Terrestrial Large 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 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 inflowering 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, 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 interpreents and make sense of the research results and the last section is on the conclusion which summarises the research findings and gives out recommendations.

METHODS

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, 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).

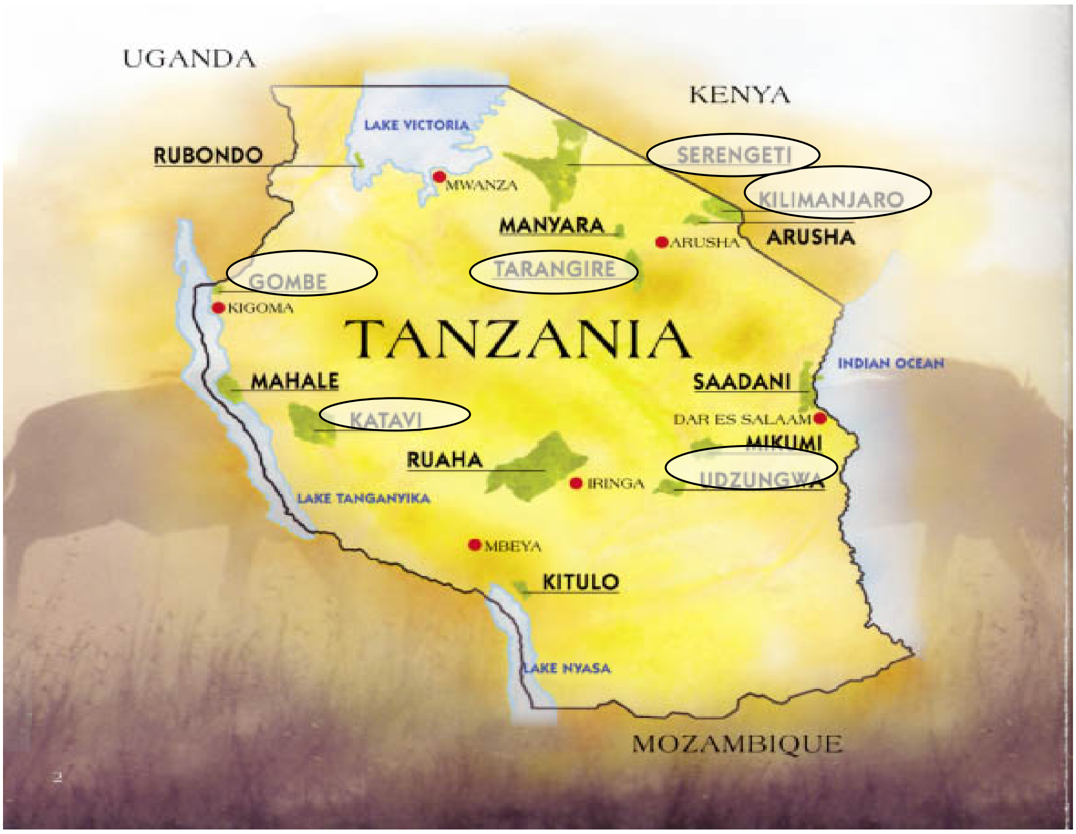
Human wildlife conflicts and economic value

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. 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 (appendix 1).



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 analysis

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).

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*

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).

