Large Terrestrial Mammals as Indicator Species for Climate Change Effects in Tanzania: Implications for Policy

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Abstract

Climate change is adversely affecting wildlife species. Species are affected differently due to the different ways they respond to climate change stresses. Terrestrial large mammals have not often been considered as potential indicators of climate change impacts. This research identified potential terrestrial large mammals as a possible indicator species for climate change effects, and analysed their implications for climate change adaptation policy in Tanzania. Desktop analysis and survey questionnaires were used to gather information and showed that some terrestrial large mammals could be used as indicator species for climate change effects in Tanzania. Both the desktop analysis and survey questionnaire revealed highly water dependent species (hippopotamus and waterbuck) and migratory species (wildebeest) as potential indicator species for climate change effects in Tanzania. Both academic and field ecologists regarded the African elephant highly as potential indicator species for climate change in Tanzania. This suggests that climate change adaptation policy in Tanzania should prioritize the use of hippopotamus, waterbuck, African elephant, and wildebeest as indicator species for climate change effects. Other species which could also be considered as a potential indicator for climate change are rhinoceros, wild dogs, buffalo, lion, leopard and cheetah

Introduction

The impacts of climate change on biodiversity can be observed around the world (Dawson *et al.* 2011, Cahill *et al.* 2012; CBD 2009). One projection, from the Intergovernmental Panel for Climate Change (IPCC) suggests that, for every 1°C rise in global mean temperature approximately 10% of species will be exposed to extinction risks (IPCC 2007). While climate change impacts are anticipated to stress ecosystems, research indicates that species respond differently towards climate change stimuli such as temperature increase and rainfall decline/increase. Species' responses include toleration, habitat shift or extinction, which are the outcomes of exceeding species tolerance level of water and temperature stresses (CBD 2009; Vie *et al.* 2009; Dawson *et al.* 2011 &Cahill *et al.* 2012).

Studies have found that species body size, genetic makeup, physiological systems such as water requirement, stresses tolerance (e.g. temperature, drought), geographical location determines how species respond towards environmental stresses (Dunlop & Brown 2008; Monzón *et al* 2011; Cahill *et al.* 2012). Many species are already being driven to alter their geographic distributions and behavior as they respond to extreme weather pattern changes that are associated with human induced climate change (Monzón *et al* 2011). When responding to a shift in climatic conditions, species tend to increase, decrease, or shift their range depending on their tolerance thresholds (Parmesan 2006; Parmesan and Yohe 2003 cited in Monzón *et al* 2011).

Changes in seasonal natural life related events (phenology) such as plants flowering and breeding are also linked to climate change effects (Parmesan 2006; ; Dunlop & Brown 2008; Cahill *et al.* 2012).

Phenology may interfere competition between species, an example from british plants, have shown some changes in flowering times whereby annual plants flower earlier than perennial plants. Similarly, plants which use insects as agents for pollination flower earlier than those which use wind as an agent for pollination (Fitter and Fitter 2002 cited Dunlop & Brown 2008). Migratory species are also affected with phenological changes. Many species migrate from one place to another for different reasons which may include seasonal food abundance, in search for water due to change of availability or avoidance of poachers and predators. However, one migration trip may be a combination of the reasons above (Robinson et al. 2005). These species depend on environmental triggers (e. g. temperature, rainfall, and flowering) to migrate (Brown 2008; Dunlop & Brown 2008; Cahill *et al*. 2012).

Phenology changes are well documented effects of climate change but they are not easy to predict and not easy to understand how might the overall change could be (Dunlop & Brown 2008; Cahill *et al* 2012). Changes in some seasonal events should not be generalized because it may be related to climate changes in one part but not necessarily in other parts of species ranges (Dunlop & Brown 2008). An example, some long distance migrating birds' arrival during spring is predisposed by climate conditions in overwintering areas, which then impacts on time availability of food and the reserve preparation. Consequently this affects the whole process of migration (Walther *et al*. 2002; Gordo *et al*. 2005 cited in Dunlop & Brown 2008).

