table 5. The overall frequencies of locomotor behavior of Bale monkeys at the three different habitat types.

	% of locomotor mode							
	BR	CL	DS	GL	L	RU	WK	Total
Afursa	8,6	14,1	42,9	2,5	22,2	3,0	6,6	100,0
Kokosa	7,5	7,5	18,9	8,5	22,2	24,1	11,3	100,0
Odobullu	3,3	13,8	19,6	0,0	44,5	5,4	13,4	100,0

BR = Bridge; CL = Climb; DS = Descend; GL = Gallop; L = Leap; RU = Run; WK = Walk

Substrate use

Table 6. The overall forest strata/ forest layer utilization of Bale monkeys in different habitat types

Study site	% forest strata use					
	G	SL	SB	MC	UC	Total
Afursa	18,4	47,3	28,3	5,3	0,7	100,0
Kokosa	31,8	42,7	24,7	0,8	0,0	100,0
Odobullu	3,2	7,1	67,5	18,9	3,2	100,0

Forest layer G = Ground; SL = Shrub layer (<5 m); SB = small trees and bamboo stratum (5-15 m); MC = Middle canopy (16-25 m); UC = Upper canopy layer (>25 m).

Support use

Table 7. The overall support use of Bale monkeys in different habitat types

Study site	% of support use		
	Terrestrail	Arboreal	Total
Afursa	18,4	81,6	100,0
Kokosa	31,8	68,2	100,0
Odobullu	3,2	96,7	100,0

Support type

Table 8. The overall support type utilization of Bale monkeys across habitat types

	BB	BS	VT	BO	BR	T	L	G	OS	Total
Afursa	0,3		7,9	5,2	46,1	19,4	2,1	19,0	0,0	100,0

Kokosa	17,9	5,3	2,1	1,3	29,7	11,2	0,1	32,1	0,1	100,0
Odobullu	21,7	39,9	1,2	4,3	20,7	2,8	6,1	3,4	0,0	100,0

BB = Bamboo branch; BS = Bamboo stem; VT = vertical trunk; BR = Branch; T = Twig; L = Liana; G = Ground; OS = others

Support size

Table 9. The overall support size utilization of Bale monkeys

Study site	% of support size				
	SM	MD	LR	VL	
Afursa	29,9	55,5	12,0	2,5	100,0
Kokosa	56,4	40,4	3,2	0,1	100,0
Odobullu	33,0	55,8	9,6	1,6	100,0

SM = Small; MD = Medium; LR = Large; VL = Very Large

Support inclination

Bale monkeys prefer horizontal support than other support types listed in Table 10.

Table 10. The overall utilization of support inclination across Bale monkey groups in different habitats

Study site	% of support inclination			
	Horizontal	Oblique	Vertical	Total
Afursa	65,7	30,7	3,6	100,0
Kokosa	73,1	26,2	0,8	100,0
Odobullu	62,6	32,1	5,3	100,0

Number of supports

Bale monkeys prefer single support than multiple support utilization regardless of habitat types (Table 11).

Table 11. The overall of number of supports utilized by Bale monkey groups in different habitats

Study site	% of number of supports utilized		
	Single	Many	Total
Afursa	72,0	28,0	100,0
Kokosa	67,7	32,3	100,0
Odobullu	65,1	34,9	100,0

V) Human wildlife conflict of Bale monkeys with the local community

A total of 7 sites were selected for the assessment of human Bale monkey conflict study depending on the forest type whether the forest is continuous or fragmented, and distance from the nearby village to Bale monkey populations and cultivated lands. In this regard, Odobullu and Harenna study sites are considered intact bamboo forest habitats where the Rira village is near to the Bale monkeys whereas the Bucko village is about 8 km far from the Bale monkey populations where they are separated each other by the tree-dominated forest. A total of 415 informants were interviewed to assess the human Bale monkey conflict studies. Of which, 87.47% and 12.5 3% of the respondents are males and females, respectively (Table 12). The low number of female informants is due to traditional culture of the local community.

Local people responded that Bale monkeys are known to raid crops in the fragmented forest habitats where they are living in between fragmented forests or near bamboo forest habitats (See Plate 12).

Table 12. Individual respondents at each village

	Male	Female	Total
Anasora	34	22	56
Bube Kersa	27	4	31
Arbegona	37	4	41
Kokosa	56	11	67
Nensebo	51	2	53
Rirra	81	0	81
Odobullu	77	9	86
	363	52	415

The data will be analyzed and prepared for publication.

Plate 12. Bale monkeys feeding on maize from the local people resulting in conflict with the communities.

PROJECT OUTCOMES AND SUSTAINABILITY

a. What are the likely outcomes arising from each of your stated objectives?

1. The study will provide conservation data on the Bale monkey population size, distribution, and habitat suitability map to delineate priority conservation areas and to establish protected areas. This result will be published in peer reviewed journals.