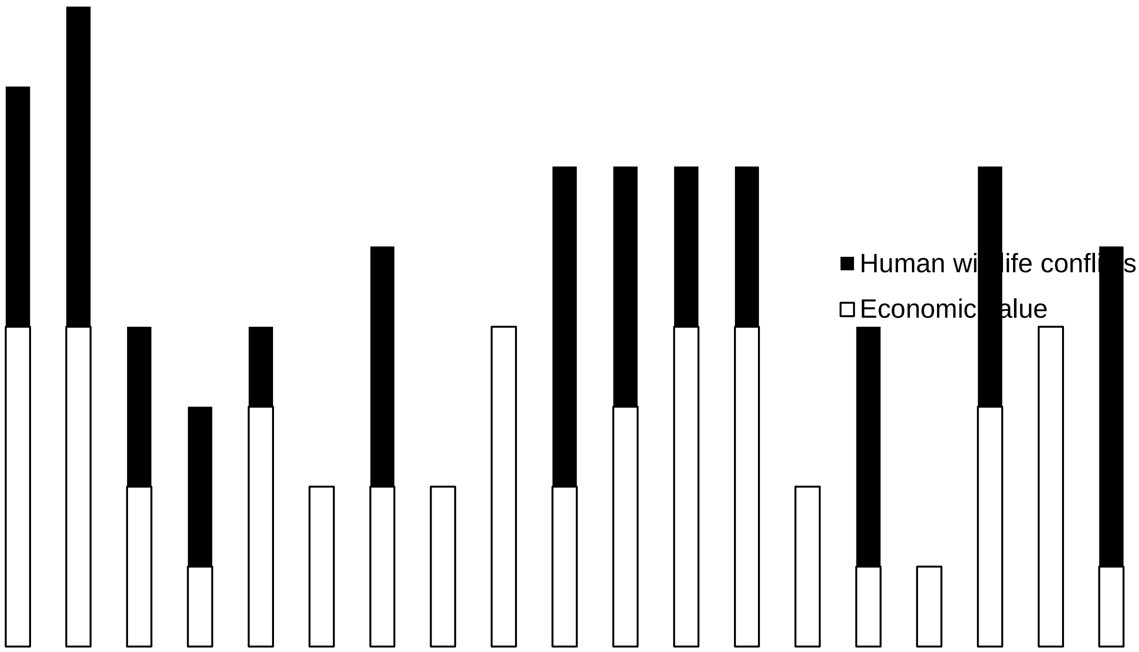


Figure 2: Economic values and human wildlife conflicts of species from the desktop analysis

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 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 Africa 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 Source: Mwingira *et al*., 2009).

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 are 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; and (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 indentified 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 experience 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.

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Appendix 1
Questionnaire on indicator species for climate change

By completing this survey, you are giving consent to participate in this research.

Please tick or highlight the answer which appear right to you.

1. Are you
    a. Female
    b. Male

2. What is your highest level of education?
    a. Secondary school
    b. Secondary school certificate
    c. Diploma
    d. Bachelors degree
    e. Masters degree and above

3. What agency/organization do you work for?
   Answer:...

4. What is your position?
   Answer:...

5. How many years have you been in your position?
   Answer:..

6. How many years of experience in wildlife research/management have you had?
    a. 0-5 years
    b. 6-10 years
    c. 11-15 years
    d. 16-20 years
    e. 21-30 years
    f. 31+years

7. To what extent do you think climate change will affect species/ecosystems in Tanzania in the next 30 years?
    a. No extent
    b. A small extent
    c. A moderate extent

d. A large extent

8. Table 1 (below) lists a number of species of large terrestrial mammals that are found in Tanzania.
    a. Please indicate whether you think these species are suitable indicators of the effects of climate change in Tanzania by placing a tick (✓) in the third column. If you do not think the species is a suitable indicator species, place a cross (✗) in the column.
    b. Please use the possible reasons provided inTable 2 to justify whether or not you think the species is a suitable indicator of effects of climate change in Tanzania. If none of the reasons provided in Table 2 are suitable OR if you have additional reasons, please list them in the fourth column.

