 

# Wildlife Corridors and Regional Biodiversity Conservation around Selected Wildlife Protected Areas in Uganda

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**Abstract**
Wildlife corridors play a vital role in regional biodiversity conservation. Ecological attributes, changes in corridors and wildlife populations, threats to wildlife corridor functionality were evaluated using a case study of the eight wildlife protected areas in Uganda. A survey was conducted from September 2017 to May 2019, using document review, interviews, the Nature Conservancy's Conservation Action Planning methodology, and Geographical Information System/remote sensing. The findings revealed a total of 20 key wildlife corridors in the landscape with key ecological attributes that augment regional biodiversity conservation. These corridors experience reducing vegetation cover, degradation, loss of connectivity, and degraded stepping stone habitats. They (corridors) are threatened by illegal activities, poaching and illegal wildlife tracking, unsustainable natural resource use, human population pressure, habitat transition/changes, wild fires, trans-boundary threats, infrastructure development, and climate change which affect habitat quality, diversity, and continuity. Despite the existing changes and threats, the elephant population, a migratory animal population increased. The wildlife corridors are important in conservation of regional biological diversity through maintaining the nativeness, pristineness, diversity, and resilience or adaptability of the ecosystems. The policy makers, wildlife managers, local authorities and other conservation bodies and practitioners should develop plans, policies or strategies to sustainably manage and conserve migratory animal biodiversity. Further research should be conducted to establish the functional connectivity of wildlife corridors including trends in their width across the landscape and come up with corridor restoration options.
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## 1. INTRODUCTION

Globally, land conversion and habitat degradation have resulted in many local wildlife extirpations and, as a consequence, populations are increasingly restricted to reserves isolated by agriculture and urbanization (Wegmann, 2014). Populations that lack connectivity to other protected areas can suffer from an inability to disperse between protected areas, compromised genetic variability within isolated populations due to lack of immigration, an inability of dwindling populations to be rescued from extirpation, and reduced opportunities for range shifts in response to global climate change (Rudnick et al., 2012; Gregory & Beier, 2014). Indeed some argue that the long-term viability of wildlife species relies on maintaining connectivity between protected areas (Rudnick et al., 2012). While connectivity areas for one species could not be used by others, estimates of connectivity might be sensitive to this choice of species (Cushman, Landguth, & Flather, 2013; LaPoint et al., 2013) and conservation strategies need to be optimized for each of these species (Cushman, Lewis, & Landguth, 2013). Many species are affected by fragmentation (Brodie et al., 2015; Liu et al., 2018) and the long-term viability of populations often depends on regional habitat connectivity (Heller & Zavaleta, 2009; Costanza & Terando, 2019; Littlefeld et al., 2019; UNEP, 2019).

The reduction of connectivity from habitat loss and fragmentation can restrict movement of organisms between sub-populations, which can result in decreased gene flow, local extinctions, and loss of biodiversity (Haddad et al., 2015). In the Albertine Graben, limited research had been done on the linkages wildlife corridors provide in the protected areas and conservation of floral and faunal biodiversity. Yet, the wildlife corridors are fundamental in facilitating migratory animals particularly chimpanzees, elephants and lions; and protection of key habitats in the Greater Virunga Landscape (WCS, 2008). Further, Ryan and Hartter (2012) revealed that in the Kibale-Queen corridor, it was uncertain if the goals of conserving flora and fauna connectivity were realised; and they recommended that this needed to be monitored. Past studies could not answers key questions: (1) how have corridors and wildlife populations changed over time; (2) what threats affect wildlife, their migration and conservation efforts, and (3) how the corridors contribute to the performance of regional wildlife? Past studies provided inadequate answers to these key questions. The findings of this study would therefore benefit wildlife managers, policy makers, local authorities, and researchers appreciate the changes and threats affecting wildlife corridors, and then guide decision making, development of policies and strategies to preserve wildlife corridors and the mammal population therein. Against this background, key three hypotheses were developed. First, that there is a relationship exists between ecological attributes, changes in wildlife corridors and wildlife populations; second, that there is a relationship between threats to wildlife, corridor functionality and conservation of biodiversity; and third, that corridors are fundamental in the conservation of regional wildlife and biodiversity. The study objectives were: (i) to evaluate the ecological attributes, changes in corridors and wildlife populations, (ii) to evaluate threats affecting wildlife corridors, and (iii) to document the role of wildlife corridors in conserving regional wildlife and biodiversity in the wildlife protected areas.

## 2. MATERIALS AND METHODS

### 2.1 Research Design

The study was conducted through a survey, and both qualitative and quantitative research methods were used. Primary data were collected using interviews with park staff, local authorities, private sector and local communities. Secondary data were obtained through review of existing park documents mainly wildlife monitoring reports, state of the park reports, and general management plans. The Nature Conservancy's Conservation Action Planning methodology generated more primary and secondary data.

### 2.2 Study Area

The area studied was bounded by altitudes 0° 34' South and 1° 09' North and longitudes 29° 28' West and 30° 56' East in the Albertine Graben, Uganda. The region covered the landscape of Kibale and Queen Elizabeth Conservation Areas which included the wildlife protected areas and forest reserves. The wildlife protected areas studied were Kibale National Park (795 $km^2$), Semuliki National Park (220 $km^2$), Toro-Semliki Wildlife Reserve (542 $km^2$) and Katonga Wildlife Reserve (207 $km^2$) in Kibale Conservation Area; and Queen Elizabeth National Park (1978 $km^2$), Rwenzori Mountains National Park (995 $km^2$), Kyambura Wildlife Reserve (157 $km^2$) and Kigezi Wildlife Reserve (330 $km^2$) in Queen Elizabeth Conservation Area (Fig.1). The landscape experiences a bimodal rainfall pattern occurring during March-May, and August- November. Annual rainfall ranges from 800 mm to 1600 mm, and is greatly influenced by altitude. The landscape lies astride the equator. It experiences small annual variation in air temperature; and the climate is generally hot and humid, with an average monthly temperatures varying between 27°C and 31°C, with maximums consistently above 30°C and sometimes reaching 38°C Average minimum temperatures are relatively consistent and vary between 16°C and 18°C. The average monthly humidity is between 60 and 80%. The high air temperatures result in high evaporation rates causing some parts to have a negative hydrological balance. The drainage consists of three main lakes; Lake Albert, Lake Edward, and Lake George and there are a number of rivers and streams. A wide variety of vegetation ecosystems and species are known to exist in this landscape; on the mountain and escarpment slopes and in the valleys and flats. The main vegetation ecosystems include montane forests, tropical forests (including riverine and swamp forests), savannah woodlands and grassland mosaics, papyrus and grassland swamps. (NEMA, 2009)

### 2.3 The sample size and sampling technique

The sample size of the respondents was determined using purposive (Kendra, 1989) and simple random (Kothari, 2004) sampling techniques. A total of 252 respondents were interviewed, and these included park staff, private sector, local authorities and local communities neighboring the case study national parks and wildlife reserves.

### 2.4 Criteria used to Identify and Evaluate Corridors

Identification of wildlife corridors was based on the six-step "checklist" for evaluating corridors (Beier & Loe, 1992). The steps are: 1) Identify the habitat areas the corridor is designed to connect, 2) Select several target species for the design of the corridor (i.e., select "umbrella species"), 3) Evaluate the relevant needs of each target species, 4) For each potential corridor, evaluate how the area will accommodate movement by each target species, 5) Draw the corridor on a map, and 6) Design a monitoring program.

### 2.5 Data Collection

Data were collected from September 2017 to May 2019 with permission from Uganda Wildlife Authority through a survey. Data was collected using Geographical Information System (GIS), interviews, the Nature Conservancy's Conservation Action Planning (CAP) methodology, and document review to collect data.

