DO SITATUNGA (*Tragelaphus Spekei*) POPULATIONS RESPOND TO FLOODS? IMPLICATIONS FOR CLIMATE CHANGE IN NORTHERN BOTSWANA

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ABSTRACT  
Sitatunga is a rare semi-aquatic antelope occurring in wetlands and swampy environments in northern Botswana. Its habitat range in the Okavango Delta is reported to have decreased over the past 100-150 years. Given the projected global climate change, it is essential to first interrogate available data on sitatunga and inundation levels in an effort to avail baseline data to be used for forecasting the behavior of sitatunga populations and distribution over the next 20 years. Regression analyses were applied to wildlife population census from 1992-2012 and 8 decades river flow data. Visualization for Sitatunga observations was also displayed using proportional symbols in ArcGIS 10.2.2. Actual numbers of sitatunga observed declined from 51 in 1996 to about 13 animals in 2008. However, recovery of sitatunga population from about 13 in 2010 to 29 animals in 2011 occurred. The decline in sitatunga population is regarded as a lag response of this species to decrease in inundation level from 1985-1995. Furthermore, population increase from 2008-2011 followed an increase in inundation levels. Therefore, sitatunga population is vulnerable to potential climate change extreme events. Policy interventions and management strategies are needed to conserve it through establishment of sitatunga corridor in prime habitats of the Delta.

KEY WORDS  
Sitatunga (*Tragelaphus spekei*), sitatunga dispersal corridor, climate change, Northern Botswana, flood variability, geospatial analysis.

1. Introduction

Sitatunga is a rare swamp antelope [1], [2] found in the Northern Botswana. It is strictly dependent on wetland or swampy habitats [3]. This makes it to be vulnerable to variability in wetlands inundation extent and projected changes in climate. According to [4] the observed and projected changes in global climate present significant challenges and opportunities for society, economies and biodiversity conservation. Furthermore, effects of climate change in the form of extreme weather conditions are already being felt worldwide [5]. As global warming intensifies, countries in moist regions will experience high frequencies of heavy floods and outbreaks of vector-borne diseases and those in the drier tropics and sub-tropics will experience high evapotranspiration rates, low precipitation events, reduced food production, droughts, famines and subsequently massive emigrations of both people and wild animals to other localities [6], [7]. Vulnerable habitats such as wetlands, especially those in arid and semi-arid regions, will face high desiccation rates and possible disappearance from the earth’s surface [8], [9], [10]. As temperatures rise and rainfall pattern changes, plants and animals will respond differently to the changed conditions. Some will attempt to relocate while others will adapt to the new conditions.

Botswana has a network of wetlands and protected areas in the North that provides refuge for semi-aquatic and dryland wildlife. The wetland network areas in Northern Botswana are the Okavango Delta and Linyanti-Chobe wetland system. Moremi Game Reserve and Chobe National Park form a network of protected areas. Any change in the distribution of species in protected areas (including contiguous wildlife management areas) may render the areas less effective in the protection of species for which they were originally established as well as maintenance of biodiversity in general [11].

The Okavango Delta supports a variety of wild animals and plants [12]. Currently, there are 423 Sitatunga individuals in the Okavango Delta. The population has declined by 56-85% in the last two decades [13], [14]. The Delta is the primary habitat for Sitatunga. There are relatively no studies done on the influence of floods on the distribution of the Sitatunga and its habitats in the Okavango Delta. Apart from the annual aerial census done by the Department of Wildlife and National Parks, and recently by Elephant without Borders [14], there are no other ecological data that have been obtained on Sitatunga, especially those that correlate the numbers and distribution with changes in inundation levels over time. The last studies on the species were done by [15] and [16].

Sitatunga is possibly threatened by drying out of its aquatic habitat caused by changes in river flows and climate variability in Northern Botswana. For example, the Sitatunga population along the Upper Kafue on the eastern edge of the Kafue National Park in Zambia was disrupted by the closure of the Itezhi-tezhi dam in the late
1970s, but a healthy population occurs in the Busanga Swamps northwest of the Kafue National Park and adjacent Game Management Areas [17]. Sitatunga species spend most of their time on their own, and all births occur in the dry season [18]. Therefore, extreme changes in climate will potentially affect the birth cycle of the antelope, especially that the dry season in Botswana occurs in winter and this coincides with peak inundation over the Delta from rainfall events in the highlands of Angola. Hence the need to assess the vulnerability of Sitatunga to potential climate changes in the Okavango Delta.