Table 1: List of species that are possible indicators for climate change effects in Tanzania

Scientific name	**Common name**	**Indicatorf or climate change effects**	**Reasons** **(**Pick the number (s) from Table 2 or enter own reason/s)
Acinonyx jubatus	Cheetah		
Alcelaphus buselaphus	Hartebeest		
Ceratotherium simum	White Rhinoceros		
Connochaetes taurinus	Common Wildebeest		
Crocuta crocuta	Spotted Hyena		
Damaliscus lunatus	Topi		
Diceros bicornis	Black Rhinoceros		

Eudorcas thomsonii	Thomson gazelle		
Equis buchelii	Zebra		
Giraffa camelopardalis	Giraffe		
Hippotragus niger	Sable antelope		
Hippotragus equinus	Roan antelope		
Hippopotamus amphibius	Hippopotamus		
Kobusellip siprymnus	Waterbuck		
Loxodonta africana	African Elephant		
Lycaon pictus	African Wild dog		
Nanger granti	Grant gazelle		
Oryx	*Oryx beisa*		
Panthera leo	Lion		
Panthera parduspardus	African Leopard		
Phacochoerus africanus	Common Warthog		

Papio anubis	Baboon		
Potamochoerus larvatus	Bush Pig		
Syncerus caffer	African Buffalo		
Tragelaphus oryx	Common Eland		
Tragelaphus strepsiceros	Greater Kudu		
Tragelaphus spekii	Sitatunga		

Table 2: Possible reasons which can make a species a good indicator of climate changeeffects(adapted from Vie et al. 2009).

1. Specialized habitat/microhabitat requirements e.g. water dependent species, enough forages
2. Narrow environmental tolerances or threshold that are likely to be exceeded due to climate change at any stage in the life cycle e.g. temperature/drought tolerance
3. Dependence on a specific environmental triggers or cues that are likely to be disrupted by climate change e.g. migratory species
4. Dependence on inter-specific interactions which are likely to be interrupted by climate change e.g. keystone species
5. Poor ability to disperse to or to colonise a new or suitable range

9. Do you consider that the species you identify above as indicator species should be included in climate adaptation policies in Tanzania?

If yes, please explain how (and if necessary, which ones)?..
..

If no, please explain why not?

……….

Appendix II
Table 1: Eleven most highly scored species against criteria for good indicator species for climate change effects in Tanzania from desktop analysis

Common name	Specialised habitat	Narrow environmental tolerance	Dependence on environmental triggers	Dependence on inter-specific interactions	Poor ability to disperse	Total
Hippopotamus	4	4	1	1	3	13
Waterbuck	3	4	1	1	3	12
Wildebeest	2	3	4	2	1	12
Lion	1	1	1	4	1	8
African leopard	1	1	1	4	1	8
Cheetah	1	1	1	4	1	8
African elephant	2	2	1	1	1	7
Rhinoceros	2	2	1	1	1	7
African buffalo	2	2	1	1	1	7
Thomson gazelle	1	1	2	2	1	7
African wild dog	1	1	1	2	1	6
Giraffe	1	1	1	1	1	5
Hartebeest	1	1	1	1	1	5

Sitatunga	1	1	1	1	1	5
Sable antelope	1	1	1	1	1	5
Eland	1	1	1	1	1	5

Table 1; Economic value- Game Fees for Mammals Hunting

NO.	**SCIENTIFIC NAME**	**ENGLISH NAME**	**FEES (USD) – Hunting by using Riffle**	**Scoring**
1	*Loxodonta africana*	African elephant	7500 (15kgs), 12,000 (27kgs) 20,000 (32 kgs)	4
	Panthera leo	Lion	4900	4
	Panthera pardus	Leopard	3500	4
	Oryx gazella	Oryx	2800	3
	Tragelaphus imberbis	Lesser Kudu	2600	3
	Litocranius walleri	Gerenuk	2500	3
	Tragelaphus strepsiceros	Greater Kudu	2200	3
	Hippotragus equinus	Roan antelope	2550	3
	Hippotragus niger	Sable antelope	2550	3
	Tragelaphus spekei	Sitatunga	2000	3
	Synceris caffer caffer	African buffalo	1900	2
	Taurotragus oryx	Eland	1700	2
	Hippopotamus amphibious	Hippopotamus	1500	2
	Lycaon pictus	Wild dog	1200	2
	Equus burchelli	Zebra	1200	2
	Kobus ellipsiprymnus	Common waterbuck	800	1
	Damaliscuss korrigun jimela	Topi	800	1
	Connochaetes taurinus	Wildebeest	650	1
	Alcelaphus buselaphus cokei	Coke’s Hartebeest	650	1
	Tragelophus scriptus	Bushbuck	600	1