*Interviews*

Interviews on presence and population of large mammals, location of wildlife corridors in the landscape, and how they (corridors) had changed over the past decades were conducted. The interview questions were similar to those used during a survey conducted on wildlife corridors in Tanzania (Van de Perre, 2014; Riggio & Caro, 2017). The questions were "Do you think there is a path (corridor) that wild animals use to move from the park?", "Where is this path located (show on map)?", "Where do the animals go?", "Which species use this path?", "What time of year do animals use this path?", "Do the animals move across cultivated land?", "How do you know about this path?", "Do you think this path will disappear? And why?" If no, "Was there a path used by animals?", "Is there something blocking the path of animal movement?", "When did the path become blocked?" The respondents were drawn from local communities neighboring the wildlife protected areas in the landscape (Fig. 1).

*The Nature Conservancy's Conservation Action Planning methodology*

Assessing, managing and monitoring the status of an ecosystem or conservation area by focusing on the most important biodiversity and ecological characteristics of the area (TNC, 2007) was done using the Nature Conservancy's Conservation Action Planning (CAP) methodology. The CAP approach identifies the status of wildlife corridors, the major threats to wildlife in the region, and how they affect animal migration and conservation efforts in the study area. This method involved various key stages:

a) Identification of respondents: Respondents (N=252) were selected using stratified random sampling and they included park staff, local authorities, private sector, and local communities.
b) Respondents were guided on how to define and identify the targets for conservation (key components of biodiversity which represent their unique biodiversity, the multiple spatial scales and levels of biological organization, and the scale at which threats and management occur.
c) For each conservation target, key ecological attributes were identified which were "believed" to be important in ensuring viability of target species and that would be seriously degraded by human-caused threat.
d) Critical threats were identified by identifying and rating of stresses affecting each conservation target
e) The participants developed conservation strategies by conducting a critical analysis of the threats and the degraded key ecological attributes of the corridors.
f) Measures to effectively manage the conservation targets were also identified.
g) A map was generated using both scientific and local knowledge of the migratory routes of the wild animals.

Finally, a list of threats to the wildlife corridors and biodiversity generated from the CAP method was printed. The list contained eleven carefully designed statements concerning the threats to guide rating of the participants' responses. The participants were asked to answer two questions to enable them comprehend the threats further as per their experiences and perceptions. First, the participants were asked them to respond by indicating their level of agreement or disagreement on a 5-point Likert scale starting from '1 = strongly disagree' to '5 = strongly agree', and second, the participants were asked to answer how worrisome they estimated each threat using the same 5-point Likert scale. The questions help prevent neutral responses from respondents (Colman et al., 1997).

*Document review*

Documents reviewed included recently published academic journal articles, state of the park reports, general management plans, and other existing relevant park documents. These documents were reviewed to generate information on how the corridors relate to the performance of regional wildlife. The information obtained complemented that got from interviews and the CAP methodology.

### 2.6 Data Analysis

Data were analysed using the Statistical Package for the Social Sciences (SPSS) Version 22 and presented in tables. Internal consistency and reliability of responses were determined using Cronbach's alpha coefficient (α). The reliability results were all acceptable as the reliability statistic Cronbach's Alpha (α) value was 0.683 for all the measures indicating a high level of internal consistence for the scale of the sample. Also, the Analysis of Covariance (ANCOVA) test revealed $F_{(1)} = 2.213$ at significance level of 0.0012 which was less than 5% hence generally accepted. Kruskals-Wallis Analysis of Variance (ANOVA) test was used for further analysis.

## 3. RESULTS

### 3.1 Wildlife Corridors and Wildlife Populations

#### 3.1.1 Wildlife Corridors and their Ecological Attributes

Identified were 20 wildlife corridors in the Kibale and Queen Elizabeth Conservation Areas (Fig. 1) which provide connectivity that enables animal migrations. Most of the corridors cross land that has been or are likely to be converted. (Fig. 1)

 

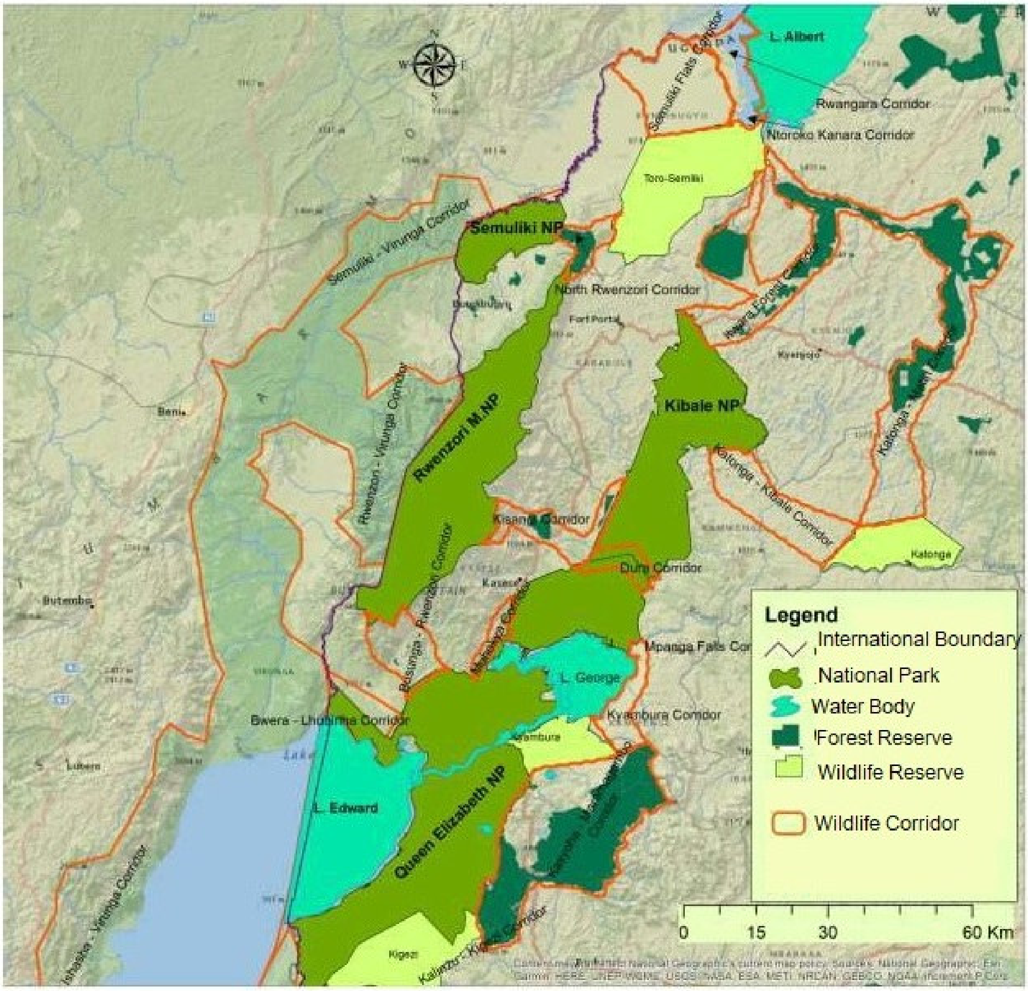


Fig. 1: Map showing Location of Wildlife Corridors in the Study Area (NP-National Park, WR-Wildlife Reserve)

