ECOLOGICAL CARRYING CAPACITY OF SAANANE ISLAND PROPOSED NATIONAL PARK, MWANZA, TANZANIA

[1]CL Nahonyo and [2]G Sangu

[1]University of Dar es Salaam, Department of Zoology and Wildlife Conservation, P. O. Box 35064, Dar es Salaam, Tanzania,

[2]University of Dar es Salaam, Department of Botany, P. O. Box 35065 Dar es Salaam, Tanzania.

ABSTRACT

The study on ecological carrying capacity of Saanane Island aimed at assessing stocking capacity of the island to provide guidance to the introduction of animals to enhance its ecological value and tourism potential. To evaluate the ecological carrying capacity of the Island, wet and dry season data were collected in 2014 for woody, herbaceous and grass species using PCQ and quadrat methods Wet and dry weights biomass of the forage material was measured to determine dry matter content and are presented as dry weight biomass. Total productivity was 4,280 kg/ha dry weight in wet season which increased to 7,965 kg/ha dry weight in dry season due to absence of disturbance such as limited grazing and fire which is rarely practiced on the Island. Woody species had a total density of 491woody plants ha^{-1}, which was not significant using unpaired two sample t test. This study suggest that the range capability of Saanane Island is 6.76 ha/ animal metabolic requirement (GU) for wet season and 9.125 ha/GU for dry season and thus the productivity of the Island is capable of sustaining 43.5 GU in wet season and 32.2 GU in dry season based on the size of the Island estimated to be 3 km^2.

Key words: *Ecology, Carrying capacity, Saanane Island, forage, herbivore*

INTRODUCTION

The concept of ecological carrying capacity has been contemplated by many authors in different perspectives; for example Bailey (1984) explained in view of species ecology and categorized as economic carrying capacity and ecological carrying capacity (Wang 2010). For wildlife management ecological carrying capacity mean equilibrium of species and environment without the influence of hunting; that means the ecological capacity is decided by the biological resources in the condition that hunting does not exist or the normal hunting has little influence on species existence (Wang 2010). In this study we define ecological carrying capacity from the definition developed by Hudak in (1999) which refers ecological carrying capacity as maximum species held by ecosystem in existing condition. Carrying capacity is thus the number of individuals an environment can support without significant negative impacts to the given organism and its environment. It is an equilibrium point at which the rate of production of edible forage equals the rate at which the forage is consumed by animals **(**Caughley 1979**).** This equilibrium point is also referred to as the saturation density or ecological carrying capacity (Mentis and Duke 1976, Mentis 1977, Caughley 1979, Bell 1986).

Saanane Island is one of the several small Islands in Lake Victoria located about 2 km off Capri point within Mwanza City. The Island was named after a greater Fisher man who lived on the island with his family for years. When he died in 1964 the Government took the island and established the first Government Zoo in Tanzania through Government Notice 567/64 and was managed by the Game Division as a Game sanctuary. The Island has experienced

various land use changes such as agriculture and fishing for Mwanza residents, then government owned zoo where various species of animals such as buffaloes, bushbucks, dik diks, duikers, elands, elephants, impala, reedbucks, black rhinoceroses, topi, warthogs, wildebeest, Burchelli's and Grevy's zebras, patas and vervet monkeys, giraffes, porcupines and crocodiles (Katalihwa 1981) were introduced to the island from different areas to graze and browse freely while dangerous animals species such as buffaloes and rhinos were kept in enclosures. The area became famous and prime tourist attraction where thousands of visitors paid visit every year and generated a lot of revenue. Gradually the status of the zoo deteriorated due to inadequate management and lack of investment. The population of introduced animals started to decline to only few remaining to date.

In 2005 new initiatives from the government emerged to re-establish Saanane game sanctuary with the view to promote into a national park, the process which prompted this assessment. TANAPA intended to know the existing status and potentiality of the Island to accommodate a plan to increase free grazing and browsing animals on the Island; to understand the available biological resources to support the existing animals and potential increase of game through introduction of other game species. Thus, this study intended to determine the ecological carrying capacity of the island to enable Tanzania National Parks determine the species and numbers of herbivores they can introduce on the island in order to develop it for recreation and photographic tourism.

MATERIALS AND METHODS

Description of the study area

Saanane Island is located 2km from the city centre at Capri Point area in the Mwanza Gulf of Lake Victoria. It lies at Latitude 2° 16.5′ and Longitude 32° 27.5′ (Figure 1). Due to various land use changes experienced by the island, the vegetation of the Island has been modified from two types of vegetation grassland and dwarf shrub grassland on the eastern gulf of Mwanza and wooded to bushed grassland on the western gulf zone (Katalihwa 1981); to open grassland, small patches of dry forest characterised by various species of *Ficus natalensis*, *Ficus ingens*, *Ficus cymosa*, *Haplocoelom mombasense* and *Trema orientalis* species. Large part of the rocky hills is covered by *Combretum* woodlands degrading to thicket, and swampy vegetation in areas touching the Lake Victoria. In some few places there are introduced plants such as *Senna siamea*, *Delonix regia*, *Carica papaya* and *Ricinus communis* (Table 1). According to Pratt and Gwynne (1997), the Island experiences a semi-arid climatic condition falling under ecoclimatic zone V. The average annual rainfall is about 800 mm, which falls between December and April/May with dry season from June to November. Daily average temperatures are around 20°C with daily range of 10°C. The annual range of temperature is less than 2°C. The island experiences southwesterly winds blowing from the drylands of central Tanzania.