	Crocuta crocuta	Spotted hyena	550	1
	Gazella thomsonii	Thomson gazelle	500	1
	Gazella grantii	Grant's gazelle	450	1
	Redunca furvorufula	Reedbuck	450	1
	Phacochoerus aethiopicus	Warthog	450	1
	Potamochoerus porcus	Bushpig	420	1
	Aepyceros melampus	Impala	390	1

Source: URT 2012 – (Wildlife Division) http://wildlife.go.tz/page.php%3Fid=39.html.

Scoring category

Low = 1 (USD 100-999); Medium = 2 (USD 1000-1999); High = 3 (USD 2000- 2999); Very high = 4 (USD 3000 and above)

Table 2: Human wildlife conflicts (HWC) (Baird et al 2009; Chadwick DH, 2011; TANAPA 2013)

No	**Species common name**	**Species scientific name**	**Score for conflicts**
1	African elephant	*Loxodonta africana*	4
2	African buffalo	*Syncerous caffer*	4
3	Olive baboon	*Papio anubis*	4
4	Common zebra	*Equis buchelii*	3
5	Lion	*Panthera leo*	3
6	Leopard	*Panthera pardus*	3
7	Hyena	*Crucuta crucuta*	3
8	African wild dog	*Lycaon pictus*	1
9	Wildebeest	*Chonochaetus taurinus*	1

Scoring: Low=1, Medium=2; High = 3, Very high= 4

Table 3: Species considered by academic ecologists and field ecologists as indicators for climate change impacts in Tanzania

Common name	Specialised habitat	Narrow environmental tolerance	Dependence on environmental triggers	Dependence on inter-specific interactions	Poor ability to disperse	Total
African elephant	4	5	0	3	2	15
Waterbuck	9	4	0	0	1	14
Wildebeest	0	0	13	1	0	14
Hippopotamus	8	4	0	0	1	13
African wild dog	2	4	0	6	0	12
Rhinoceros	6	4	0	0	1	11
Lion	1	1	2	6	0	10
African buffalo	5	2	1	0	1	9
Cheetah	1	1	0	1	6	9
African leopard	1	1	1	3	2	8
Thomson gazelle	1	1	1	1	1	4
Giraffe	3	1	0	0	0	4
Hartebeest	2	0	0	0	1	3
Sitatunga	2	0	0	0	0	2
Sable antelope	1	0	0	0	0	2
Eland	0	1	0	0	0	1

Grant gazelle	0	0	0	0	0	0
Hyena	0	0	0	0	0	0

Table 2: Economic value and human wildlife conflicts species criteria

Species	**Scientific name**	**Economic value**	**Human wildlife conflicts**	**Total**
African elephant	*Loxodonta africana*	4	4	7
Lion	*Panthera leo*	4	3	7
Leopard	*Panthera parduspardus*	4	2	6
Cheetah	*Acinonyx jubatus*	4	2	6
African buffalo	*Syncerus caffer*	2	3	6
Hippopotamus	*Hippopotamus amphibius*	2	3	6
African wild dog	*Lycaon pictus*	2	2	5
Rhinocerus	*Diceros bicornis*	4	1	5
Giraffe	*Giraffa camelopardalis*	4	1	5
Zebra	*Equus buchelii*	2	2	4
Common wildebeest	*Connochaetes taurinus*	1	1	2

Appendix III
LITERATURE REVIEW
OVERVIEW OF CLIMATE CHANGE TREND IN TANZANIA
Tanzania has several climates across the country due to inland lakes, various vegetation types, topography and being close to Indian Ocean. Two seasons exist, namely the dry season and the wet season (Devisscher 2010). Two rainfall regimes exist. The first runs from November to April in the southern and western part of the country, which has a uni-modal distribution. The second rainfall season, which is bimodal, occurs in northern and coastal regions from October to December and from March to May. Northern highlands and Lake Victoria are relatively wet while the central and western regions respectively are semi-arid (Devisscher 2010, Shemsanga *et al*. 2010).