Table 1: Wildlife Corridors and their Ecological Attributes

| Name of corridor | Protected areas they connect | Wildlife that use them | Ecological attributes |
|---|---|---|---|
| Kalinzu-Kigezi corridor | Kalinzu Forest Reserve, Kigezi Wildlife Reserve and the southern part of Queen Elizabeth National Park | Chimpanzees and Elephants | Links Kalinzu Forest Reserve, Kigezi Wildlife Reserve and the southern part of Queen Elizabeth National Park. Migratory route. |
| Kasyoha-Kitomi/ Kalinzu-Maramagambo (Kasyoha-Maramagambo) corridor | Kasyoha-Kitomi Forest Reserve and Kalinzu-Maramagambo Forest Reserve | Chimpanzees, Elephants, Wild Pigs, Duikers, Striped Jackal, Serval Cats, and Jennets | Existence of grassland. Link Queen Elizabeth Protected Area (QEPA) with Kasyoha-Kitomi forest reserve to Kalinzu and Maramagambo forest reserves. Migratory route |
| Kyambura-Kasyoha-Kitomi corridor | Queen Elizabeth National Park | Elephants, Chimpanzees and Birds | Links Kyambura Wildlife Reserve to Kasyoha-Kitomi Forest Reserve. Migratory route |

 

| **Name of corridor** | **Protected areas they connect** | **Wildlife that use them** | **Ecological attributes** |
|---|---|---|---|
| Kyambura Gorge-Kasyoha-Kitomi corridor | Queen Elizabeth National Park | Chimpanzees, Lions and Bird Life | Savanna vegetation. Dense riverine forest and a fast flowing Kyambura River which pours into the Kazinga Channel amidst a papyrus swamp. The gorge is a home to chimpanzees, lions and bird life. Migratory route<br>Link Kasyoha-Kitomi Forest reserve and Kyambura Wildlife Reserve. Provides food and water sources to the diverse fauna. Offers safe havens for security of the wild fauna |
| Mpanga Falls corridor | Kibale | Cycads *Encephalartos whitelockii* | Critical site for conservation of Cycads *Encephalartos whitelockii* |
| Kibale-Queen corridor | Queen Elizabeth Protected Area and Kibale National Park | Elephants | It's part of the Lake George Ramsar site. Varied habitats mainly grassland, swamp forest, woodland and bushland. Migratory route. Safe havens for security. Genetic variability. Provides food and water sources for wild fauna. |
| Kisangi corridor | Kibale National Park and Rwenzori Mountains National Park | Elephants and hippos | Links the western part of Kibale National Park with the south-eastern part of Rwenzori Mountains National Park through Kisangi forest reserve. Migratory route |
| Katonga-Kibale corridor | KNP, Katonga Wildlife Reserve, Lake Mburo National Park | Sitatunga waterbucks, hippos, primates and birds | Links KNP with Lake Mburo National Park. Migratory route for elephants. Distinct vegetation types - the open grasslands, riverine grasslands, wooded grasslands, woodlands, riverine woodlands and wetland, which enhances the faunal diversity. |
| Katonga-Matiri corridor | Katonga Wildlife Reserve and Toro-Semliki Wildlife Reserve | Elephants | Links Katonga and Toro-Semliki wildlife reserves through Matiri, Ibambaro, Kitechura, Kagombe and Muhangi forest reserves. Key migratory route |
| Itwara Forest corridor | KNP to Toro-Semliki Wildlife Reserve | Elephants | Links the northern part of KNP to Toro-Semliki Wildlife Reserve through River Muzizi and Itwara forest reserve. Links the northern part of KNP through a series of degraded small forest reserves of Oruha, Kyehara, Kikumiro, Kibego, Kagona and Muhangi. Migratory route for elephants |
| Ntoroko-Kanara corridor | Ntoroko-Kanara Wildlife Sanctuary, Rwangara Community Wildlife Area TSWR | Elephants, Shoebill Stock | Habitat to the endangered shoebill stork population that breeds in this wetland. Links reserve to DR Congo. Conserves a fragile and degraded strip of land along Lake Albert. Migratory route for elephants. |
| Rwangara corridor | Toro-Semliki Wildlife Reserve | Shoebill Stock, Elephants, Buffaloes, Uganda Kob | Link between TSWR and DR Congo. Varied habitats for animal species. Migratory route of wildlife. Wetlands and forests which are breeding grounds for some fauna, watering points for animals, and congregation areas for the game. |
| Semliki Flats corridor | Toro-Semliki Wildlife Reserve | Kobs and Buffalos | Controlled Hunting Area |

| Name of corridor | Protected areas they connect | Wildlife that use them | Ecological attributes |
|---|---|---|---|
| North Rwenzori corridor | RMNP, Semuliki National Park and TSWR | Primates mainly Chimpanzees, Black and White Colobus Monkeys, Red Tailed Monkeys, Blue Tailed Monkeys, Baboons and Vervet Monkeys | The forest fragments that link TSWR with Northern part of RMNP and eventually SNP. An extensive network of *Celtis-Chrysophylum*, riverine forest. Habitat to a variety of primates |
| Semuliki-Virunga corridor (Semuliki-Ituri forest-Virunga corridor) | SNP and Virunga National Park | Elephants, Buffalos, Chimpanzees, Antelopes and Sitatunga | Links the SNP and North Virunga National Park (VNP) through the Ituri forest. A transitional zone between the Congo basin and the East African region forming part of the Guinea-Congo biome. Existence of Ituri forest<br>Link with VNP. Migratory route |
| Virunga – Rwenzori | RMNP and Virunga National Park | Elephants | Links the western part of the RMNP with the VNP |
| Ishasha-Virunga | Southern sector of QENP and Virunga National Park | Elephants, topi, the tree-climbing lions and hippos. | Riverine woodland and woody grassland. Link between QEPA and VNP. Provides refuge for animals from DR Congo. |
| Bwera/Virunga Lhubiriha | QENP and Virunga National Park | Elephants | Mixed wetland, grassland and woodland habitat that support few resident wildlife species. Link between QENP and VNP. Serves as the only protected migratory route for wildlife between the two parks. Has food and water sources for the wild fauna. Safe havens for security. Population size of grazing/ browsing species and their reproduction rate. Genetic variability. Species composition and re-generation |
| Muhokya | QENP and KNP | Elephant, Uganda kob, Waterbuck and Buffalo | Linkage between Dura and Kasenyi. Migratory route for elephants. Key food and water source for the fauna. Safe havens for security. Population size of grazing/ browsing species and reproduction rate. Genetic variability. Species composition and re-generation |
| Busunga-Rwenzori | QENP and RMNP | Elephants | Link between QENP and RMNP through River Nyamugasani. Migratory route for elephants |

**3.1.2 Changes in the Wildlife Corridors and Wildlife Populations**

*Changes in vegetation in the landscape.*—The vegetation in the Kibale and Queen Elizabeth Conservation Areas has remained fairly intact from 1964 to 2015 (Fig. 2). However, there is an observed remarkable reduction in vegetation cover outside the wildlife conservation areas in the central forest reserves and private land over years as manifested in the disappearing greenness. Specifically, the landscape has become less green as seen in the vegetation map of 1990 compared with that of 2015 especially in the forest reserves and private land. (Fig. 2).