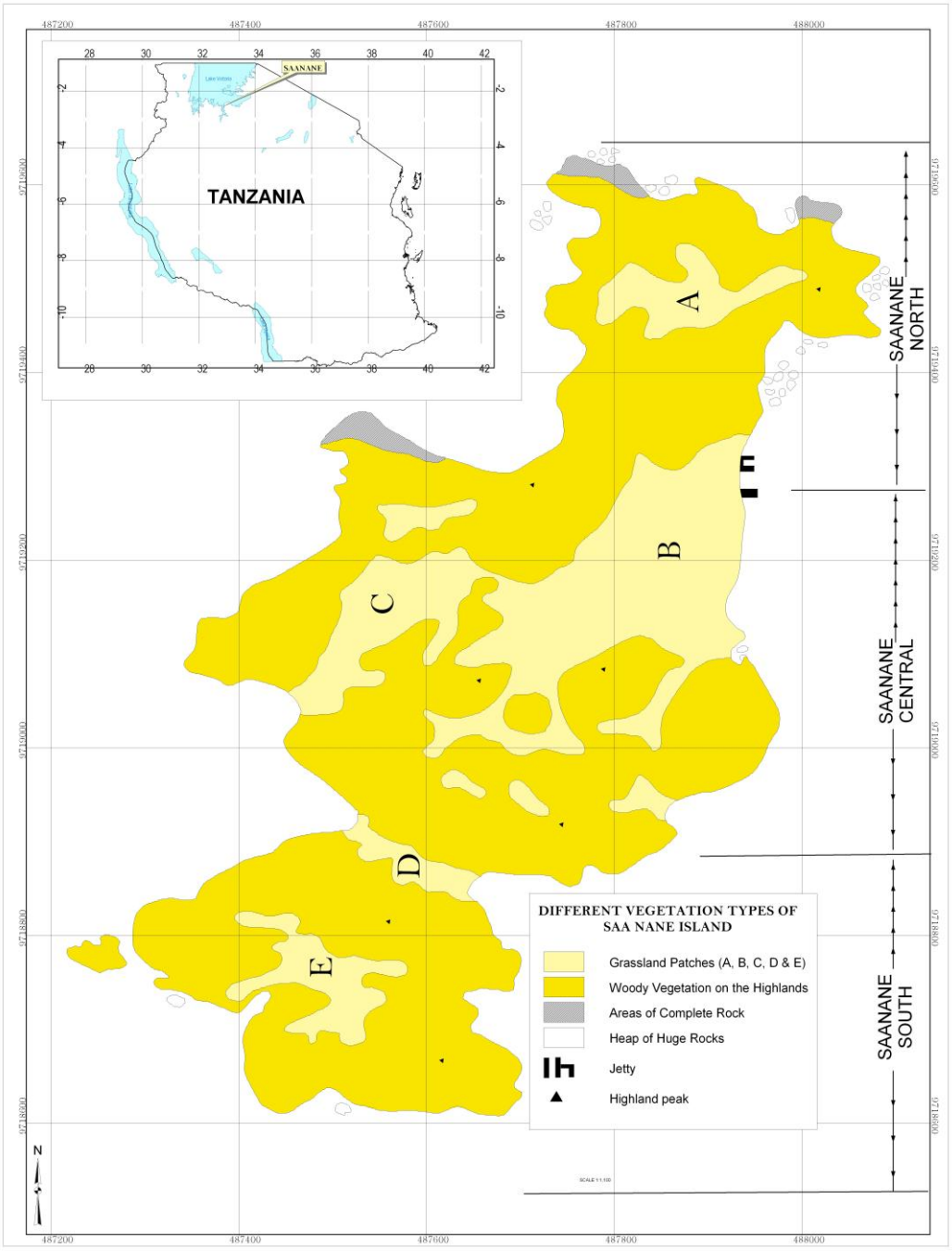

Figure 1: Saanane Island Mwanza, showing vegetation classification and zones

Table 1: Size of areas for different vegetation types in Saanane Island, Mwanza

SN	Vegetation type (see Map above)	Plot No.	Area (km^2)	Area (Hectares)	Percentage of total area
1	Grassland patch A	24 - 38	0.013622	1.3622	2.7
2	Grassland patch B	39 - 43	0.071863	7.1863	14.1
3	Grassland patch C	14 - 23	0.021962	2.1962	4.3
4	Grassland patch D	9 - 13	0.006116	0.6116	1.2
5	Grassland patch E	1 - 8	0.014317	1.4317	2.8
6	Heap of huge rocks	-	0.010564	1.0564	2.1
7	Woody vegetation on the highlands	-	0.364736	36.4736	71.5
8	Areas of complete rock	-	0.007089	0.7089	1.4
	Total	43	0.509991	50.9991	100

Sampling procedures

Prior to sampling a reconnaissance survey was carried to familiarize with the island, describe the vegetation and classify it. The study described and classified vegetation according to Greenway (1973) and White (1983). The description and classification combines physiognomic and floristic criterion including the dominant species in the community.

Samples were collected from stratified systematic sampling covering a total of 8 transects (5 grassland patches and 3 in woody patches) established on the Island. Five transects were established in the grassland patches where one transect cutting across the center of the patch was laid. Grass and herbaceous materials were sampled in 1m x 1 m quadrates that were laid randomly along the transect line. The random location of the quadrates were chosen from folded papers that bared X, Y coordinates representing distance from Zero mark assuming the transect line as a base for Y axis with X axis taken as horizontal distance crossing the Y axis at 90^O degree in either left or right side of the transect line. Data collected from these quadrats were cover abundance for grass and herbs, species composition, height and biomass.