One projection shows that, Tanzania will warm from 2-4 ^{o}C by the year 2100 (Mwingira *et al*. 2011). Wet season are expected to warm less than dry seasons. Rainfall is predicted to decline by 20 percent in the interior of the country and increase in the northeast, south east and Lake Victoria basin in the northern part of the country, from 20-30 percent (Figure 1). Temperature is expected to increase less in the coastal regions than in the interior by 10 percent (Mwingira et al. 2011). The predicted changes in both temperature and precipitation are expected to lengthen dry seasons and intensify seasonal droughts in the country interior (Mwingira *et al.* 2011). These climate change predictions signal a stressful future for some species of wildlife due to water scarcity and possibly inadequate forages.

Ninety five per cent of wildlife population is in protected areas (PAs) in Tanzania (URT 2012). Tanzania has many terrestrial Protected Areas (PAs) network distributed all around Tanzania. They cover a total of 371,008 km^2 which is equivalent to 37.8% of the total area of Tanzania (URT 2012). Most PAs are located in the interior part of Tanzania, where according to the above prediction, it is expected to warm more and the rain will decrease noticeably. Wildlife species in Tanzania are therefore likely to be adversely affected by climate change in the future. Rainfall decline and temperature increase are the main abiotic factors responsible for the wildlife species population decrease and extinctions (Midgley 2011; Cahill *et al. 2012*; Jones *et al.* 2013).Wildlife in PAs located in the coastal regions, north east and south east are likely to be affected negatively with floods and some species will benefit from the projected increase in rainfall.

Figure 1. A map of Tanzania showing protected areas network
Source:
http://pctanzania.org/repository/Environment/Tech%20Manual/tz_protected_areas.jpg

ECOLOGICAL AND SOCIO- ECONOMIC IMPLICATION OF CLIMATE CHANGE EFFECTS IN TANZANIA

Ecological implications of climate change effects

Ecosystems are being transformed at a greater speed by the anthropogenic climate change effect and the scale is on the rise (Arponen 2012; Fordham *et al.* 2012, National Academies 2013). Phenological change and shift of species ranges are some of the main discussed impact of climate change on wildlife (Newson *et a.l* 2008). In the course of responding, other species fail to cope with the stressors and ending up dying which may lead to extinction (Cahill *et al.* 2012; National Academies 2013).

Phenological alteration

Phenology is the study of seasonal and cyclic natural events of both flora and fauna such as migration, breeding, flowering in relation to climate (Varrin *et al*. 2007; National Academies 2013; Fordham *et al.* 2012). To maintain their life cycle events, animals use different indicators, both biological (e.g. flowering) and physical (e.g. wind, temperature) as a signal for a particular event to happen (Cahill *et al*. 2012. For example, migrating animals, would

start migrating when they see certain species of plants coming out or flowering (Varrin *et al.* 2007; Dunlop & Brown 2008). However, photoperiod or the rate of change in photoperiod could be other reasons of migration (National Academies 2013). Anthropogenic climate change has been discussed by many studies to alter these events, by changing signal occurrence in terms of time, direction and intensity (Varrin *et al.* 2007; Eppink *et al.* 2007, Cahill *et al.* 2012). A number of species have been observed to arrive at the destination 10 to 15 days earlier than they used in some decades back., Other species such as butterflies and plants show up earlier than usual (in the USA and UK) (National academies 2013).
In Australia, it has been recorded that changes on the first arrival date of the migratory birds 3.5 days per decade and 5.1 days per decade last date of departure (Beaumont *et al*. 2006 cited in Dunlop & Brown 2008; National Academies 2013). A meta –analysis study by Parmesan and Yohe (2003) found changes in spring event's timing for 172 species of birds and shrubs - United States, trees (mostly from Europe), butterflies (mostly from Great Britain), herbs and amphibians. They found an average advancement of 2.3 days per decade (95% CI 1.7-3.2 days per decade) (cited in Dunlop & Brown 2008).