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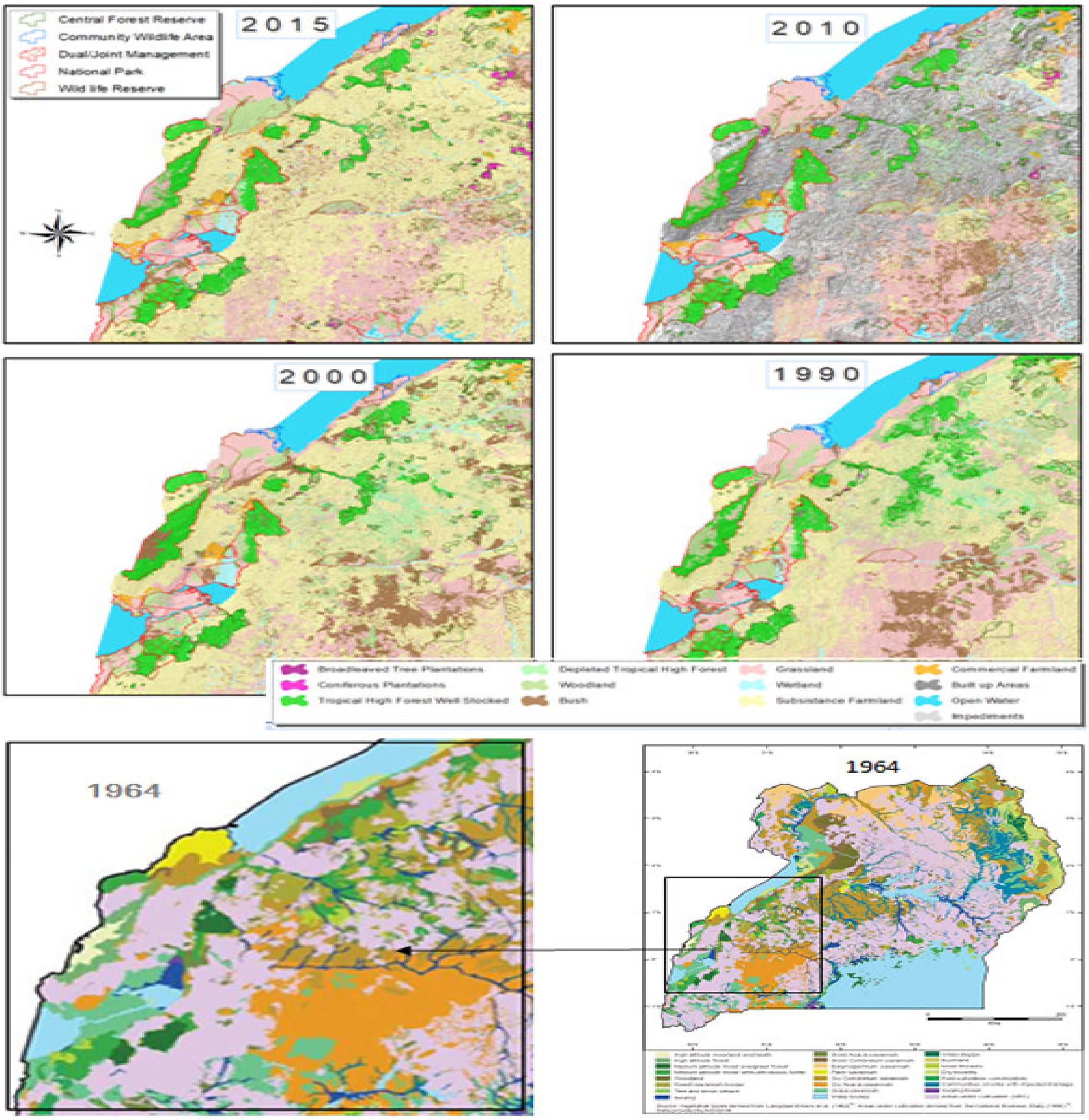


Fig. 2: Map showing vegetation change in the Kibale-Queen Elizabeth landscape

*Changes in migratory animal populations.*—The elephant population across the landscape has had a general increase since 2000, an indication that they have remained a cornerstone of conservation of biological diversity. The lion population has declined since 1980 while the chimpanzee population has not grown over the years. (Fig. 3)

 

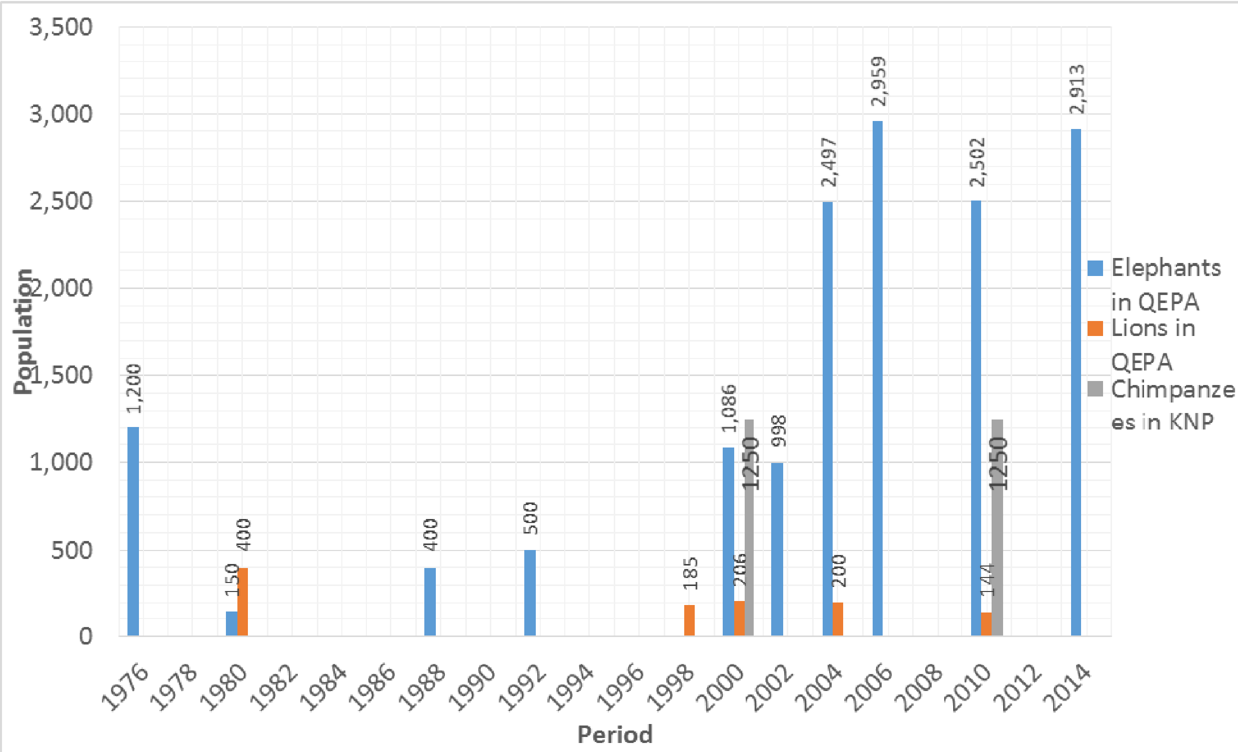


Fig. 3: Population Trends of Migratory Animal Populations (Raw data adopted from UWA, 2018a)

*Degradation in corridors leading to reduced corridor width.*—From the CAP results, the wildlife corridors across the landscape have been degraded over the past years resulting in reduced corridor width. For instance, according to the Community Conservation Ranger at Kyondo Ranger Post, 400 acres of land were curved out of the Kibale-Queen corridor, and as a result, the Ranger Post which was formally located inside the corridor now sits on community land.

*Loss of connectivity and migratory routes.*—Some of the wildlife corridors have lost connectivity, for instance, the Busunga-Rwenzori and the Kisangi corridors have lost connectivity to the Rwenzoris (Fig. 1) through human activity mainly cultivation.

*Degraded stepping stone habitats.*—The landscape presents degraded stepping stone habitats (a special type of habitat linkage that facilitates dispersal along a patchwork of isolated habitat patches within a matrix of unsuitable or inhospitable habitat) mainly forest reserves, and wetlands that connect wildlife corridors which enables animal migrations. For instance, the central forest reserves of Matiri, Ibambaro, Kitechura, Kagombe which form the Itwara corridor that links Kibale National Park with Toro-Semliki Wildlife Reserve and those of Oruha, Kyehara, Kikumiro, Kibego, Kagona, and Muhangi which form the Katonga-Matiri corridor that links Katonga Wildlife Reserve and TSWR have been degraded through cultivation hence disrupting connectivity to the wildlife PAs (Fig. 1).