The habitat range for sitatunga in the Okavango Delta is reported to have decreased over the past 100-150 years [15]. It used to include the whole Delta and adjacent areas such as along the Thamalakane River in Maun. Currently, sitatunga occurs only in certain portions of the Okavango Delta especially the panhandle area [13]. The cause of the shrinkage of the sitatunga distribution and habitat is relatively unknown but natural phenomena such as droughts, reduced floods from Angolan highlands, and human activities such as poaching, expansion of settlements and displacement by livestock are the likely drivers of the contraction of the habitats. The high desiccation and increased evapotranspiration rates caused by the El Niño effect could also be increasing total dissolved salts, forcing animals to move to areas with abundant and sweet surface water.

Sitatunga mainly feed on reed plants (Cyperus papyrus) found in the flooded areas of the Delta. Changes in inundation level over the Delta due to climate extreme events, i.e reduced flow, or increased flow would also determine the type of vegetation occurring in the Delta and ultimately the habitat range for sitatunga. Given the projected global climate change, we found it necessary to first interrogate the available data on sitatunga and inundation levels in an effort to avail baseline data to be used for forecasting the behavior of sitatunga populations and distribution over the next 20 years. This will be done in relation to the river flow levels and climate variability over the Okavango Delta. The ultimate goal is to provide information that can inform development of adaptive conservation strategies for the sitatunga and other similar aquatic ungulates in the Okavango Delta and other wetlands in semi-arid regions.

The objectives of this study were (i) to determine trends in the population estimates of sitatunga in the Okavango Delta from 1991-2012 and relate the trends to inundation levels (river flow level) over the same period, with focus on NG/21 and NG/25 which are primary habitats for sitatunga in the Delta.

2. Methods and Materials

2.1 Description of the study area

The study was conducted in the Okavango Delta with special focus on NG/25 and NG/21 in the northern part of the Okavango Delta (Figure 1). A confluence of Cubango and Cuito Rivers between Namibia and Angola just west of the Zambezi Region marks the beginning of the Kavango River, which enters Botswana at Mohembo (Figure 1). Downstream of Mohembo, the Okavango River is confined in a rifted graben in the region known as the panhandle [19]. After flowing through the panhandle, a narrow swamp confined on both sides by high ridges of the Kalahari sand, the river spreads into a delta-shaped system of swamps and distributary channels covering an area of about 22 000 km² [20].

NG/25 and NG/21 respectively occur in the west and east of the area where the Delta begins to spread. They are primary habitats for the sitatunga in the delta with NG 25 supporting not less than 70% of the Delta’s population. At present, there is no human settlement within NG/25. The concession is, however surrounded by three villages (Etsha-1, Tubu, Jao) which are ~15 to 20 km away from the area. The latest human population in these settlements is estimated at 7184 people [21].

Figure 1. Physical Geography of the Okavango Delta showing the study area.
2.2 Data Collection and Analysis

Sitatunga population estimates covering 1991-2012 time period were obtained from the Botswana Government’s Department of Wildlife and National Parks (DWNP) aerial surveys database. As there were some years in which DWNP did not carry out surveys during this period, other census data were obtained from the Jao Concession (with David Kays’s permission) which conducted surveys from 2008 to 2012. The DWNP has divided the country into spatial blocks called the strata to ease coverage, efficiency of the survey, enhance data analysis and interpretation per block. This standardized systematic stratification method was adopted from [22]. Sampling intensity within each stratum depends on wildlife densities with low wildlife densities being flown at wider spacing between transects enabling only 1.8% of the area to be covered and those rich in wildlife such as those in the Okavango Delta being flown at closer transect spacing to enable over 21.6% of the area to be covered. The flights maintain a nominal speed of 90 knots and a height of 300ft (91m) above ground throughout the surveys with the help of radar altimeters. Observers on board the flights are responsible for sighting and calling the species seen and counting the number of individual animals. At the same time the location of the sighting is recorded using an aircraft mounted Global Positioning System (GPS).

The actual sightings recorded are then input into the Botswana Aerial Survey Information System (BASIS, Version II, 2007) program for calculation of the population estimates (and variance) of each species per strata or a combination of strata of interest, following the Jolly’s (1969) [23] method for unequal-sized strata. This program also allows for derivation of population trends and distribution maps for species of interest (DWNP 2012). The surveys are generally done during the dry period to allow for increased visibility.