Climate change is already having an impact on biodiversity in Tanzania. Increase in periodic drought length and frequencies as a result of changes in temperature and rainfall patterns are negatively affecting some species such as crocodiles, hippopotami and African elephants (Shemsanga *et al.* 2010; Devisscher 2010; WWF 2013; Mwiturubani *et al* 2011; Mwingira *et al.* 2011). Research that has explored climate change impacts on migratory birds and plant behavior found that some migratory birds have been seen in their destination earlier or late than normal and some plants have shown some changes in time of flowering (Robinson *et al* 2005; Newson *et al.* 2008; Mawdsley *et al.* 2009). However, little research has been done on examining terrestrial large mammals as possible indicators of climate change effects in Tanzania. I use the definition of indicator species from the National Geographic Education, which defines it as 'an animal which is very sensitive to environmental changes in its ecosystem (National Geographic Education 2013). Indicator species can easily be affected by the damage to the ecosystem and show early warning that habitat suitability is in decline.

The overall aim of this research was to identify large terrestrial mammals as potential indicator species for climate change effects and determine their usefulness in climate change adaptation policy in Tanzania. The specific aims for this study were 1) to identify terrestrial large mammals as potential indicator species for climate change effects in Tanzania from a desktop analysis, 2) to document the views of academic and field ecologists on what they consider to be important terrestrial large mammals as indicator species for climate change effects in Tanzania, and 3) to assess the usefulness of the desktop study, and academic and field ecologists' views on climate change adaptation policy in Tanzania.

The remainder of this paper is structured as follows: methods section explains the tools

used for data collection and data generation; results section is the next and it presents the results of the research; discussion of the result is the section which interprets and make sense of the research results and the last section is on the conclusion which summarises the research findings and gives out recommendations.

Methodology

This study used a desktop analysis and survey questionnaires to gather information and generate data. Both methods used biological characteristics of good indicator species for climate change effects from Vie *et al.* (2009). These characteristics are: 1) specialized habitat/microhabitat requirements which are likely to be interfered by climate change; 2) narrow environmental tolerances/threshold that are likely to be exceeded due to climate change at any stage in the life cycle; 3) dependence on a specific environmental notification, that are likely to be disrupted by climate change; 4) dependence on inter-specific interactions which are likely to be interrupted by climate change; and 5) poor ability to disperse to or to colonize a new or suitable range (Vie *et al.* 2009, p.79).

Desktop analysis

A total of 27 species of large terrestrial mammals (≥15kg) was subjected to analysis using the Vie *et al.* 2009 criteria. Species were scored according to the extent to which their characteristics matched Vie *et al.* (2009) criteria for good indicator species for climate change effects. Justification for scoring was sourced from the International Union for Conservation of Nature (IUCN) red list 2013; Delany & Happold 1979; Eltringham 1979 and Santin *et al.* 2013. These sources have detailed information on the characteristics of large African mammals, particularly on their habitats, interactions with other species (social or solitary animals), home ranges, territories,

and their tolerance levels on droughts and high temperatures, mechanisms they use during environmental stressors, dispersal ability and migratory species.

Species were scored as: Low=1, Medium = 2, High = 3, and Very high = 4, according to how well the species met the criteria in Vie *et al.* (2009) (Appendix II).