*Community level effects / human population effects.*—The human population surrounding the Kibale-Queen Elizabeth landscape which is part of the Greater Virunga Landscape is highly populated with an increase of 3% per annum (GVTC, 2017) which exerts pressure on the parks.

Fig. 4: Elephants crossing a road in the Bwera/Virunga-Lhubiriha corridor

**3.2 Threats to Wildlife Corridors and Corridor Functionality**

The threats were analyzed using Kruskal-Wallis ANOVA at confidence interval of α =0.05. Poaching and illegal wildlife tracking, increasing human population, wild fires, trans-boundary threats, degradation of wildlife corridors, unsustainable natural resource use, climate change, development of roads, and other infrastructure (Fig. 4) were significant. These threats interfere with animal movements across corridors. Further, illegal activities mainly pit sawying, illegal fishing, grazing, illegal harvest of resources and encroachment on the wildlife corridors present key threats (Table 2). However, statistically not significant threats were human wildlife conflicts (p=0.082), and pollution (p=0.239) (Table 2).

Table 2: Kruskals-Wallis ANOVA test results of responses on the level of agreement of respondents that the threats affect Kibale-Queen Elizabeth Landscape (n=252, df = 3, α =0.05)

| Threats to wildlife conservation | Sum of Squares | Mean Square | Mean Likert Score | Kruskal-Wallis | P value |
|---|---|---|---|---|---|
| Illegal activities | 8.912 | 2.971 | 4 | 1.377 | 0.002 |
| Poaching and illegal wildlife tracking | 8.704 | 2.901 | 5 | 12.320 | 0.000 |
| Increasing human population | 11.487 | 3.829 | 5 | 5.338 | 0.000 |
| Human-wildlife conflicts | 3.908 | 1.303 | 2 | 1.961 | 0.082 |
| Wild fires | 13.271 | 4.424 | 4 | 3.639 | 0.003 |
| Trans-boundary threats | 9.469 | 3.156 | 4 | 2.688 | 0.020 |
| Degradation of wildlife corridors | 21.440 | 7.147 | 4 | 2.953 | 0.012 |
| Unsustainable natural resource use in the corridors | 10.930 | 3.643 | 5 | 4.440 | 0.001 |
| Pollution | 17.935 | 5.978 | 2 | 2.864 | 0.239 |
| Development of infrastructure network inside corridors | 12.527 | 4.176 | 4 | 2.726 | 0.019 |
| Climate change impact in the corridors | 16.938 | 5.646 | 4 | 6.901 | 0.000 |

The stakeholders' response on how worried they felt about the threats yielded statistically significant results (P<0.05) on illegal activities, poaching and illegal wildlife tracking, human population increase, climate change impacts, and threats across boundaries (Table 3). However, human-wildlife conflicts, (p=0.204), degradation in wildlife corridors (p=0.204), pollution (p=0.810), infrastructure development network (p=0.768), and unsustainable natural resource use (p=0.719) were statistically non-significant (Table 3).

Table 3: Kruskals-Wallis ANOVA test results of responses on how worrisome the respondents estimated the threats that affect Kibale-Queen Elizabeth Landscape (n=252, df = 3, α =0.05)

| Threats | Sum of Squares | Mean Square | Mean Likert Score | Kruskal-Wallis | P value |
|---|---|---|---|---|---|
| Illegal activities inside the wildlife corridor | 16.877 | 5.626 | 4 | 4.371 | 0.001 |
| Poaching and illegal wildlife tracking | 5.244 | 1.748 | 5 | 5.075 | 0.000 |
| Increasing human population | 20.157 | 6.719 | 4 | 3.948 | 0.002 |
| Human-wildlife conflicts | 27.127 | 9.042 | 4 | 3.582 | 0.004 |
| Wild fires | 18.273 | 6.091 | 4 | 13.489 | 0.000 |
| Trans-boundary threats to biodiversity conservation | 0.183 | 0.183 | 4 | 0.799 | 0.001 |
| Degradation of wildlife corridors | 0.392 | 0.392 | 2 | 1.659 | 0.204 |
| Unsustainable natural resource in the corridors | 0.194 | 0.194 | 2 | 0.131 | 0.719 |
| Pollution | 0.094 | 0.094 | 2 | 0.058 | 0.810 |
| Development of infrastructure network | 0.152 | 0.152 | 1 | 0.088 | 0.768 |
| Climate change impact | 0.392 | 0.392 | 4 | 1.659 | 0.004 |

### 3.3 The Role of Wildlife Corridors in Conserving Regional Wildlife and Biological Diversity

From the documents reviewed, the wildlife corridors play a pivotal role in conserving biological diversity-mainly conservation of migratory animal species, maintaining biological connectivity (Taylor et al., 1993), maintaining perpetuity of migratory animal populations (Pulliam, 1988), and maintaining viable habitats for safety of migratory animal population against existing threats by providing refuge or "safe haven" for wildlife (UWA, 2016).

## 4. DISCUSSION

### 4.1 Wildlife Corridors and Wildlife Populations

The wildlife corridors in the landscape present key ecological attributes to the animal populations mainly providing linkage amongst each other, migration routes, safe havens for security, food, water, habitats, animal population size and reproduction rate, and genetic variability that enable migration of animal populations within the broader landscape. Generally, the wildlife corridors offer key ecological attributes that enable movement of migratory animal populations within the broader landscape. Ecological connectivity provides the capacity for the movements of organisms, for gene flow, and for range shifts (Beier et al., 2011, Keeley et al., 2018), and thereby is a key factor in the long-term viability of populations, particularly for animal species (Cushman et al., 2009). Most of the corridors cross land that has been or are likely to be converted without conservation attention, and therefore, experience significant changes. The results agree with those of past research that corridors have been degraded (Obua et al., 2010; MWE, 2016) as a result of various threats (Plumptre et al., 2007; Baguette et al., 2013; Runge et al., 2015; GVTC, 2017; UWA, 2018b; Katswera et al., 2020). The vegetation outside the wildlife conservation areas mainly in the central forest reserves and private land had reduced over years due to human population influx into the forest reserves as a result of non-deterrent laws, institutional weaknesses, greed and corruption, and this vegetation change could affect survival and movement of animal species that are sensitive to degradation and habitat change. The reduction in vegetation could also be as a result of changing climate. This finding agrees with the hypothesis that ecological attributes, changes in wildlife corridors and wildlife populations are strongly related.

Recent research indicates that the change in vegetation is due to degradation and deforestation as a result of agricultural activities, high demand for forest products, weak law enforcement and policy implementation (Obua et al., 2010) is due to weak governance in the forestry sector, illegal and unregulated trade of forest products, and the unsecured forest tenure rights (MWE, 2016). The reduction in vegetation (Fig. 2) disrupts the continuity and linkage of the animal migratory routes (Fig. 1). Reduced connectivity between habitats exacerbates these threats by increasing the isolation of breeding populations, the likelihood of movement through inhospitable matrix, and the proportion of edge habitat, reducing successful dispersal between suitable habitat patches (Fahrig, 2002; Bowne & Bowers, 2004); and therefore, an effective habitat corridor provides a continuous, or near continuous, link of suitable habitat through an inhospitable environment (Noss, 1993). However, the vegetation in the wildlife conservation areas had remained fairly intact from 1964 to 2015 because of sustained management by park management.