Phenology changes are well documented but they are not easy to predict and not easy to understand how might the the overall change be (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 (Gordo *et al*. 2005 cited in Dunlop & Brown 2008).

There are some lifecycle events which are directly linked to seasonal factors (e.g.photoperiod) that will be unaffected by climate change. Another example is an onset of summer storms which is difficult to claim climate change is responsible (Mantyka-Pringle *et al* 2012). But changes in timing will still occur in such cases (Dunlop & Brown 2008). While we explore adeverse impacts of climate change to species life events, there also some positive impacts to species such as plants. Plants uses CO2 as one of the raw materials to make their own food. Given other importants raw materials, when CO2 increases in the atmosphere we expect plants productivity to increase. However, Dunlop & Brown (2008) argue that plant productivity in the event of increased CO2 in the atmosphere does not happen uniformly to all plants species. It varies across different environmnents, favouring species from water stressed envinronments (Eppink 2007). Likewise, climate change effects do not happen uniformly across geographical areas. While other species may be facing climate change stressors difficulties, other species on the other geographical part may be having conducive environments for their survival.

Some argue that species are just evolving by responding to the natural climate change variability which changes over time and have been happening for decades (Arponen 2012; Cahill *et al*.2012). Studies show that human induced climate change is interfering with the evolution processes by causing it to happen too fast to the point other species cannot cope with the speed (Anderson 2012). In addition, changes of phenology may disrupt some important species interactions within the ecosystem, thus destabilizing the ecosystem

(Eppink *et al.* 2007**).** Species extinction may happen when climate change causes decline in species upon which the other species depend on for survival. For example prey for predators, parasite hosts and some herbivores, species such as pollinators which are important for reproduction (Cahill *et al.* 2012).

In Tanzania, there are a number of migrating species locally and internationally such as birds (flamingos) and large terrestrial animals (wildebeest and zebra) migrating between Tanzania and Kenya twice a year (TANAPA 2010). As they migrate, these animals are food to other animals (carnivores), if for example due to changed pattern of rainfall and temperature leading to shortage of food and water, migratory species may decide to change the route to pass where water is plenty for refueling (Mwingira *et al*. 2011). In doing so, they might negatively affect other species by missing out food that depends on them.

Shifts in species ranges
Interaction between life and physical environment is important for both flora and fauna. Physical environment attributes such as climate conditions like precipitation, temperature, salinity among others may be reasons for species' temporary or permanent distributions (Varrin *et al*. 2007; Eppink 2007). Climate change has impacted on these attributes by changing their patterns and as a result animals respond by shifting their ranges to look for a conducive environment to cater for their life requirement. Approximately 10 percent of species studies have moved to more tolerable ranges for survival and reproduction (National Academies 2013). However, slower moving species and those restricted to particular environmental niches, such as seals and polar bears, are more vulnerable to death if they are forced to tolerate altered conditions (Cahill *et al.* 2012).