Human wildlife conflicts and economic value

The 27 species were analysed according to their interaction with local communities adjacent to national parks to understand which species are highly involved in human wildlife conflicts. Both grey and peer reviewed literature, were used to gather information on human wildlife conflicts (e.g. reports from the Protection and Community Outreach departments of Tanzania National Parks). The economic value of species was also analysed using national game fees obtained from the Tanzania's Ministry of Natural Resources and Tourism, Wildlife Division (URT 2013). The reason for this was to get some light on how important different species of wildlife are in the tourism business in Tanzania which translates into national economic prospect.
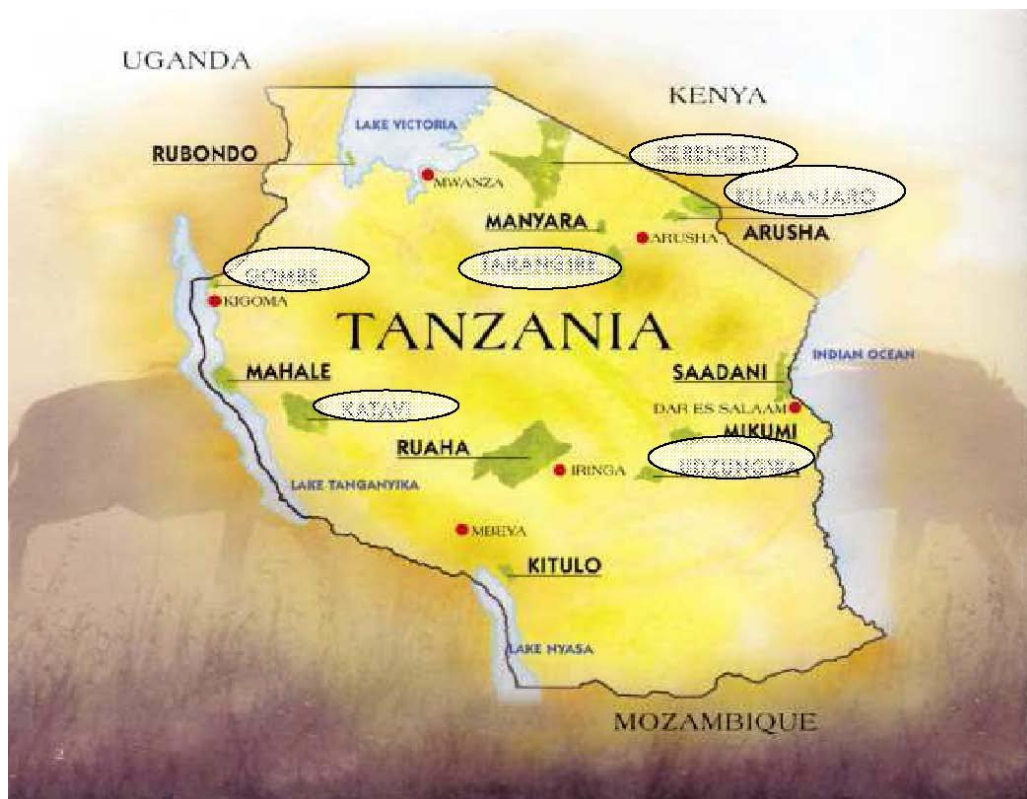
Survey questionnaire

Questionnaires were emailed to 20 people. They consisted of 10 field ecologists and 10 academic ecologists. A purposive sampling strategy was employed to select the field ecologists, based on their location at different sites across Tanzania and their field experience (≥4 years), and on the assumption that climate change effects may differ due to geographical location and that more experienced field ecologists would have more insights regarding climate change effects on species (Fig. 1). Field ecologists were from Udzungwa National Park, Serengeti National Park, Gombe National Park, Kilimanjaro National Park, Tarangire National Park,

Ruaha National Park, and Mkomazi National Park. The academic ecologists were selected on the basis of their long term experience of their institutions (>4 years) in teaching and researching wildlife-related disciplines, with an assumption that they will have more relevant insights than those with less experience. The academic ecologists were based in Sokoine University of Agriculture and the College of African Wildlife Management.

The questionnaire included both quantitative and qualitative information.

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Quantitative questions focused on the experience in researching/managing wildlife, the extent to which climate change is expected to affect both species and ecosystems in the next 30 years, and the value of species as potential indicator species from a list of 27species. The respondents were asked to use the Vie *et al*. (2009) characteristics of good indicator species for climate change effects. One open ended question was included to allow respondents to express their views on the usefulness of identified species in climate change adaptation policy in Tanzania

Source: http://www.tanzaniaparks.com/images/TZNP_map.jpg&imgrefurl=

Fig.1. Map of Tanzania showing locations of the National Parks. The circles show where the field ecologists came from in the survey questionnaires

Results

Desktop review
Highly water dependent species (the hippopotamus and waterbuck) and migratory species (wildebeest) were scored as the most relevant potential indicator species for climate change effects (Table 1).