Aerial surveys by Jao Concession in NG25 also followed the Norton-Griffiths systematic stratified sampling technique and used Jolly (1969) [23] for data analysis. A Cessna 206 aircraft flying at a constant flight height of 106 m (350 ft) above the ground level was used, and belt transects varied between 1.9 and 23.5 km and at 1.4 km apart. The average flying speed (ground speed) during the survey was 185.0 km/hr.

Chase (2013) [14] through his Elephant Without Borders Research Group also conducted census of sitatunga in the Okavango Delta but his estimates and actual numbers were many times higher than those obtained by DWNP and Jao Concession, and were as a result excluded from the analysis. Since Jao Concession provided only the actual numbers sighted, we made use of these numbers by also investigating trends in the actual numbers, with inclusion of actual numbers from surveys done by DWNP from 1991-2012. The estimates and actual numbers observed were each plotted on a line graph and trends established by fitting and selecting a regression model that best described the data with a higher coefficient of determination (R-square).

Flood data for the 1935 -2012 period was obtained from Okavango Delta Information System (ODIS) database based at the Okavango Research Institute. Similarly, a series of regression models were fitted onto it to establish the best model to describe the data.

GPS points were obtained from DWNP and Jao Concession manager. And Visualization for Sitatunga observations was displayed using proportional symbols in ArcGIS 10.2.2 [24]. This shows the concentrations of sitatunga in the Okavango Delta from 1991-2013.

3. Results and Discussions

3.1 Sitatunga population trends in relation to changes in inundation levels

Since 1991, there has been a steady decrease in the sitatunga populations, dropping from over 2233 individuals to only 63 animals in 2012 (Figure 2). A 2-order polynomial regression line fitted well within the data with R$^2$ of 0.82. Other models such as linear and quadratic regression had a lesser R-square, indicating their inadequacy in approximating the real data points. The population recorded in 2012 is a little bit higher than the one for 2007 suggesting a little increase in the number of Sitatunga, but this increase can only be obvious if the next surveys obtain higher values than that of 2012. No counts of animals were done in 2007-2011 and this created a gap in knowing the behaviour of the population in that 5-year period. However, surveys done by Jao Concession in 2008-2011 and 2012 respectively provided actual numbers of sitatunga that were observed.

![Figure 2. Population trend of sitatunga in the Okavango Delta from 1991-2012 (source of data: DWNP 2012).](image)

The actual numbers of Sitatunga observed show a consistent decline from 51 in 1996 to about 13 animals in 2008, and a recovery of the population from about 13 animals in 2010 to 29 in 2011, though there was a drop to...
19 animals in 2012 (Figure 3). In 2012 when there was a decline in the actual numbers of sitatunga sightings, water level in the Delta was the highest in more than three decades, indicating an inverse relationship between highest flood levels and sitatunga population size. The decline in sitatunga population can also be a lag response of this species to the decrease in inundation levels that occurred between 1985 and 1995 (Figure 4).

![Figure 3](image)

**Figure 3.** Actual numbers of sitatunga seen in the Okavango Delta (NG25 and NG21) from 1994-2012. (Source of data: DWNP from 1994-2006; Jao Concessions data from 2008-2012).

![Figure 4](image)

**Figure 4.** An 8-year decade of water levels in the Okavango Delta, as recorded at Mohembo water gauge Station.

In 2007, the Kavango River in Namibia that flows into the Okavango River experienced above normal water levels (Table 1). This followed a period of drought spell in the region from 2002-2006, which also inversely affected sitatunga population as shown in figure 3. The 2010-11 recovery in river flow levels, which is captured in figure 4 coincided with a recovery of sitatunga population in the Okavango Delta. Therefore, sitatunga population in the Okavango Delta responds to inundation levels upon it.

**Table 1.** 2007 water levels in the source rivers for the Okavango and Linyanti-Chobe Rivers in Northern Botswana

<table>
<thead>
<tr>
<th>River</th>
<th>Site</th>
<th>Water level readings [m]</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Zambezi River</td>
<td>Katima Mulilo</td>
<td>Day 05-Feb-2007</td>
<td>One day before 04-Feb-2007</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.59</td>
<td>4.48</td>
</tr>
<tr>
<td>Kwando River</td>
<td>Kongola</td>
<td>2.87</td>
<td>2.88</td>
</tr>
<tr>
<td>Chobe River</td>
<td>Ngoma Gate</td>
<td>No flow</td>
<td>No flow</td>
</tr>
<tr>
<td>Kavango River</td>
<td>Rundu</td>
<td>3.83</td>
<td>3.84</td>
</tr>
</tbody>
</table>

**Source:** Ministry of Agriculture, Water and Forestry-Hydrological Services, Namibia

3.2 Sitatunga habitat range under present climate

Figure 5 shows sitatunga habitat range in the Okavango Delta and its hotspot habitats under current climatic conditions. Places with sitatunga observations of 10 counts or more indicate its occurrence hotspots. Observation areas with values from 5-10 have average to above average sitatunga animal populations. And places with observations from 1-5 have low population densities of sitatunga.