The population of elephants has increased in the past years (Fig. 3). This increase could be attributed to the existence of wildlife corridors that provide linkage of PAs, migration routes, safety, food, water, and habitats for sustaining mammal populations. Further, improved management by the wildlife agency through recruitment of the wildlife protection force, enhanced patrols by rangers, and increased vigilance and monitoring through deployment of security team at strategic entry and exit points are other factors that contribute to the general increase in mammal population. Specifically, the recovering elephant population is probably due to improved better security in the region, immigrations and high reproduction success (Katswera et al., 2020). However, the lion population has had a steady decline (Fig. 3). The decline in lion population was due to habitat loss, diseases, and poisoning by livestock farmers, and knocking by speeding vehicles (UWA, 2018a).

Wildlife corridors have been degraded resulting into reduced corridor width. The reduction in widths of corridors was probably due to anthropogenic factors mainly agricultural encroachment, settlement, unclear boundaries, and infrastructure development. Increasing human population puts pressure on the corridors through agricultural encroachment and settlements (Plumptre et al., 2007). For instance, the Muhokya corridor narrows to about 100 m width (Plumptre et al., 2007), and the connection of Kasyoha-Kitomi Forest Reserve with Kyambura Wildlife Reserve has since reduced in size (UWA, 2008).

Some wildlife corridors especially the Busunga-Rwenzori corridor and the Kisangi corridor lost connectivity to the Rwenzoris (Fig. 1), and this loss affects animal migrations. In addition, the Katonga-Kibale corridor which used to provide a continuous link from Kibale National Park through Katonga Wildlife Reserve and Lake Mburo National Park to Tanzania also lost its connectivity (UWA, 2018b). The loss of connectivity could mainly be due to anthropogenic and natural factors contributing to reduction in vegetation cover hence affecting the migration of mammals across the corridors. Further, severe encroachment through settlements, agriculture and infrastructure development is a common phenomenon across protected areas (UWA, 2018b).

The stepping stone habitats in the landscape that connect the corridors have been degraded, disrupting connectivity to the wildlife PAs hence interrupting the animal migratory movements. Other studies indicate that stepping stone habitats are particularly important for migratory species that rest and refuel at stop-over sites between the end-points of their migratory route (Runge et al., 2015). Degradation of the stepping stone habitats was due to anthropogenic factors mainly agricultural encroachment, and human settlement around the Kibale-Queen Elizabeth landscape.

Further, human population surrounding the Kibale-Queen Elizabeth landscape has grown, and this growth has associated community level effects / human population effects. Higher population density has created pressure on the corridors through need for agricultural land, resource off-take, illegal fishing and destruction of fish breeding zones, setting of fires, and poaching which have ultimately degraded the wildlife habitats, and growth in infrastructure development that may result into fragmentation of the landscape (GVTC, 2017). The human population surrounding the Kibale-Queen Elizabeth landscape which is part of the Greater Virunga Landscape is growing at almost 3% per year; and the population density of communities living within a radius of 5 kilometers from the park boundary range between 100 – 500 person/km$^2$, with higher population densities in the southern section ranging from 500 to over 1000 person/km$^2$ (GVTC, 2017).

### 4.2 Threats to Wildlife Corridors and Corridor Functionality

The changes experienced in the corridors were due to natural factors; and anthropogenic threats—poaching, population pressure, fires, transboundary issues, degradation in the corridors, unsustainable natural resource use, development of infrastructure network inside corridors, climate change impact, and illegal activities mainly pit sawying, illegal fishing, grazing, illegal harvest of resources and encroachment on the wildlife corridors. These threats affect habitat quality, diversity and continuity, resulting into habitat degradation, gapping in the forests, and interference with the animal migratory routes. This finding agrees with the second hypothesis that threats to wildlife, corridor functionality and conservation of biodiversity are strongly related. The illegal activities were due to anthropogenic threats mainly expansion of human settlement, infrastructure, agricultural activities, and uptake of in-park resources for livelihoods (Katswera et al., 2020) and change in land use patterns (UWA, 2013). Other factors are limited alternative sources of livelihoods, high poverty levels, poor perception of the value of natural ecosystems, and weak governance. These illegal activities affect habitat quality, diversity and continuity.

Poaching and illegal wildlife tracking was mainly for commercial purposes (for trade in bush-meat and ivory), trophy hunting, and to a limited extent for home consumption, and in retaliation for lion attacks on livestock. This threat is especially high in savanna corridors and acacia savanna woodlands since they are easily accessible. Here, the wild animals are more visible and open to attack and more likely to stray into adjacent community land. Poaching and illegal wildlife tracking was due to the demand for wild meat and associated products, and inadequate park manpower and patrols.

Habitat transition/changes/habitat loss is as a result of invasive alien species (*Lantana camara*, *Dichrostychs ceneria,* and *Euphorbia candelabrum)* which have eroded biodiversity through their proliferation and spread, displacing or killing native flora and fauna and affecting ecosystem services. These invasive alien species have eroded quality of the corridors resulting into disturbed migration routes across protected areas, and an increase in cases of problem animal incursions in search for forage. Habitat loss, degradation, and fragmentation are among the largest threats to biodiversity worldwide and they predominantly lead to the decline of local populations through the loss of available resources (Baguette et al., 2013). Degradation or loss of the wildlife corridors will reduce their ability to protect habitats and conservation targets therein leading to avoidance of corridors by migratory animal species (UWA, 2008). The high proliferation of *Lantana camara*, *Dichrostychs ceneria,* and *Euphorbia candelabrum* is mainly due to agricultural conversion which has led to encroachment on the corridor boundary; livestock grazing, expansion of human settlements into corridors; and uncontrolled fires which have led to the loss of vegetation diversity, where fire has been used to convert the corridor to grazing land, which is less nutritious or palatable for wildlife (WCS, 2008).

Human-wildlife conflicts take the form of damage to crops and livestock, injury to humans and livestock, and death of humans and livestock; and could be attributed to habitat degradation, increasing animal population in a shrinking habitat, proximity to community land, changing land use patterns, human population pressure leading to settlements and cultivation in wildlife dispersal zones.

Wild fires affect the aesthetic view of the park, destroy pasture for wild animals, slay slow-moving fauna, and reduce habitat quality, destroy nesting sites of breeding fauna. Wild fires are exacerbated by the presence of elephants that destroys immature trees, prevent regeneration, promote growth of facilitate growth of fire-resistant vegetation, leading to reduction in floral diversity.

Trans-boundary threats to biodiversity conservation are mainly poaching across borders, trafficking of wildlife and forest products, seasonal incursions of pastoralists for water and grazing resources, fishing, charcoal burning, and timber harvesting. The wildlife corridors in the conservation areas have high biodiversity ecosystems and link across international borders which are largely porous. People from neighboring countries enter and engage in illegal activities and resource off-take for subsistence and commercial use. Trans-boundary threats were due to the trans-boundary nature of corridors. These trans-boundary issues threaten the type and preference of habitats by the animals, and are probably due to recurrent civil wars in the Democratic Republic of Congo which result into influx of wild animals into the Queen Elizabeth Protected Area for safety (UWA, 2008).

The degradation in corridors affects migration of large mammals especially the larger fauna—elephants, lions and primates—that tend to require larger habitat needs (especially for hunting and feeding). This reduction is attributed to anthropogenic factors mainly agricultural encroachment, settlement, unclear boundaries, and infrastructure development. Pollution in the corridors results from agricultural, industrial, mining, and municipal waste discharges and dumping. Pollution poses a potential threat to biodiversity through habitat modification or loss (NEMA, 2016).

Development of infrastructure network has led to reduction in corridor values, for instance, the growing road network and power line, cutting through the Kyambura gorge corridor and its escarpment banks that links Kyambura and Kasyoha-Kitomi, make deep intrusions into the underground riparian forest that is a home to chimpanzees, elephants, and lions. The road network in the parks and wildlife reserves crosses the wildlife corridors exposing the migratory animals to road kills. The discontinuity of these corridors has resulted into wildlife casualties through road kills, and discontinuous migratory routes for inhabitant animal population (UWA, 2008).