Economic value and human wildlife conflicts
Species that are highly valued by tourism businesses in Tanzania are lions, African elephants, rhinoceros, African leopards, cheetah, wildebeest, wild dos and giraffes. African elephants are leading in causing human wildlife conflicts in Tanzania. Other species that cause conflicts are lions, hippopotami, Olive baboons, buffaloes, hyenas, African leopards and wild dogs (Figure 2).

Survey questionnaire
A response rate of sixty five percent (13/20) was achieved. A total of seven field ecologists and six academic ecologists responded including five females. All 13 respondents identified some species as possible indicator species for climate change effects in Tanzania, but only 12 respondents supported the species identified to be considered in the climate change adaptation policy in Tanzania. The remaining respondent, while not disagreeing, indicated that extensive scientific research is required to support the findings. Academic and field ecologists gave their priorities for possible potential indicator species for climate change effects in Tanzania as African elephants, water bucks, wildebeests and hippopotami (Table 2).

Table 1: Potential indicator species for climate change effects in Tanzania; data derived from the desktop study. The numbers in brackets represent specie's total scores.

| Status	Common name	Scientific name
High	Hippopotamus (13) Waterbuck (12) Wildebeest(12)	*Hippopotamus amphibius Kobusellip siprymnus Connochaetes taurinus*
Medium	African elephant(8) Lion (8) Cheetah (8) African buffalo(7) African leopard (7) Rhinoceros (7) Thomson gazelle(6) African wild dog (6)	*Loxodanta africana Panthera leo Acinonyx jubatus Syncerus caffer Panthera pardus Diceros bicornis Eudorcas thomsonii Lycaon pictus*
Low	Giraffe (5) Zebra (5) Hertebeest (5) Sitatunga (5) Sable antelope (5) Common eland (5)	*Giraffa camelopardalis Equus buchelii Alcelaphus buselaphus Tragelaphus spekeii Hippotragus niger Taurotragus oryx*
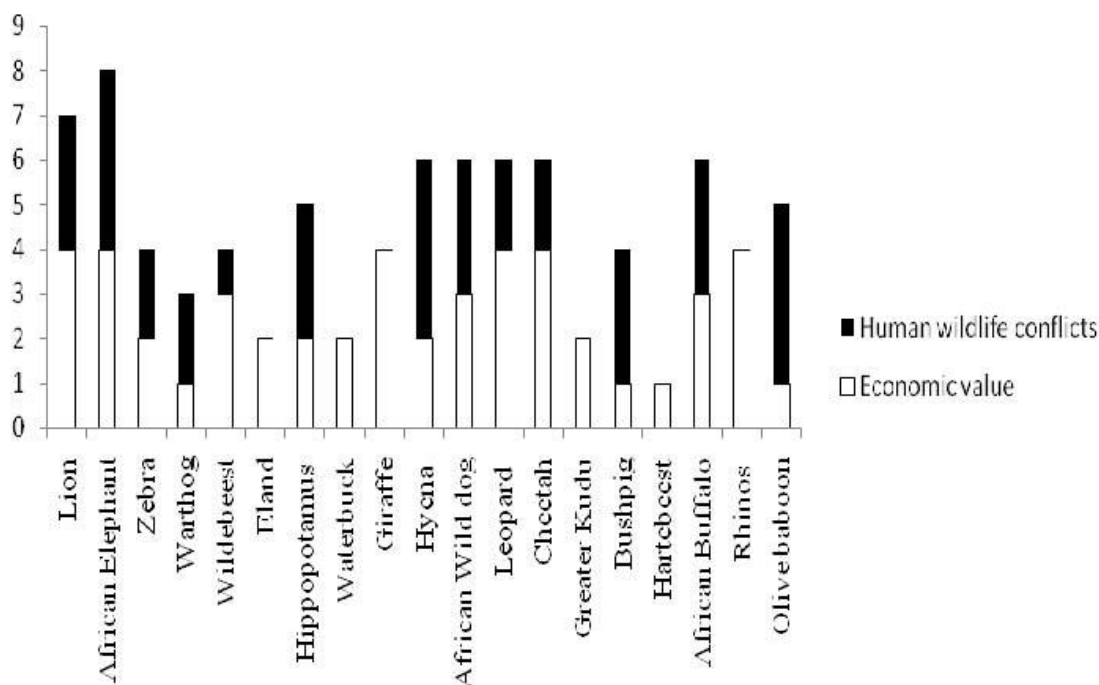
Figure 2: Economic values and human wildlife conflicts of species from the desktop analysis