2. The feeding ecology, activity and ranging patterns data will be published in two peer reviewed journals. The results will help to devise management scheme to establish protected areas.

3. The study on the human wildlife conflict between Bale monkeys and local community will help to design management action and help to create awareness and to resolve the conflict. This information will also be published in a reputable scientific journal.

4. In general, all the reports and the published documents will provided to the Federal Ethiopian Wildlife Conservation Authority and to the regional, zone and district political leaders and wildlife officials to implement the conservation and management of the species and its habitats. In addition, awareness, workshops and posters will be provided to conserve the species.

a. Manuscripts to be published from this project:

From the data collected in this study, the following 4-6 manuscripts will be published in reputable journals.

1. Addisu Mekonnen, Peter J. Fashing, Afework Bekele, Eli K. Rueness, Anagaw Atickem, R. Adriana Hernandez-Aguilar, and Nils Chr. Stenseth (in prep, Abstract submitted to IPS Congress). Dietary plasticity of Bale monkeys (*Chlorocebus djamdjamensis*) in continuous and fragmented forests in the southern Ethiopian Highlands.
2. Addisu Mekonnen et al. (in prep.). Population estimate, density and habitat preference of the Bale monkey (*Chlorocebus djamdjamensis*) in Harenna and Shedem Forests of the Bale Mountains, Ethiopia.
3. Addisu Mekonnen et al., (in prep.). Geographic distribution and habitat suitability of Bale monkeys (*Chlorocebus djamdjamensis*) in the southern Ethiopian Highlands.
4. Addisu Mekonnen et al. (in prep.). Activity time budget, ranging ecology and habitat use of Bale monkeys in continuous and fragmented forests in the southern Ethiopian Highlands.
5. Addisu Mekonnen et al., (in prep.). Locomotor and postural behaviour of Bale monkeys (*Chlorocebus djamdjamensis*) in continuous and fragmented forests in the southern Ethiopian Highlands.
6. Addisu Mekonnen et al., (in prep.). Human-wildlife conflict of the Bale monkeys (*Chlorocebus djamdjamensis*) in the southern Ethiopian Highlands.

b. How will your project contribute towards long-term conservation of the species or habitat concerned?

Progress report for the Ethiopian Wildlife Conservation Authority has been submitted to help conserving the monkeys. Final report will also be submitted to the Ethiopian Wildlife Conservation Authority the Oromia, and Southern Nations and Nationalities People's Regions (SNNPR), Zone, Woreda (district) political leaders, officials, NGOs and local communities. The research teams have created awareness at different study sites for the local communities to conserve the monkeys and their habitats. The current and new Bale monkey localities discovered in this and the previous study will help to attract tourists both domestic and foreign that generates income which help for sustainable development of the local community and the country at large.

c. How will your project contribute towards conservation in your region/ bio-area and have you identified any potential problems in achieving long-term impact?

From this study, data has been collected on the remaining distribution pattern, population estimate and habitat suitability modelling where these data is very imperative to revise its current Vulnerable status in the IUCN Red List to Endangered status where the population size is decreasing, their previous bamboo forest habitat has been degraded, deforested or eliminated for agricultural land expansion due to the increasing human population in Ethiopia. The present ecological study in the intact bamboo forest habitat, degraded bamboo fragment and bamboo-less habitats suggested that the species showed dietary flexibility adjusting their diet in the available food resources. However, they still prefer to feed on bamboo based on their availability where they consumed about 90% at the intact bamboo forests, 48% in the degraded bamboo fragment and 1.8 % in the non-bamboo forest habitat. This suggests that afforestation of bamboo in the degraded habitat will increase the availability of food resources for the monkeys. In addition, the perception of the local people towards conservation of Bale monkeys depends on the habitat type where local people showed in the highest negative attitude at the Kokosa fragmented study site. So, conflict resolution and awareness creation mechanisms will be designed.

d. How will you disseminate your results? Please give details on as many as possible.

The result of this research will be published in the peer reviewed scientific papers, reports to Federal Ethiopian Wildlife Conservation Authority, the Regional Wildlife Conservation Authority, IUCN/SSC, and NGOs working for wildlife and bamboo forest conservation like FARM-Africa and SOS Sahel Ethiopia. In addition, awareness was created through community education and focus group discussion in the local communities. For instance, I have also established contact with BBC Earth News media (Eg. See the Bale monkey news from my previous studies http://news.bbc.co.uk/earth/hi/earth_news/newsid_8587000/8587712.stm), and also obtained Spot Satellite Image from Planet Action Fund for habitat suitability modelling (http://www.planet-action.org/web/85-project-detail.php?projectID=10369).