Our results indicate that places around Jao flats in the Okavango Delta are hotspot areas for sitatunga observations, whereas NG25 falls within the average to above average category. NG21 has low densities in terms of sitatunga observations. Other sitatunga animal observations occurred in the Linyanti-Chobe swamp in Northern Botswana (Figure 5). Explanations for high observations of sitatunga at Jao flats could be that the area provides habitat for a stable group of sitatunga, whereas intrasexual competition could have resulted in dispersal of sitatunga at NG25 and NG 21. A similar trend was observed in DRC by [25]. Therefore maintenance of NG25 and NG21 on opposite sides of Moremi Game Reserve is important for dispersal of sitatunga in the Okavango Delta in order to maintain a healthy gene pool of the species.
Extreme flooding is likely to reduce the habitat range for sitatunga as much of it will be occupied by water forcing the animals to stay on the edges of its habitats. This will also make the species to be vulnerable to poachers. Conversely, drying of the Okavango Delta could also mean reduction of suitable habitats for sitatunga and a change in the vegetation structure and availability of food resources for the animals.

Terrestrial ecosystems such as the Okavango Delta are continuously responding to variability in biotic and abiotic influences. Daily and seasonal fluctuations in temperature, humidity and light are obvious characteristics of any natural system, and they define the spatial distribution of biomes and species [26]. The structure and functioning of the Okavango Delta ecosystem is influenced by inundation patterns upon it. However, due to increases in temperature from increased greenhouse gases in the atmosphere [5], the inundation pattern in the Delta is likely to change. Even though ecosystems usually persist through drought years and wet years, climate change extreme events of unusually cold and unusually warm years will have a drastic impact on the structure and functioning of ecosystems throughout the world. It is well documented that extreme climate events will occur over Southern Africa [27]. This includes the whole Okavango River drainage basin, especially in the highlands of Angola where floodwaters for the Delta originates. According to Williamson (1986) [16] sitatunga prefer to be in shade on hot days whereas lechwe seldom do so. This means sitatunga is sensitive to hot weather conditions or heat waves such as the one that occurred in Botswana at the beginning of 2016.

3.3 Policy Implications for Sustainable Management of Sitatunga

The results reveal a time lag response of the Sitatunga population to changes in water levels in the Okavango Delta, suggesting that the changing hydroclimatic conditions may be observed in a few years to come. The response also points to the vulnerability of this semi-aquatic antelope to changes in water levels and other climatic conditions. The potential of NG25 as a prime habitat for Sitatunga should be explored further with the aim to protect the species from disturbance by humans and to allow the animal to move around flooded areas within this wildlife management with ease. The gazettement of NG21 and NG25 as part of a corridor for sitatunga dispersal in the Okavango Delta should be considered as crucial if the animal species has to persist in existence at its present habitat range. Other causes of sitatunga population decline besides changes in inundation levels in the Okavango Delta or the pressures that have accelerated changes in inundation to increase threat to the sitatunga populations have to be taken into consideration to ensure conservation and sustainable management of the species.

4. Conclusion and Future work

Sitatunga population in the Okavango Delta is vulnerable to potential future climate change extreme events. The habitat range for the species will shrink from potential extreme flooding and its food resources will also be affected by possible drying of the Okavango Delta. Geospatial analysis maps depicting spatial and-temporal distribution of sitatunga in relation to water levels over the Okavango Delta are being prepared. These will help to determine areas that are most frequently preferred by sitatunga and to do comparative statistical analysis tests. Ground-truthing exercises will also be conducted to generate quality control data on the species and its habitat. The resultant maps will provide a guide in possible formulation of policy interventions and management strategies needed to conserve sitatunga populations taking into consideration potential future climate extreme events. This could be done through establishment of sitatunga dispersal corridor or sanctuary in the prime habitats of the Delta. Other causes of sitatunga population decline besides changes in inundation levels in the Okavango Delta or the pressures that have accelerated changes in inundation to increase threat to the sitatunga populations will also be researched to inform policy decisions for conservation and sustainable management of the species.
Acknowledgement(s)

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References