Climate change impacts affect wildlife populations. Climatic factors regulate wildlife populations through changes in rainfall amounts, temperatures and levels of irradiation. These influence the quality and availability of food for wild animals resulting into high levels of inter and intra competition for food thereby affecting reproduction and survival rates and species shifts. Furthermore, climate change may be experienced in form of extreme weather events such as prolonged droughts and floods, disease outbreaks and proliferation of invasive species which lead to wildlife mortality (UWA, 2018a).

### 4.3 The Role of Wildlife Corridors in Conserving Regional Wildlife and Biological Diversity

Despite the changes experienced in the wildlife corridors and their associated threats, they (corridors) continue to play vital role in the conservation of regional wildlife and biological diversity. They contribute to conservation of animal species through ensuring their long-term survival across the landscape. The population of elephants had generally increased over the past decades due to protection, management and conservation work by park management (Katswera et al., 2020). This finding supports our third hypothesis that corridors are important in the conservation of regional biodiversity. The corridors enable movements of animal populations, including migratory species; and also to withstand poaching pressures due to their connectivity and trans-boundary nature which factors provide escape routes, a large size to maintain viable animal populations. Wildlife corridors are also important for water, food and safety, and for sustaining animal populations. The corridors maintain biological connectivity of animal species, plant communities, and ecological processes. Faunal connectivity remains a high priority from a conservation perspective in the Kibale-Queen Elizabeth landscape and will likely continue to be the primary driver in managing this landscape. The conservation goals of corridors in biodiversity hotspots are often directed at maintaining biological connectivity (Taylor et al., 1993), ensuring persistence and sufficient habitat to maintain existing fauna and flora. Further, the corridors maintain perpetuity of populations/ minimum viable populations. This perpetuity of populations could be as a result of improved management, and formulation and implementation of appropriate legal and policy frameworks. Finally, the corridors maintain viable habitats for safety of mammal population against existing threats. The corridors enable wildlife to escape from poaching and insecurity and provide a refuge or "safe haven" for wildlife (UWA, 2016). Other studies confirm these roles. Connectivity influences demography (Clobert et al., 2001), promotes dispersal and colonization (Hanski, 1998), maintains genetic diversity (Hendrick, 2005), increases a species' ability to respond to perturbations and changing climates (Heller & Zavaleta, 2009), and supports long term persistence in heterogeneous landscapes (Vasudev et al., 2015). Consequently, increasing landscape connectivity has been identified as a fundamental strategy for mitigating impacts of climate change on biodiversity (Heller & Zavaleta, 2009).

## 5. CONCLUSION

The wildlife corridors in the landscape present key ecological attributes to the mammal populations mainly providing linkage between wildlife protected areas, migration routes, safe havens for security, water and food sources, habitats for mammal populations and reproduction rate, and genetic variability that enable migration of animal populations within the broader landscape. These ecological attributes support an increase in mammal populations, hence the corridors are a cornerstone of conservation of biological diversity. However, the wildlife corridors experience changes in vegetation, changes in migratory animal populations, changes in corridors as a result of degradation, loss of connectivity and migratory route, and degradation of stepping stone habitats, and effects of growing human population. Despite the changes and threats experienced in the wildlife corridors, corridors still represent the wildest or most natural lands that provide ecological linkages between protected areas that ensure survival of migratory mammals. The corridors ensure long-term survival of mammal populations across the landscape, enable movements of animal populations, including migratory species; and also withstand poaching pressures due to their connectivity and trans-boundary nature which factors provide escape routes, a large size to maintain viable animal populations, maintaining viable habitats for safety of migratory animal population, and maintaining biological connectivity of animal species, plant communities, and ecological processes. In view of these findings, this study concludes that wildlife corridors are important in conservation of regional biological diversity through maintaining the nativeness, pristineness, diversity, and resilience or adaptability the ecosystems. The major limitation to conservation of wildlife and regional biodiversity in corridors has been inadequate information on the wildlife corridors—changes, threats, and animal populations that migrate through them which this study has addressed. Maintaining or enhancing the naturalness of wildlife corridors through reducing anthropogenic impacts and managing the impacts of climate change is a strategic direction to ensure wildlife corridor preservation. The study findings, analysis and conclusion could be used by policy makers, wildlife managers, local authorities and other conservation bodies and practitioners to develop plans, policies or strategies to sustainably manage and conserve wildlife and regional biodiversity. The National Forestry and Tree Planting Act, 2003 should be reviewed to capture issues of conservation and sustainable management of wildlife resources in the forest reserves. The findings further present opportunities for the conservation bodies to develop informed decisions, and invest resources in the protection and restoration of degraded/fragmented stepping stone habitats that connect protected areas to maintain their functional and structural connectivity nature. The wildlife corridors identified are structural in nature, and therefore, further research should be conducted to establish the functional connectivity of wildlife corridors including trends in their width across the landscape and come up with corridor restoration options. Finally, the presence of existing stepping stone habitats and strips of vegetation on private land that connect with wildlife protected areas in the landscape offers an opportunity for planning, development and management of a regional corridor network to ensure wildlife corridor preservation.

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**Authors' contributions**
J.K. initiated and shared the research idea, drafted the concept, coordinated the data collection and analysis and wrote the first draft of the manuscript. N.M.M and C.K.T assessed the draft concept of the manuscript, made conceptual guidance to collect right data and made critical intellectual adjustments on the first manuscript to make it a clear scientifically and logically drafted manuscript. All authors assessed and approved the final copy

 

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**REFERENCES**

Abrahms, B., Sawyer S. C., Jordan, N. R., McNutt, J. W., Wilson, A. M., & Brashares, J. S. 2016. Does wildlife resource selection accurately inform corridor conservation? *Journal of Applied Ecology,* **54,** 412–422 doi: 10.1111/1365-2664.12714

Agency for International Development (USAID) and the Government of Uganda (GoU). 2015. Uganda Environmental Threats and Opportunities Assessment (ETOA). Final ETOA report.

Baguette, M.; Blanchet, S.; Legrand, D.; Stevens, V. M.; & Turlure, C. 2013. Individual dispersal, landscape connectivity and ecological networks. *Biol. Rev.,* **88,** 310–326.

Beier, P., Spencer, W., Baldwin, R. F. & McRae, B. H., 2011. Toward best practices for developing regional connectivity maps. *Conservation Biology,* **25**, 879–892.

Beier, P., & Loe, S. 1992. A checklist for evaluating impacts to wildlife movement corridors. Wildlife Society Bulletin 20:434-440.

Beninde, J., Veith, M., & Hochkirch, A. 2015. Biodiversity in cities needs space: a meta-analysis of factors determining intra-urban biodiversity variation. *Ecol Lett*, **18:** 581–592. https://doi.org/10.1111/ele.12427

Bowne, D. R., & Bowers, M. A. 2004. Interpatch movements in spatially structured populations: A literature review. *Landsc. Ecol.* **19**, 1–20.

Brodie, J. F., Giordano, A. J., Dickson, B., Hebblewhite, M., Bernard, H., & Mohd-Azlan, J. 2015. Evaluating multispecies landscape connectivity in a threatened tropical mammal community. *Conservation Biology,* **29**, 122–132.

Clobert, J., Danchin, E., Dhondt, A. A. & Nichols, J. D. (eds). 2001. *Dispersal.* Oxford University Press, Oxford.

Colman, A. M., Norris, C. E., & Preston, C. C. 1997. Comparing rating scales of different lengths: Equivalence of scores from 5-point and 7-point scales. Psychological Reports, **80**, 355-362

Costanza, J. K., Abt, R. C., McKerrow, A. J., & Collazo, J. A. 2017. Bioenergy production and forest landscape change in the southeastern United States. *GCB Bioenergy* **9**, 924–939. https://doi.org/10.1111/gcbb.12386.

