International Journal of Biodiversity and Conservation

Volume 7 Number 9, September 2015
ISSN 2141-243X

Academic Journals

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International Journal of Biodiversity and Conservation

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Vol. 7(9), pp. 388-393, September, 2015
DOI: 10.5897/IJBC2015.0845
Article Number : 5E634A554900
ISSN 2141-243X

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International Journal of Biodiversity and Conservation

Full Length Research Paper

The dinoflagellate genera *Ornithocercus* Stein, *Podolampas* Stein and *Pyrocystis* Murray from the Grand-Lahou lagoon complex, Côte d'ivoire

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Received 22 April, 2015; Accepted 11 August, 2015

The present paper reports 8 species of the dinoflagellate genera *Ornithocercus* Stein, *Podolampas* Stein and *Pyrocystis* Murray from the Grand-Lahou lagoon complex. For *Ornithocercus* and *Podolampas* genera, dichotomous key for identification of species is presented. Diagnostic descriptions, illustrations and geographic distribution are provided for all taxa. Most species were neritic or neritic-oceanic and tropical or sub-tropical in nature which is indicative of the area of study. New distribution records (*Podolampas elegans* Schütt and *Pyrocystis robusta* Kofoid) for the Côte d'Ivoire part of the Gulf of Guinea originated mainly from an oceanographic station (Station 2: Grau of Lahou) situated further from the coastline.

Key words: Côte d'Ivoire, dinoflagellates, Grand-Lahou lagoon complex.

INTRODUCTION

Dinophyceae commonly called dinoflagellates constitute a very important group of marine phytoplankton. It's comprised of various species in terms of habitat and nutrient uptake. These species contribute to primary production in oceans and include diverse tropical species reported in many waters worldwide (Kim et al., 2013).

Significant works on the taxonomy and ecology of marine Dinophyceae have been carried out in many countries like: Japan, Germany, U. S. A., Eastern Africa etc (Sournia, 1967). In Côte d'Ivoire, there have been few studies on phytoplankton taxonomy, species composition and distribution including the dinoflagellate genera *Ornithocercus* Stein, *Podolampas* Stein and *Pyrocystis* Murray (Reyssac, 1970; Dandonneau, 1971; Dufourand Durand, 1982; Couté and Iltis, 1985; Dufour, 1994; Komoé et al., 2014).

Unfortunately no thorough systematic studies have been carried out along the Côte d'Ivoire seaboard. Taking into account the above lack of information, the following work was carried out on the Grand-Lahou lagoon complex water near the Atlantic Ocean. The main objective of this study is to provide a taxonomic and floristic account of species from genera *Ornithocercus*, *Podolampas* and *Pyrocystis* occurring in Grand-Lahou

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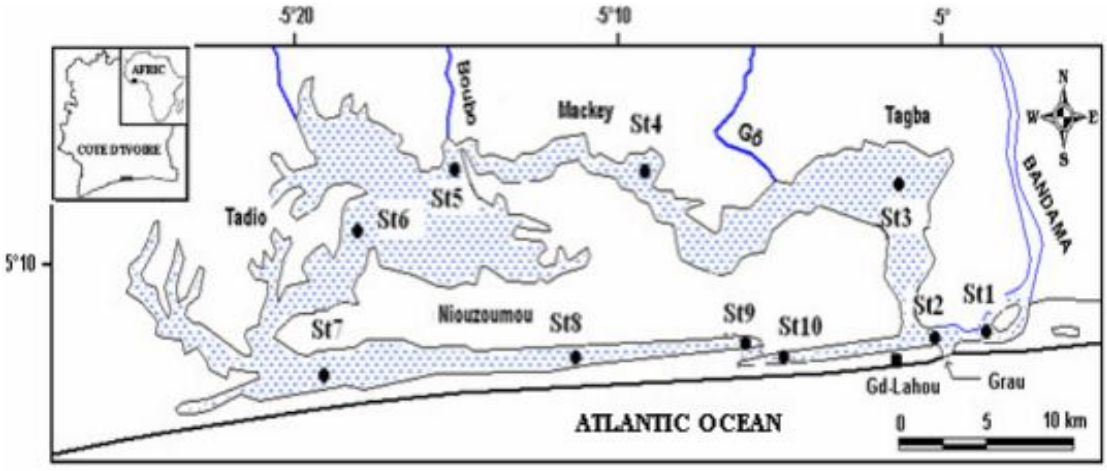

Figure 1. Map of the study area, showing the sampling stations (St).