Table 2. Categories of indicator species for climate change effects, according to surveyed academic ecologists and field ecologists in Tanzania. The numbers in brackets represent species' total scores

Status	Common name	Scientific name
High	African elephant (15) Waterbuck (14) Wildebeest (14) Hippopotamus (13)	*Loxodanta africana Connochaetes taurinus Connochaetes taurinus Hippopotamus amphibius*
Medium	African wild dog (12) Rhinoceros (11) Lion (10) African buffalo (9) Cheetah (9) African leopard (8)	*Lycaon pictus Diceros bicornis Panthera leo Syncerus caffer Acinonyx jubatus Panthera parduspardus*
Low	Thomson gazelle (4) Giraffe (4) Hartebeest (3) Zebra (3) Sitatunga (2) Common eland (1)	*Gazella thomsonii Giraffa camelopardalis Alcelaphus buselaphus Equus buchelii Tragelaphus spekeii Taurotragus oryx*

Table 3. Comparison summary for the desktop analysis and survey questionnaire. The number in brackets represents species total score

Status	Desktop analysis	Survey questionnaire
High	Hippopotamus (13) Waterbuck (12) Wildebeest (12)	African elephant (15) Waterbuck (14) Wildebeest (14) Hippopotamus (13)
Medium	African elephant *(8)* Lion *(8)* Cheetah (8) African buffalo (7) African leopard (7) Rhinoceros (7) Thomson gazelle (7) African wild dog (7)	African wild dog (12) Rhinoceros (11) Lion (10) African buffalo (9) Cheetah (9) African leopard (8)
Low	Giraffe (5) Zebra (5) Hartebeest (5) Sitatunga (5) Sable antelope (5) Common eland (5)	Thomson gazelle (4) Giraffe (4) Hartebeest (3) Zebra (3) Sitatunga (2) Eland (1)

Hippopotami, waterbucks and wildebeests scored high in both desktop analysis and survey. The academic and field ecologists also scored African elephants as high potential indicator species for climate change effects in Tanzania while the desktop analysis resulted in medium ranking for this species (Table 3).

Discussion
This study identified several large terrestrial mammal species as indicator species for climate change effects in Tanzania and analysed their usefulness in climate change adaptation policy in Tanzania. The results showed that high water dependent species and migratory species are highly regarded as potential indicator species for climate change effects in Tanzania. There were some clear differences between what species academic and field ecologists considered as potential indicator species with what the desktop study found.

Highly water dependent species and migratory species in terrestrial ecosystems are more vulnerable to climate change effects than other species. Hippopotami, in particular, depend on water while other species such as waterbuck must drink every day (IUCN 2013). These species have a low level of tolerance to water stress (Delany & Happold, 1979; Eltringham, 1979; Western 2008; Vie *et al.* 2009).