Shift in species range is an adaptive strategy for species when stressed by environmental conditions; but this phenomenon could be felt in species population decline due to local extinction as environmental conditions rules (Varrin *et al*. 2007). Devisscher (2010) argue that these effects could be compounded if species are restricted to few key sites because they can easily become extinct in the event of extreme weather events. Habitat fragmentation and habitat loss tend to interfere species migration by blocking their migration routes. In the event of climate change extremes such as water scarcity and increased temperature, habitat fragmentation could exacerbate species decline and possibly the extinction of some species because they will not be able to shift to new ranges as a coping strategy during harsh environment (Mwingira *et al.* 2011; Cahill *et al.* 2012).
Socioeconomic implication of climate change effects in Tanzania
Wildlife is a very important resource, both socially and economically in Tanzania. Tourism is the second highest contributed to GDP in Tanzania after agriculture with approximately 70 percent of tourism in Tanzania wildlife based (URT 2007; TTB 2010). The sector provides employment to many Tanzanians. It also provides meat as a source of protein through legal hunting (URT 2007). However, a growing number of challenges face wildlife conservation in Tanzania such as poaching, habitat fragmentation, habitat loss, invasive species, politics, human wildlife conflicts and human population increase among others.

Climate change has been documented to have damaging impacts on biodiversity and envisaged to become a leading driver for the biodiversity loss in the coming decades

(Robinson *et al.* 2005; IPCC 2007; CBD 2009; Cahill *et al.* 2012; National Academies 2013; WWF 2013). However, many researchers argue that it is difficult to tell whether species extinctions have been caused by climate change effects solely because of the complexity in tracking down and making sure it is not other stressors which have caused the species loss (Dunlop & Brown 2008; Cahill *et al.* 2012; Mantyka- Pringle *et al* 2012). Others argue that, climate change effects are having synergistic effects with other environmental stresses and thus causing even greater impacts to the environment (Devisscher 2010; Mwingira *et al.* 2011; National Academies 2013).

GOOD INDICATOR SPECIES FOR CLIMATE CHANGE EFFECTS

The climate varied causes different species to respond in three possible ways (Robinson *et al*. 2005; Cahill *et al*. 2012). Firstly a species can move by changing the geographical location (migration). Secondly a species can remain in the same geographical location and cope or adapt to the changes, and thirdly, a species can go extinct because they are not able to do either move or adapt (Robinson *et al*. 2005; Cahill *et al*. 2012; National Academies 2013). However, no species have explicitly become extinct because of a changing climate, yet although the Golden Toad (*Bufo periglenes*) may be one such case and many are predicted (Robinson *et al*. 2005, p17). Nonetheless, there is adequate proof on local extinctions happening due to climate change, for example, a decline in rainfall may cause water stress, death and local extinction particularly for terrestrial species (Cahill *et al*. 2012, p.2).

Indicator species centrality

Not all species are affected by climate change equally due to the complex interaction of species within the ecosystem. Overall impacts of climate change to the ecosystem could be demonstrated by a few species which are sensitive to climate change, such as keystone species (Sinclair 2003; Dunlop & Brown 2008). Species differ in size, genetic and physiological requirements and functions which all together inform the habit, habitats, food, reproduction, geographical distribution and their response to environmental stressors including climate change stressors such as temperature and droughts (Tylianakis *et al.* 2008). Climate change indicator species can provide important information and could be very useful for the management of both species and ecosystem. Specifically indicator species could be used as a management tool whereby protected areas management could use them to enhance management. Indicator species may also be used for monitoring purposes with regard to climate change effects, indicator species could as well be an important information which can bring together policy makers and decision makers to enhance conservation (Vie *et al* 2009). This necessitates a need to consider policy action based on different species which are indicators of climate change effects.

Criteria for good indicator species

According to Mawdsley (2009), a good indicator species should address the following attributes: should have a great impact on the conservation policies; socioeconomic factors and on the targeted species or ecosystems for conservation. The following are some of the best criteria to consider for climate change indicator species defined by Vie *et al.* (2009);

1. Specialized habitat/microhabitat requirements e.g. water dependent species, enough forages

2. Narrow environmental tolerances or threshold that is likely to be exceeded due to climate change at any stage in the life cycle e.g. temperature/drought tolerance

3. Dependence on a specific environmental triggers or cues that are likely to be disrupted by climate change e.g. migratory species

4. Dependence on inter-specific interactions which are likely to be interrupted by climate change e.g. keystone species

5. Poor ability to disperse to or to colonise a new or suitable range

Together with Vie *et al.* 2009 criteria, the following are different good criteria for climate change indicator species from peer reviewed literature.