Determining grasses and herbaceous cover abundance

Cover abundance for grasses and herbaceous materials were estimated as percentage coverage of the growing materials within the quadrats in a total of 43 quadrats measuring 1m x 1m selected randomly in the 5 grassland patches present in Saanane Island. Mean percentage cover together with average height were used to estimate the available ground resources for grazers. Similarly within each plot, species composition were determined through identification of all grass and herbaceous species covering the quadrat. The information on species composition was useful in establishing palatable species constituting the patch sampled. Palatability of the species was established from observation of how frequent the species is grazed and scored a value from 0 to 5, with 5 representing a highly palatable species and 0 non palatable. The observation on palatability was complimented by available literatures and expert knowledge of palatable species. Differences in mean percentage cover per patch were compared using Analysis of Variance test to determine if there were any significant differences in abundance among the existing grassland patches on the Island.

Determining grass and herbaceous biomass

Biomass to determine the amount of organic matter per unit area (Kg/ha^{-1}) was conducted by harvesting and weighing grasses and herbaceous material growing within the quadrat. In this method a number of 1m x 1m quadrats representing proportionately each study block was harvested. The grasses and herbs were cut and weighed before drying to obtain wet weight and then oven dried at a controlled temperature of 70^0C and weighed again to obtain dry weight (Smut and Whyte, 1981). Weighing of samples was repeated until series of consecutive readings produced constant values. For more accuracy in terms of palatability and grazing values, the different grass species were stored separately.

Determination of Density of the woody vegetation

Density of the woody species were assessed from 3 transects established in each of the three zones (north, central and south) covered by woody vegetation. In each of the zone PCQ method was applied by establishing one central transect where series of points along the transect line were laid cutting across the zone. The area around each established point was divided into four equal quarters and nearest trees from the center at each quarter was identified and distance, DBH and height measured then averaged across the four quarters to obtain the average distance (*d*) at each sample unit or point. After all points have been measured an average distance ($\bar{x}_d$) is calculated for all samples. From the average distance a mean area (MA) is calculated as follows:

Mean Area (MA) MA (area/plant) = $(\bar{x}_d)^2$

Then density (plants/area) is derived by calculating the inverse of MA

Estimating grazing capacity and stocking rate

In estimating the grazing capacity for the herbivores to be introduced into the island the study established the grass production for both wet and dry seasons. This was done by harvesting a number of 1m x 1m squares proportional to the grassland patch. The grass materials were placed in bags for weighing. The harvested grasses and herbs were oven dried to constant weight in a laboratory at 70^0 C. The dry weight was subtracted from the wet weight to calculate the moisture percentage of the harvested grass. This gave the total dry material of all quadrats. This figure was then converted to production per hectare as per Smit (2005):

$$y = d \div \left[\frac{DM \times f}{r} \right]$$

Where:

y = grazing capacity (ha/GU)

d = number of days in a year (365)

DM = total grass dry material production per hectare.

f = utilization factor, expressed as a Decimal (not all produced material can be used by the animal, therefore, f = 0.3)

r = daily grass DM needed/GU (2.5% of body mass = 4.5kg/day).

GU- is the metabolic equivalent of blue wildebeest (100% grass feeder) with an average mass of 180kg.

Since the different grass species were pooled together, the utilization factor used is f = 0.3 as a mean between palatable and unpalatable species. Examining the grazing capacity is important in order to know the number of animals that can be supported by the grass biomass produced.

Data analysis

Data for cover abundance among the grassland patches were compared using Analysis of Variance to determine significant difference in cover abundance among the five grassland patches of the

Island. Similarly differences in density of wood species among the four zones were compared using Analysis of Variance test. Whereas two sample t test was used to compare density of the woody species obtained in this study and the density reported by (Katalihwa 1981). The significant level was taken at $P < 0.05$ with Duncan multiple comparison test for significant differences.

RESULTS AND DISCUSSION

Grass and herbaceous cover

Grass and herbaceous cover were generally high; Table 2 indicates that all the grassland patches sampled had mean percentage cover above 90.97 ± 2.23 with slight variations among the patches which was found to be insignificant. Among the patches grassland patch D had the highest mean percentage grass and herbaceous cover, whereas grassland patch A had the lowest mean percentage cover. The high values for percentage grass and herbaceous cover reported corresponds with rainy season, which is considered the period of maximum production in most grassland. In East African grasslands high grass cover tend to correlate significantly with rain and soil moisture contents (Boutton et al. 1988).