6. Discussion

The Bale monkey (*Chlorocebus djamdjamensis*) is a little-known primate species endemic to the montane forests of southern Ethiopia. Until recently, Bale monkeys were believed to be confined to bamboo forest habitats in the Bale Mountains, specializing on the young leaves of highland bamboo (*Arundinaria alpina*) (Mekonnen et al., 2010a,b: Butynski et al., 2008). However, recent surveys showed that Bale monkeys persist in several small and isolated forest fragments where bamboo was eradicated decades ago (Mekonnen et al., 2012). However, the only population estimate was carried out at the Odobullu Forest and the whole range of the species was not documented fully. Thus the current study was aimed to fill these gaps.

The current study documented new Bale monkey populations in the Sidamo highlands of southern Ethiopia. In addition, population estimates were conducted in the continuous bamboo forests in the Harenna and Shedem Forests of the Bale Mountains and total population count in the fragmented and isolated populations. Thus the spatial distribution and population estimate and habitat suitability data for the little-known Bale monkeys is the first prerequisite for focusing effective conservation and management plans for the species and its preferred habitats.

In addition, the study was aimed to assess the effect of habitat loss and degradation on the Bale monkey populations by comparing their feeding ecology, activity time budget, ranging ecology, habitat use and utilization, locomotor and postural behaviour, and human monkey conflict in continuous bamboo forest (Odobullu Forest), fragmented bamboo forest (Kokosa), and fragmented forest where bamboo has been extirpated decades ago (Afursa). The preliminary results showed that both fragmented forest populations consumed relatively species-rich diets (18 species in Afursa and 24 species in Kokosa). Grass spp. and *Hagenia abyssinica* were the first and second most often consumed foods at Afursa accounting 27% and 25% of their overall diet, respectively. Bamboo and grass spp. were the first and second most often consumed foods at Kokosa contributing 48% and 18%, respectively. Bale monkeys at Odobullu Forest consumed a species-poor diet of only 5 plant species, of which bamboo and *Psychotria orohila* contributed 91% and 5%, respectively. These findings suggest that Bale monkeys are capable of extreme dietary plasticity, adjusting their diets to the food species available in fragments. Despite this encouraging evidence of dietary plasticity, without longitudinal data on population trends, the long-term conservation prospects for Bale monkeys in forest fragments remain unclear.

Bale monkeys in the intact bamboo forest prefer to use bamboo forest habitat than monkeys in the fragments in which monkeys in the fragments are adapted to inhabit to the habitat types available in small fragmented forests and shift to feed even on unselected food items available in the intact forests. The activity time budget spend by the study groups in both intact and fragmented habitats showed comparable results. However, Bale monkeys in the fragments relatively use larger home range sizes. In addition, Bale monkeys in the intact forest habitats are more arboreal than monkeys living in the fragmented habitats suggesting that Bale monkeys spend considerable time feeding on grass to supplement the reduction or loss of bamboo further endangering the monkeys due to persecution by humans as they raid on crops and possibly infection by parasites.

The current study showed that the magnitude of human monkey conflict is intense depending on the habitat types occupied by the monkeys. For instance, monkeys living between fragmented and isolated forest fragments surrounded by anthropogenic matrix raid crops resulting in conflict with the local community. The respondents showed that the monkeys feed on varieties of crops, vegetables and fruits that share the resources of the local community. As a result, local people use different preventative strategies and also hunt the monkeys using local snares (Plate 13), dogs and other strategies. However, the monkeys living in the Odobullu Forest surrounded by the tree-dominated forest which are far from the local people do not raid on crops with no potential conflict with monkeys. Thus, the study suggests human settlement near the natural primate habitats would result in conflict with the local people because hungry primates due to the primary loss of their food species can raid crops to supplement their diet. This will in turn create potential conflict with the monkeys. Therefore, to reduce and control human monkey conflict, afforestation and restoration of their primary food species (bamboo) would be recommended in the fragmented and mountainous degraded habitats that are not suitable for traditional agriculture. In addition, other strategies will also be recommended in the detailed manuscript.

Plate 13. Local snare used to trap Bale monkeys at Anasora (*Left* full photo with rope holding the flexible wood used for closing the gate after entrance of the monkey/s and tied with the maize inside the local snare to attract the monkeys *Right*)

In general, Bale monkeys are highly threatened with extinction due to habitat loss and fragmentation, destruction of bamboo forest (Plate 14), hunting due to their crop raiding behavior and also hybridization with both vervet and grivet monkeys (Mekonnen et al., 2012; Haus et al., 2013; Mekonnen pers. obs.). In recent surveys, both adult vervet and Bale monkeys were observed in the same group suggesting that the threatened Bale monkeys are probably be further endangered by current and future hybridization (Plate 15).

Plate 14. Plate showing deforestation of the bamboo forest in southern Ethiopia.

Plate 15. Both Bale monkey (Left) and Vervet monkey (Right) living in the same group in the Guji areas.

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