Terrestrial water dependent species
Animal species which depend highly on water are vulnerable to climate change effects (Mwingira *et al.* 2011; Devisscher 2010). Such species include buffalo, elephant, hippos, crocodile, elands, zebra and wildebeest. Many of these species require regular and large quantities of water for survival and to perform other physiological functions such as body cooling. Increased temperature and decline in rainfall as a result of climate change are likely to impact these species in a negative way and force them to respond in any of the three mentioned possible ways above. But Vie *et al.(* 2009), emphaised that not all species which depend on water can be good indicator for climate change.

Threatened and endemic species
Animal species which are threatened or endemic species are a concern in the face of a changing climate (IUCN 2006; Cahill *et al.* 2012). Reduced population and special habitat requirement are the concern. Endemic species restricted to a particular geographical location climate change effect may cause them to become extinct because they are restricted to a special habitat. In the event of increased temperature and decreased rainfall, the best way to respond is to remain there and adapt. A species that cannot adapt may become extinct. In addition, endangered and endemic species may also be subjected to other human stressors such as poaching therefore they are even more vulnerable to the impacts of climate change (Mwingira *et al*. 2011; National Academies 2013).

Migratory species
Many large mammal 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). Large herbivores such as wildebeest, Zebra and elephants migrate more than other groups of terrestrial animals. They are bulk feeders eating grasses and also most depend on water for drinking. Other animals which migrate include Mountain Gorilla and carnivores such as lions, however these are more local rather than extended migrations (Robinson *et al*. 2005). When herbivores migrate they will follow seasonal changes in vegetation ensuring that the herd has adequate food resources at all

times. Changes in temperature and rainfall patterns caused by climate change may force migratory animals to change their migratory route and timing (Devisscher 2010; Newson *et al*. 2008).

Mwingira et al. (2011) argue that changing migratory routes expose species into dangers including running into poachers or human settlements/ farms thus increase human wildlife conflicts. This change in timing or route of the migration may cause system wide impacts as predators may experience a shortage of prey availability which could lead to population reductions or extinction for some of predator species (Mawdsley *et al*. 2009). Tanzania harbors a massive seasonal wildebeest and zebra migration which may be altered due to future climate change impacts (Devisscher 2010).

Keystone species

Keystone species refers to a species which its presence or absence determines the stability or instability of an ecosystem (Sinclair 2003). Predator and prey relationship in an ecosystem is a good example. A lion is a keystone specie because it subsequently checks the population of herbivores and herbivores check the population of grass they feed on (Mawdsley *et al*. 2009; Herley 2011). Climate change may interfere the interaction between the keystone species and other species by either decreasing the population of keystone species or other species and consequently may destabilize the ecosystem (Herley 2011). Studies have shown that, losses of key stone species in an ecosystem have had considerable impacts on the ecosystem, thus protecting these species against anthropogenic activities is imperative (Herley 2011).

SIGNIFICANCE OF CLIMATE CHANGE ADAPTATION POLICY ON BIODIVERSITY

Climate change adaptation refers to any human activities aimed at reducing the negative climate change effects on the environment, both physical and biological one (Mawdsley *et al*. 2009, p. 1081). Climate change adaptation policy could be useful in addressing a national legislative requirements for biodiversity conservation by management decision making considering the potential climate change implications. Having a robust policy can help reduce climate change vulnerability to species and ecosystem and increasing adaptive capacity through active and adaptive management (Hulme 2005; New South Wales Government 2010). Climate change adaptation policy may be useful not only in developing adaptation and mitigation strategies with regard to climate change effects but also could be useful to inform local community in a timely manner of climate change effects and this could be helpful in building a more cohesive and more climate change adaptive capacity (New South Wales Government 2010; Hepworth 2010).

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