Table 2: Percentage mean cover and Height for grassland patches on Saanane Island

Grassland patch	Mean % cover	Mean Height
Capri Point –A	91.12 ± 9.94	97.23 ± 54.01
Shamba la Mwanzo – B	92.16 ± 13.03	145.76 ± 58.99
Mungure Site – C	95.89 ± 4.59	118.09 ± 92.01
Shamba la Mamba - D	98.97 ± 2.23	147.15 ± 83.8
Shamba la Mwisho – E	95.20 ± 9.03	74.18 ± 35.10

High grass and herbaceous cover on the island is attributed to fewer disturbances (fire, grazing and cutting). Being a protected area incidences of fire (except controlled if any) are very rare. Grazing on the other hand is currently considered insignificant given the population and diversity of the grazing species found on the island. Only one species of medium sized grazer; Impala with the population of about 9 individuals was recorded on the island. Other herbivores were relatively small browsers and grazers including vervet monkeys, De Brazza's monkeys, and hyraxes while hippopotami are reported to be occasional visitors to the island. Grazing factor alone is likely known to produce a significant reduction in vegetation / species cover on grassland. Han et al. (2008) noted that overgrazing in China were responsible for reduction of plant cover and exposed soil surface. Saanane being a semi-arid Island its primary productivity is largely determined by rainfall and not affected by animal density concurring with Illius and O'Connor (2000) argument.. Thus the productivity in this case can only be limited by rainfall and temperature.

Species composition (richness)

Species composition of the Island is high with woody patches constituting high composition than grassland patches. Results from the survey indicate a total of 72 species belonging to 29 families and 55 genera were identified from the island (Table 3). The most represented family is Graminae followed by Euphorbiaceae, with a total of 18 species in 15 genera and 6 species in 6 genera respectively. The most frequent species in the area are *Digitaria velutina* with 56% index of occurrence followed by *Digitaria milanjiana* and *Cynodon dactylon* with 45% index of occurrence whereas species like *Eleusine indica* was considered

rare. This paper categorized three vegetation growth forms namely grasses, forbs and trees; of the three categories woody species recorded the highest species richness with 30 species followed by forbs 27 species and grasses had 21 species. Table 3 summarises the list of trees, forbs and grass species recorded on the island. In terms of abundance *Ficus natalensis, Ficus ingens, Ficus cymosa,* are the most abundant woody species followed by *Haplocoelom mombasense, Combretum apiculatum Combretum hereroense* and *Phyllanthus guineensis.*

Table 3: Species composition of the Saanane Island, Mwanza

Tress species		**Forbs species**		**Grass species**	
Family	**Species**	**Family**	**Species**	**Family**	**Species**
Mimosaceae	*Acacia brevispica harms*	Rosaceae	*Alchemilla cryptantha* Steud. Ex.A.Rich.	Gramineae	*Aristida edoensis* Hochst.
Bombacaeae	*Adansonia digitata L.*	Commelinaceae	*Anailema pedunculosum* C.B. Clarke.	Gramineae	*Brachiaria brizantha (A.Rich.) Stapf*
Euphorbiaceae	*Acalypha neptunica Müll.Arg.*	Aloaceae	*Aloe flexilifolia* Christian	Gramineae	*Cenchrus ciliaris L.*
Mimosaceae	*Albizia petersiana* (Bolle) Oliv	Compositae	*Bidens pilosa* L.	Gramineae	*Chloris gayana* Kunth
Capparaceae	*Boscia salicifolia* Oliv.	Commelinaceae	*Commelina albescens* Hassk.	Gramineae	*Chloris pycnothrix* Trin.
Capparidaceae	*Capparis erythrocarpus* Isert.	Capparaceae	*Cleome hirta* (Klotzsch) Oliv.	Gramineae	*Cynodon dactylon* (L.)Pers.
Combretaceae	*Combretum apiculatum* Sond.	Papilionaceae	*Crotalaria cleomifolia* Welw.	Cyperaceae	*Cyperus rotundus* L.
Combretaceae	*Combretum hereroense* Schinz	Cucurbitaceae	*Cucumis prophetarum* L.	Gramineae	*Dactyloctenium aegyptium* (L.) Willd.)
Burseraceae	*Commiphora eminii* Engl.	Euphorbiaceae	*Euphorbia hirta* L.	Gramineae	*Digitaria milanjiana* (Rendle) Stapf
Burseraceae	*Commiphora africana* Endl.	Sterculiaceae	*Hermania kirkii*	Gramineae	*Digitaria velutina* (Forssk.) P.Beauv.
Euphorbiaceae	*Euphorbia candelabrum* Kotschy.	Malvaceae	*Hibiscus aethiopicus* L.	Gramineae	*Eragrostis tenuifolia* (A.Rich.) Hochst. Ex Steud