Figure 3: Hippopotami enjoing their aquatic habitat

Figure 4: Hippopotamus congregating in a small water pool due to water shortage in the river system in Katavi National Park

Wildebeest are migratory species and were identified as good indicator species for climate change in Tanzania. These species depend on the environmental cues to migrate such as temperature, rainfall and new grass production, which is likely to be affected by climate change variability (Western 2008; Cahill *et al.* 2012; IUCN 2013). These findings are in line with Mwingira *et al* (2011) who demonstrated that climate change is already having impacts on wildlife through prolonged droughts in Tanzania. The migration of wildebeests is very important to the Tanzania's economy as they are a major attraction for tourists and therefore contribute significantly to the national economy (URT 2012).

The desktop study indicated that the African elephants, African buffalo and some carnivores are also a good indicator species for climate change, but are lower priority compared to the hippopotami, waterbucks and wildebeests. According to the desktop analysis , hippopotami, waterbuck and wildebeests are more vulnerable to criteria number (1) specialized habitat/microhabitat requirements which are likely to be interfered by climate change, (2) narrow environmental tolerances/threshold that are likely to be exceeded due to climate change at any stage in the life cycle; (5) poor ability to disperse to or to colonize a new or suitable range of Vie *et al* (2009) (IUCN red list 2013; Delany & Happold 1979; Eltringham 1979 and Santin *et al.* 2013). It can be argued that, these species are more vulnerable and have low climate change adaptive capacity contrary to the African elephants, African buffalos and carnivores. Climate change adaptive capacity refers to 'the ability of a system or species to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantages of opportunities, or to cope with the consequences' (IPPC 2007). This could be linked to having various habitat options (less specialized habitats) which make African elephants, African buffalos and carnivores, not too specific to a particular habitat and thus less vulnerable to climate change effects. An example, African

elephants are found in dense forest, open and closed savanna, grassland (IUCN 2013). African elephants can travel long distance to look for suitable environments, which make them less vulnerable to climate change effects (Western 2008). Even if African elephant can travel long distance to search for conducive environment, they are actively forced to select habitats such as riverine which provide all necessary resources, particularly water, forages and shades (Shannon *et al* 2006 cited in Kevin *et al.* 2011).

Habitat distractions and habitat fragmentations affect species, climate change adaptive capacity because they restrict species in one area (Cahill e*t al.* 2012). Human activities such as settlement, agricultural expansion and infrastructure development have contributed to habitat destruction and habitat fragmentations (Msoffe *et al.* 2011; Mwiturubani 2011). These developments have resulted in limited or no movements of African elephants, as well as other species, from one Protected Area to another. Shift in species range is an adaptive strategy for species when stressed by environmental conditions; but with habitat fragmentation, species become more susceptible to climate change effects (Varrin *et al.* 2007). In Tanzania, African elephants today, cannot easily move from Tarangire National Park to Lake Manyara National Park in the northern Tanzania as a result of human settlement developments (Hulme 2005; Mwingira *et al.* 2011 Mantyka-Pringle). This suggests that, African elephant species in this ecosystem will have difficulties to adapt to climate change stressors in the future.

Both academic and field ecologists in Tanzania scored the African elephants highly as a potential indicator species for climate change effects, but was scored medium in the desktop analysis (Figure 3). African elephants are highly involved in human wildlife conflicts in Tanzania (Figure 2). Some respondents mentioned that conflicts between human and wildlife are increasing due to droughts. This shows a close linkage to climate change variability, which results into more often drought occurrences that in turn stresses wildlife species through reduced water availability and inadequate forages (Hepworth *et al.* 2010; Mwingira *et al* 2011). This has a range of implications: Firstly, local communities could be impacted greatly through crop damage, increased risk to life and destruction of water points. Consequently, African elephants expose themselves to increased poaching risk from these local communities (Mwingira *et al.* 2011; Mantyka-Pringle et al 2012). According to the data from ecologist and protection departments of Tanzania National Parks, human wildlife conflicts caused by African elephants have been increasing for the past five years (TANAPA 2013).