Cushman, S. A., Landguth, E. L., & Flather, C. H. 2013. Evaluating population connectivity for species of conservation concern in the American Great Plains. *Biodiversity and Conservation.*

Cushman, S. A., Lewis, J. S., & Landguth, E. L. 2013. Evaluating the intersection of a regional wildlife connectivity network with highways. *Movement Ecology,* **1**.

Cushman, S. A., Mckelvey, K. S., Schwartz, M. K., 2009. Use of empirically derived source-destination models to map regional conservation corridors. *Conservation Biology*, **23,** 368–76. https://doi.org/10.1111/j.1523-1739.2008.01111.x PMID: 19016821

Fahrig, L. E. 2002. Effect of habitat fragmentation on the extinction threshold: A synthesis. *Ecol. Appl.* **12,** 346–353.

Fynn, R. W. S., & Bonyongo, M, C. 2010. Functional conservation areas and the future of Africa's wildlife. *Afr J Ecol.*; **49**, 175-88.

Gregory, A. J, & Beier, P. 2014. Response variables for evaluation of the effectiveness of conservation corridors. *Conserv Biol.*; 28:689±695. https://doi.org/10.1111/cobi.12252 PMID: 24606549

GVTC. 2017. Greater Virunga Trasboundary Collaboration Annual Conservation Status Report 2015. Trasboundary Collaboration (GVTC)

Haddad, N. M., Brudvig, L. A., Clobert, J., Davies, K. F., Gonzalez, A., & Holt, R. D. 2015. Habitat fragmentation and its lasting impact on Earth's ecosystems. Sci Adv., **1**(2):E1500052.

Hanski, I. 1998. Metapopulation dynamics. *Nature,* **395,** 41–49.

Heller, N. E., & Zavaleta, E. S. 2009. Biodiversity management in the face of climate change: a review of 22 years of recommendations. Biol. Conserv., **142**, 14–32. https://doi.org/10.1016/j.biocon.2008.10.006.

Hendrick, P. W. (2005) Genetics of Populations. Jones and Bartlett Publishers, Boston.

Katswera, J., Mutekanga, M. N., & Twesigye, C. K. 2020. Biodiversity Conservation and Threat Reduction in Kibale and Queen Elizabeth Conservation Areas, Uganda. *East Afr. J. Biophys. Comput. Sci., **1***(**1**), 1-22.

Keeley, A. T., Ackerly, D. D., Cameron, D. R., Heller, N. E., Huber, P. R., Schloss, C. A, et al., 2018. New concepts, models, and assessments of climate-wise connectivity. Environmental Research Letters,. **13**(7), 073002.

Kendra, P., 1989. Teaching and Methods of social surveys, Research and statistics. Railway crossing Sitapur Road, Luiknow.

Kothari, C. R., 2004. Research Methodology. Methods and Techniques. Second Edition. New Age International (P) Ltd. New Delhi, India.

LaPoint, S., Gallery, P., Wikelski, M., & Kays, R. 2013. Animal behavior, cost-based corridor models, and real corridors. *Landscape Ecology,* **28,** 1615–1630.

Liu, C., Newell, G., White, M., & Bennett, A. F. 2018. Identifying wildlife corridors for the restoration of regional habitat connectivity: A multispecies approach and comparison of resistance surfaces. *PloS One,* **13**, Article e0206071.

MWE. 2016. State of Uganda's Forestry. Ministry of Water and Environment, Kampala Uganda

NEMA. 2016. State of the Environment Report for Uganda 2014. National Environment Management Authority (NEMA), Kampala.

NEMA. 2009. Environmental Sensitivity Atlas for the Albertine Graben. National Environment Management Authority (NEMA), Kampala

Noss, R. F. 1993. Wildlife corridors. pp. 43–68 *in* Ecology of Greenways. (Eds. D.S. Smith and P.C. Hellmund). (University of Minnesota Press: Minneapolis, USA).

Obua, J., Agea J. G., & Ogwal, J. J. 2010. Status of forests in Uganda. *African Journal of Ecology*. DOI: 10.1111/j.1365-2028.2010.01217.x

Plumptre, A. J., Kijurakwinja, D., Treves, A., Owiunji, I., & Rainer, H. 2007. Transboundary conservation in the Greater Virunga Landscape: its importance for landscape species. *Biological Conservation,* **134,** 279-287

Pulliam, H. R. 1988. Sources, sinks, and population regulation. *Am.Nat. 132*, 652–61

Riggio, J., & Caro, T. 2017. Structural connectivity at a national scale: Wildlife corridors in Tanzania. PLoS ONE 12(11): e0187407. https://doi. org/10.1371/journal.pone.0187407

Rudnick, D. A., Ryan, S. J., Epps, C. W., Hartter, J., Perkl, R. M., & Preziosi, D. V. 2012. The role of landscape connectivity in planning and implementing conservation and restoration priorities. *Issues in Ecology,* **16,** 1–20. 660–668

Runge, C. A., Watson, J. E. M., & Butchart, S. H. M. 2015. Protected areas and global conservation of migratory birds. *Science* **350:** 1255–58. http://doi.org/10.1126/science.aac9180

Ryan, S. J., & Hartter, J. 2012. Beyond Ecological Success of Corridors: Integrating Land Use History and Demographic Change to Provide a Whole Landscape Perspective. *Ecological Restoration***, 30(**4), 2012 ISSN 1522-4740 E-ISSN 1543-4079

Taylor, P. D., Fahrig, L., Henein, K., & Merriam, G. 1993. Connectivity is a vital element in landscape structure. *Oikos,* **68,** 571–73

TNC. 2007. Conservation Action Planning Handbook: Developing Strategies, Taking Action and Measuring Success at Any Scale. The Nature Conservancy, Arlington, VA.

UNEP. 2019. Frontiers 2018/19 Emerging Issues of Environmental Concern, United Nations Environment Programme. Nairobi, Kenya. https://doi.org/978-92-807-3553-6.

UWA. 2018a. State of Wildlife Resources in Uganda .Uganda Wildlife Authority (UWA), Kampala

UWA. 2018b. Katonga Wildlife Reserve Draft General Management Plan. Uganda Wildlife Authority (UWA), Kampala.

UWA. 2016. Elephant Conservation Action Plan for Uganda, 2016-2026. Uganda Wildlife Authority (UWA), Kampala

UWA. 2013. Uganda Wildlife Strategic Plan 2013-2018. Uganda Wildlife Authority (UWA), Kampala

UWA. 2006. Toro Semliki Wildlife Reserve General Management Plan, 2007 – 2017. Uganda Wildlife Authority (UWA), Kampala

Van de Perre, F., Adriaensen, F., Songorwa, A. N., & Leirs, H. 2014. Locating elephant corridors between Saadani National Park and Wami-Mbiki Wildlife Management Area, Tanzania. *Afr J Ecol*., **52**, 448-457

Vasudev, D., Fletcher, R. J. J., Goswami, V. R. & Krishnadas, M. 2015. From dispersal constraints to landscape connectivity: lessons from species distribution modeling. *Ecography,* **38,** 967–978.

Wegmann, M., Santini, L., Leutner, B., Safi, K., Rocchini, D., Bevanda, M., et al. 2014. Role of African protected areas in maintaining connectivity for large mammals. Phil Trans R Soc B.; **369**: 20130193. https://doi. org/10.1098/rstb.2013.0193 PMID: 24733948

WCS. 2008. Queen Elizabeth Conservation Area Corridor Action Plan, 2008. Wildlife Conservation Society (WCS), Kampala