Tress species		**Forbs species**		**Grass species**	
Family	**Species**	**Family**	**Species**	**Family**	**Species**
Moraceae	*Ficus cymosa*	Acanthaceae	*Hypoestes forskaolii* (Vahl) R.Br.	Gramineae	*Eragrostis cilianensis* (All.) Vign.
Moraceae	*Ficus glumosa* (Miq) Del.	Fabaceae	*Indigofera errecta* Hochst.Ex A.Rich.	Gramineae	*Eragrostis ciliaris* (L.) R. Br.
Moraceae	*Ficus ingens* (Miq) Miq.	Fabaceae	*Indigofera hirsuta* L.	Cyperaceae	*Harpchne schimperi*
Moraceae	*Ficus natalensis* Hochst.	Acanthaceae	*Justicia metamensis*	Gramineae	*Hyarrhenia filipendula* (Hochst.) Stapf.
Moraceae	*Ficus sycomorus* L.	Labiatae	*Leonotis nepetifolia* (L.)W.T.Ait.	Gramineae	*Loudetia arundinacea* (Hochst.ex.A.Rich.) Hochst.ex.Steud
Sapindaceae	*Haplocoelum mombasense* Bullock	Polygonaceae	*Oxygonum stuhlmanii* Dammer	Gramineae	*Panicum coensis*
Malvaceae	*Harrisonia abyssinica* Oliv.	Agavaceae	*Sansevieria suffruticosa* Frosty Spears	Gramineae	*Rhynchelytrum repens.* (Willd.)C.E.Hubb
Rubiaceae	*Keetia spinosa*	Papilionaceae	*Tephrosia pumila* (Lam.)Pers	Gramineae	*Setaria homonyma* (Steud.) Chiov.
Annonaceae	*Monanthotaxis caffra* (Sond) Verdc.	Papilionaceae	*Tephrosia villosa* (L.) Pers		
Bignoniaceae	*Markhamia lutea* (Benth.) K. Schum.		*Tridax procumbens* L.		
Ochnaceae	*Ochnaschein furthiana*	Tiliaceae	*Triumfetta annua L.*		
Rubiaceae	*Phyllanthus guineensis* Pax	Compositae	*Vernonia poskeana* Vatke &Hildebrandt		
Sterculiaceae	*Sterculia africana* (Lour.) Fiori.	Papilionaceae	*Vigna frutescens* A.Rich.		
Bombacaceae	*Synadenium glaucescens* Pax				
Euphorbiaceae	*Teclea simplifolia* (Engl.) Engl.				
Euphorbiaceae	*Trema orientalis* (L.) Bl.				
Rubiaceae	*Vangueria*				

Tress species			**Forbs species**		**Grass species**	
Family	**Species**		**Family**	**Species**	**Family**	**Species**
	apiculata K.Schum.					
Verbanaceae	*Vitex fuscheri* Gürke					
TOTAL	**14**	**28**	**16**	**24**	**2**	**19**

Density of the woody vegetation

The result on density of the woody species obtained on the island by our study indicates that densities of the wood plants have relatively increased on the northern and southern zones compared to the density values reported by Katalihwa (1981). This study found that the density of woody species in northern zone is 83 woody plants ha^{-1} whereas the central zone recorded a density of 213 woody plants ha^{-1} and the southern zone had a density of 195 woody plants ha^{-1} making a total density of 491woody plants ha^{-1}. Comparing the density reported by Katalihwa (1981) and the density obtained in our study using unpaired two sample *t* test (t =0.1611, DF=4, P = 0.8798) showed no significant difference between the two findings.

In terms of density per species our study found that *Capparis erythrocarpos, Trema orientalis, Combretum apiculatum, Commiphora eminii, Grewia mollis, Grewia bicolor and Commiphora africana*. as the most dominant species with densities of 46 plants ha^{-1}, 35 plants ha^{-1}, 26 plants ha^{-1}, 19 plants ha^{-1}, 17 plants ha^{-1}, 11 plants ha^{-1} respectively constituting the browsed plant species. In comparison with Katalihwa (1981) findings the composition of the browsed species constituted of *Acalypha fruticosa, Capparis erythrocarpos, Sterculia africana, Vitex fischeri and Haplocoelum mombasense*. With the central and southern woody zones dominated by *Combretum apiculatum* with density of 71 plants ha^{-1} followed by *Synadenium glaucescens* (59 plants ha^{-1}) and *Acacia brevispica* (35 plants ha^{-1}). Contrary to Katalihwa (1981) study, which found that most of the highly browsed species had their canopies within 2 m high, our study found most of the browsed materials having their canopies above 3.5 m high.

The observed changes in terms of total density as well as density per species might be attributed to a number of factors including the age differences between Katalihwa study and our study, disturbance regime such as fire, cutting and cultivation, decline in the population of grazers and browsers on the Island to almost negligible numbers during this study. It is evident that the density of woody species has increased on the Island adding more resources especially for browsers if they were to be introduced on the Island.

Non –wood species

Most of the grass species sampled belonged to the height class 50 – 100cm followed by height class 100 – 150 cm. Figure 2 shows that the height class 50 – 100 cm represented 60% of the species sampled. Of all grassland patches, patch A, and to a lesser extent patch E had more species on the height class 50 – 100; this class included most of the palatable species. On grassland patches B and D the sampled species were mostly on the height class below 50 cm. Grazing was evident probably due to the presence of few grazers apparently one species. Introduction of heavy grazers such as wildebeest, zebra and hartebeest living in association, would possibly shift the non-wood growth characteristics of the island.

Foraging materials in the Island

The foraging materials available in the study area constitute grasses and forbs that can be grazed by grazers and woody vegetation that can be browsed by browsers or mixed feeders. The data presented on grass and herbaceous cover and woody density are the core resources available for the animals inhabiting the Island. This study alone can only provide some indication on grazing and browsing scenarios on the island. The number of species utilising the patches is substantially low compared to the food resources available. It is anticipated that a high diverse of grazers might change the trend in species grazed due to forage preference. Introduction of species that depends on one another relative to feeding habits (feeding facilitation or succession) would play a vital role in enhancing species coexistence.

Figure 3 indicates that the grazing curve is considerably higher than the browser's curve because comparisons were made on the percentage grasses and forbs found on the grasslands. Similarly the lower value on the browser's curve is associated with presence of grazer species (Impala) on the island as opposed to absence of heavy browsers such as Topi on the grasslands. Browser species frequently encountered in the Island were Tree hyraxes found mostly on shrubby thickets surrounding kopjes rather than grassland patches. Similarly their contribution to heavy browsing is relatively low due to probably small body size and selective forage on the browsing materials.