This research also found that carnivores (lions, African leopards, cheetahs, and wild dogs) are potential indicator species for climate change effects, but they are ranked as medium in both the desktop analysis and survey responses (Figure 3). One explanation for this could be that carnivores depend entirely on inter-specific interaction among several different species (Eltringham 1979; Vie *et al.* 2009). Carnivores are refereed as keystone species. These are species that are very important to the ecosystem because they keep the ecosystem stable; their absence may destabilize the ecosystem and even result in ecosystem collapse at times (Eltringham 1979; Sinclair 2003; Herley 2011). Since carnivores depend on other species such as wildebeest, buffalo, waterbuck which are likely to be affected

by climate change, they are suitable as an indicator species all be it at a lower power than the highest ranked species. Climate change effects, human activities such as poaching and habitat destructions are expected to negatively impact prey species population more which in turn will affect the carnivores (Hulme 2005; Monzon *et a.l* 2011).

Rhinoceros and African wild dogs are endangered species in Tanzania, and were also identified as possible indicator species but as a low priority. Species with low abundance are vulnerable to climate change effects as they are more prone to extinction as a result of climate change induced habitat alteration (Tylianakis *et al.* 2008; Cahill *et al* 2012; IUCN 2013). This reality, however, does not mean that endangered species are necessarily good indicator species (Vie *et al.* 2009). Rhinoceros and wild dogs have some strong characteristics of the Vie *et al.(* 2009) categorisation and thus they are accepted as potential indicator species for climate change effects in Tanzania although at a lower power than those species that are highly ranked.

Desktop analysis and experts viewed the identified indicator species for climate change effects in Tanzania as important species which are useful in monitoring climate change effects on wildlife species in the long term. Since there are millions of species and taxa, it is not possible to monitor the effect of climate change on wildlife species, which respond to climate change effects differently without having a suite of indicator species. Through indicator species we can as well monitor impacts of climate change on the ecosystem perspective (Newson *et al.* 2009; Dawson *et al.* 2011). Both methods (desktop analysis and survey questionnaires) recommended the species identified as potential indicator species (hippopotami,

waterbucks, wildebeest and African elephants) to be prioritized in the climate change adaptation policy in Tanzania. These species could be used to evaluate the impact of climate change in a long run in Tanzania and could as well be used to gauge the effectiveness of climate change adaptation policy in Tanzania and beyond.

Conclusion

Indicator species can provide valuable information with regard to climate change effects and could be useful for the management of both indicator species and the entire ecosystem. The findings of this research demonstrate that there some of the largest terrestrial mammals in Tanzania are suitable indicator species for climate change impacts. These species are hippopotami, waterbucks, wildebeests and elephants. Other species with potential to be suitable indicators of climate change effects, although to a slightly lesser extent are Africa buffalo, rhinoceros and carnivores (lions, cheetahs, leopards and wild dogs).

Academic and field ecologists ranked African elephant species as a high potential indicator species for climate change effects in Tanzania, while this was ranked only at a medium level in the desktop analysis. Desktop analysis considered African elephants had less strong criteria against the criteria for good indicator species for climate change effects by Vie *et al* (2009). The experts' field experiences showed that African elephants are a main cause of human wildlife conflicts, the rate at which increases under drought conditions. Droughts are considered to be a major impact of climate change and expected to increase with increased climate variability (Mwingira *et al.* 2011; Monzon *et al.* 2011). The desktop analysis and experts' opinions show that, species which are highly dependent on water and those which

migrate long distances are potentially excellent indicator species for the impacts of climate change in Tanzania.

It is impossible to monitor all species from the climate change effects, given the size of taxa and species diversity affected, but it is possible that, using a suite of indicators, various of the physical and ecological key processes through which wildlife could be impacted by climate change could be monitored (Newson *et al.* 2009; Arponen 2012). It is recommended that future monitoring for potential climate change impacts in Tanzania utilise the species identified through this research as indicator species to develop, amend and gauge the success or otherwise of national and international climate change adaptation policies. As climate change is occurring at a global scale and not just restricted to Tanzania, it is highly likely that these species will also prove pivotal to monitoring the effectiveness of global climate change adaptation policies and how they are impacting on the biodiversity of Tanzania.

Acknowledgement

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