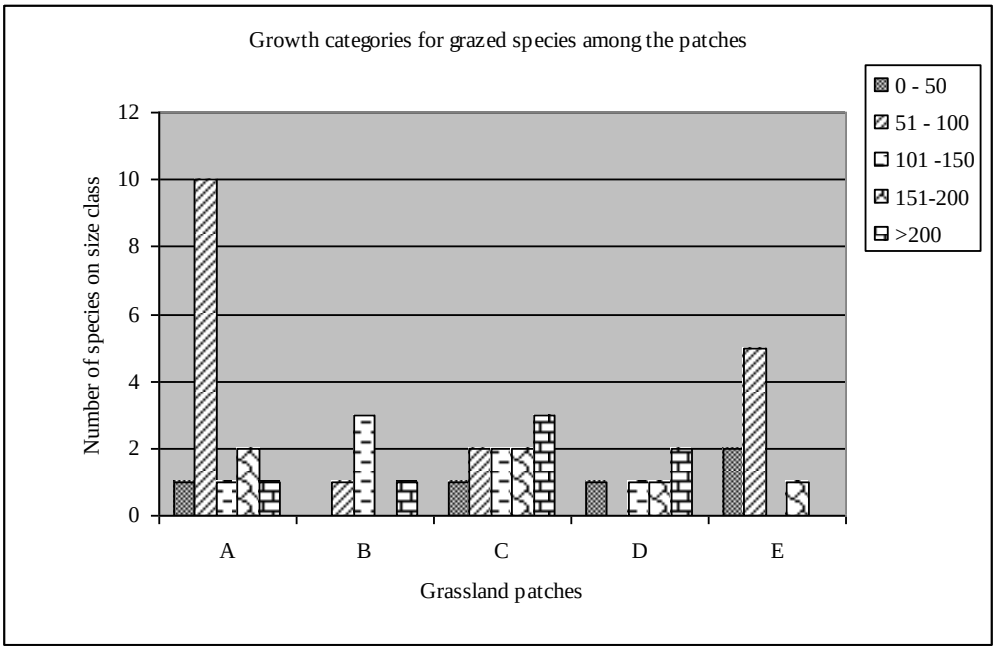

Figure 2: Growth form for non-wood species on Saanane Island, Mwanza.

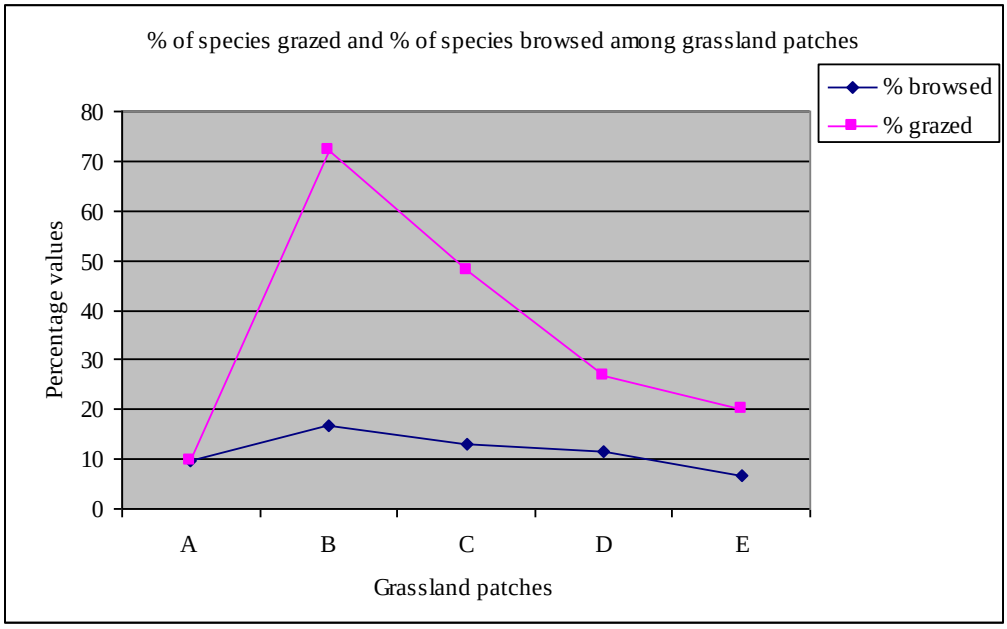

Figure 3: Palatability/ percentage of species grazed and browsed among the grassland patches.

Island vegetation biomass (productivity)

The total productivity of the Island is estimated to 4,280 kg/ha dry weight in wet season which increased to 7,965 kg/ha dry weight in dry season. Increased biomass value in dry season is associated with absence of disturbance such as limited grazing contributed by few grazers inhabiting the Island as well as fire which is rarely practiced on the Island. Although a general trend of increased biomass in dry season can be pointed out, great variation among the patches contributing to total productivity can be seen with highest biomass contribution coming from grassland patches A, B and D. The high productivity particularly live biomass is associated with minimal grazing on the island. Grazing factor by itself has a significant impact on the productivity of the area. Illius and O'Connor (1999) concluded that intensive utilization by herbivores may reduce primary production while increasing the chances of flourishing in coming years of production. It is common for some of the grazed species such as *Themeda triandra* to flourish following grazing or disturbances.

Table 4: Wet season Biomass production on Saanane Island, Mwanza

Sample site	Total Wet weight (kgs)	Mean wet weight (kgs)	Total Dry weight (kgs)	Mean dry weight (kgs)
Capri Point	28.35	1.89	6.341	0.423 ± 2.86
Shamba la Mwanzo	13.00	2.60	2.565	0.513 ± 2.05
Mungure Site	16.75	1.68	4.279	0.428 ± 2.32
Shamba la Mamba	7.50	1.50	1.468	0.294 ± 3.21
Shamba la Mwisho	11.00	1.38	3.751	0.469 ± 3.23

There is a considerable seasonal variation in the productivity of the Island; the mean dry weight however, increased for most of the patches except for two grassland patches of Shamba la Mwisho and Capri Point where the mean values were similar to wet season values (less than 0.5 kg) due to presence of young grasses regenerating after the two patches had been burned before the dry season sampling was conducted. Table 5 shows that, the mean dry weight for grassland patches at Capri Point had dropped from 0.423 ± 2.86 kg in wet seasons to 0.372 ± 0.74 kg: whereas the mean dry weight for Shamba la Mwisho (Butimba) was the same for both wet and dry season. Although large part of Shamba la Mwisho was burned to allow new regeneration of the foliage materials to support animals, the amount of grasses (*Cynodon dactylon*) remaining on the ground produced more or less similar weight with that found in wet season. The increased mean dry weight in dry season was recorded for Shamba la Mwanzo from 0.513 ± 2.05 kg to 1.21 ± 0.35 kg, from 0.428 ± 3.23 kg to 1.26 ± 0.49 kg for Mungure Site and from 0.293 ± 3.24 kg to 1.16 ± 0.42 kg for Shamba la Mamba, respectively.

Table 5: Dry season Biomass production on Saanane Island, Mwanza

Site	Total wet weight in Kg	Mean	Total dry weight in Kg	Mean
Shamba la Mwanzo	13.2	2.5 ± 0.96	6.30	1.21 ± 0.35
Shamba la Mamba	19.5	3.68 ± 1.34	6.17	1.16 ± 0.40
Shamba la Mwisho	10.8	2.05 ± 0.75	3.39	0.46 ± 0.60
Capri Point	8.2	0.72 ± 1.26	4.55	0.37 ± 0.74
Mungure Site	26.8	2.56 ± 0.80	13.84	1.26 ± 0.49

The variations noted in mean dry weight of biomass for the two seasons, affected the values for the grazing capacity. The dry season was found to have greater capacity to support herbivores due to high biomass recorded at the time though the forage was of poor quality due to high percentage of fibrous tissue. These somehow unusual results possibly came about because the wet season sampling was dome too early hence giving small biomass values for the wet season. After this sampling the grasses continued to grow and accumulate mass which was observed during the dry season sampling. This was also possible because most areas on the island remained unburned and relatively ungrazed leaving the graze and browse materials intact.

Grazing Capacity and Stocking capacity

Although the ecological carrying capacity of an area can be estimated; in practice it is not actually the quantity of organisms or animals that will be sustainably supported in a given habitat or geographical area is what matters. In real terms one has to consider about using optimum numbers of individuals due to the fluctuating nature of the habitat quality. In this case the *stocking capacity* concept becomes applicable. This is taken as the number of individuals that can be supported in a habitat even when it is at its most difficult condition in terms of productivity usually in dry season because most of our rangelands productivity is directly proportional to rainfall.

Alternatively stocking capacity can be taken as comprising of 50% of the estimated *ecological carrying capacity*. This then provides allowance for harsh periods the habitat goes through especially in the dry seasons. In determining stocking density a number of parameters such as size of the habitat, type of forage available in terms of quantity and quality, feeding behavior of the animal species and weight of animal species have to be taken into consideration. Other factors like social organization behavior of the species, soil characteristics, land scape and terrain of the area are important as well.

Critical to this paper is the available biomass and weight of the animal species to be supported by available island productivity. Energy and dry matter intake (DMI) of animals is proportional to body weight. Larger animals usually require more food to maintain their metabolic processes than animals with small body weight. When considering introduction or maintaining animals in an area the total live biomass of the herbivores is an important factor in knowing whether the animals can be sustainably supported on available biomass or not. The density of animals per unit area is an important indicator of the herbivore biomass present. Current studies suggest that the range capability of Saanane Island is 6.76 ha/GU for wet season and 9.125 ha/GU for dry season, respectively.

This study therefore suggest that the range capability of Saanane Island is 6.76 ha/GU (animal metabolic requirement) for wet season and 9.125 ha/GU for dry season, respectively. Increase in range capability for the dry season is due to the fact that during dry season the forage quantity and quality tends to decline such that to sustain the animal metabolic requirement (GU) the range size has to increase relatively to the wet season range size. Given that 1 GU = 180 kgs of live herbivore body mass it means that 6.76 ha are needed to support 180 kgs of live herbivore body weight for a year for wet season and 9.125 ha for dry season respectively. Considering that the Saanane is 3.0 km^2 in size and taking into account that at least 96% of the island comprises of woody vegetation and grassland (forage materials) this is equivalent to 294 ha of range land.

Thus during wet season the Island range capability can sustain 43.5 GU whereas in dry season the Island range capability can sustain 32.2 GU. This means the total live weight of all animals that can be supported on the island should roughly not exceed 5,796 kgs, which represent acritical capacity during dry season. The interpretation of this data should consider that some areas on the island are not accessible by the animals hence are not utilised that means range utilization is rather localised in certain areas only. Similarly, when other factors such as available forage in terms of quantity and quality, feeding behavior of the animal species and weight of animal species and social organization behavior of the species are considered the real stocking capacity might decline slightly below the presented values.

CONCLUSION

Considering the size of the Saanane Island (c. 3 km^2) as adopted from the total size of Saanane and considering that at least 96% equivalent to 294 ha of the island is covered by woody and grassland vegetation, the total productivity of the Island is estimated to be 4,280 kg/ha and 7,951kg/ha for wet and dry season respectively. From the total productivity our study suggest that the range capability of Saanane Island is 6.76 ha/GU for wet season and 9.125 ha/GU for dry season, respectively. Thus during wet season the Island range capability can sustain 43.5 GU whereas in dry season the Island range capability can sustain 32.2 GU. This means the total live weight of all animals that can be supported on the island should roughly

not exceed 5,796 kgs, which represent acritical capacity during dry season. The interpretation of this data should consider that some areas on the island are not accessible by the animals therefore utilization is rather localised in certain areas only. The island though small has all the potentials of being developed into a flourishing wildlife park due its rich habitat varieties, diverse forage species of both grasses and browse material. However, the potential of the island to support herbivores will be enhanced by habitat management and opening connectivity routes to allow animals move freely in all the habitats on the island. Previous studies also found the island to be both ecologically and economically viable as a wildlife area.

ACKNOWLEDGEMENTS

We thank the Tanzania National Parks (TANAPA) for funding this research and Chief Park Warden and Ecologist of Saanane proposed National Park for logistical support and all the staffs who participated in the field work.

REFERENCES

Bell RHV 1986 Carrying capacity and off-take quotas. In: R.H.V. Bell and E. McShane-Caluzi (eds*) Conservation and Wildlife Management in Africa.* U.S. Peace Corps, Washington D.C.

Boutton TW, Tieszen L L and Imbamba, SK 1988 Seasonal changes in the nutrient content of East Africa Grassland vegetation. *Afr. J. Ecol*. **26**: 103- 115.

Caughley G 1979 What is this thing called carrying capacity? In: MS Boyce and LD Hayden-Wing (eds.) *North American Elk: Ecology, Behaviour and Management.* University of Wyoming, Lamarie.

Greenway PJ 1973 A classification of the vegetation of East Africa. *Kirkia*, **9**: 1-68.

Han JG, Zhang YJ, Wang CJ, Bai WM, Wang YR, Han GD and Li LH 2008 Rangeland degradation and restoration management in China. *Th. Rang. J*. **30**: 233–239.

Hudak TA 1999 Rangeland Mismanagement in South Africa: Failure to Apply Ecological Knowledge. *Hum. Ecol.* **27**(1):55-78.

Illius AW and O'Connor TG 2000 Resource heterogeneity and ungulate population dynamics. – *Oikos* **89**: 283–294**.**

Illius AW and O'Connor T G 1999 On the relevance of nonequilibrium concepts to semi-arid grazing systems. *Ecol. Appl.* **9**: 798–813.

Kaboni EL and Rweyemamu F 2006 *Soil condition and productivity potential for pasture and trees in the Saa nane Island Game Reserve, Mwanza-Tanzania.* Lake Zone Agricultural Research and Development Institute.

Katalihwa M 1981 *Wild Animals in Captivity in Tanzania: with special reference to Saa Nane Island Zoo*. MSc Thesis, University of Dar es Salaam.

Mentis MT 1977 Stocking rates and carrying capacity for ungulates on African Rangelands. *S. Afr. J. Wildl. Res.* **7**:89-98.

Mentis MT and Duke RR 1976 Carrying Capacity of Natural veld in Natal for Large wild herbivores *Afri. J. Wildl. Res.* **7**: 89-98.

O' Connor TG 1999 On non-equilibrium in arid and semi-arid grazing systems. *J. Biogeogr*. **29**: 1595-1618.

Pratt DJ and Gwynne HD 1997 *Rangeland Management and Ecology in East Africa*. Hodder and Stoughton.

Sayre NF 2007 Carrying Capacity: Genesis, History and Conceptual Flaws. Prepared for the Environmental Politics Colloquium, 26 January 2007, Berkeley University. 1-35. Available at: http://globetrotter.berkeley.edu/bwep/colloquium/papers/Sayre2007.pdf. Source:

Michigan Department of Natural Resources website (http://www.michigandnr.com/publications/pdfs/wildlife/viewingguide/images/eco_carrycapacity.jpg. Accessed 28th September 2017.

Smit N 2005 Calculating your land's game carrying capacity. Game and environment. *Farmers Weekly: 45-46.* http://www.wildliferanching.com/content/grazing-capacity-game. Accessed 28th September 2017.

Smuts GL and Whyte PO 1981 Relationships between reproduction and environment in the hippopotamus *(Hippopotamus amphibious)* in Kruger National Park. *Koedoe* **24**:169-185.

White F 1983 *The vegetation of Africa*. The descriptive memoir to accompany the UNESCO/ AETFAT/UNSO vegetation Map of Africa. UNESCO, Paris France.

Sinclair ARE and Duncan P 1972 Indices of condition in tropical ruminants. *E. Afri. Wildl. J.* **10**: *143-149.*

Wang X 2010 Research Review of the Ecological Carrying Capacity. *J. Sust. Dev*. **3**:3

White RJ 1987 Big Game Ranching in the United States. Wild sheep and Goat International, New Mexico.