Table 1. Sampling sites (stations) in the Grand-Lahou Complex, July 2004 to June 2006.

Station	Location	Geographic coordinates
St1	Channel of the Bandama river	5°08'47.9''N, 4°59'19.3'' W
St2	Grau of Lahou	5°08'17.3'' N, 5°00'16.9'' W
St3	Tagba	5°11'28.4'' N, 5°04'09.9'' W
St4	Mackey village	5°11'56.5'' N, 5°09'02.5'' W
St5	Channel of Boubo river	5°12'39.6'' N, 5°14'23.6'' W
St6	Ebounou	5°08'02.3'' N, 5°12'34.9'' W
St7	Badadon	5°07'39.5'' N, 5°17'58.2'' W
St8	Coco village	5°08'15.3'' N, 5°09'04.6'' W
St9	Factory of Sicor	5°08'32.9'' N, 5°05'11.1'' W
St10	Groguida	5°08'11.3'' N, 5°04'49.3'' W

lagoon complex water.

MATERIALS AND METHODS

Grand Lahou lagoon (5°, 07-5°, 14 N, 4°-5°, 25W, 190 km^2, mean depth of ca. 3 m) spreads on about 50 km along the Gulf of Guinea coastline (Lecolle, 1971). It comprises of four basins (Lae, 1982) (Figure 1). The Tadio lagoon (90 km^2, 2-3 m in maximum depth) is the large stone. It undergoes the influence of a small forest river (Boubo) having two floods in May-July and October-November, the former one being the most important.

The Niouzoumou lagoon (15 km^2, 3 m in maximum depth) is a narrow basin parallel to the coastline. It is enclosed and sheltered on the superior strand of a 3,000 ha coconut agro-industrial plantation. The Mackey lagoon (28 km^2), the shallowest basin (2 m in maximum depth) joins the Tadio and Tagba lagoons. The Tagba lagoon (57 km^2) located at the eastern extremity has an average depth of 3 m, but its depth can reach 8 m at the level and near the channel. It communicates directly with the sea by the only outlet of the complex, the Grand-Lahou channel, and receives water inputs of the Bandama river during the unique floods occurring in October-November (N'doua et al., 2009).

The phytoplankton samples for taxonomy studies were collected during the period from July 2004 through June 2006 with 20 µm mesh plankton net by vertical tows in the centre of the stream at every sampling station (Table 1). Samples were transferred into plastic vessel (40 ml) and fixed with 40% formalin buffered with borax to a final concentration of 5% (Throndsen, 1978).

Observations were carried out using an Olympus CX31 microscope, equipped with a digital camera. The identification and distribution of the species were based on the research done by Abé (1967a, 1967b), Saifullah et al. (2008), Okolodkov (2010) and others.

RESULTS

The pH values varied between 6.63 and 9.23; surface temperature varied between 17.25 and 30.43°C and the conductivity between 0.5 and 41.64 mS cm^{-1}. The surface salinity varied between 0. 25 and 26.95‰. Nitrates and phosphates values varied from 0.31 to 17.94 mg L^{-1} and from 0.07 mg L^{-1} to 2.24 mg L^{-1}, respectively.

Taxonomic remarks: The different species observed are

described alphabetically. Rule scale bars in illustrations represent 20 µm. New taxa to the algal flora of Côte d'Ivoire are designated with one asterisk (*).

Genus *Ornithocercus* Stein

Key to the identified species of genus *Ornithocercus* Stein
1. Left sulcal list quadrate shaped……*O. quadratus*
1. Left sulcal list not quadrate shaped…….2
2. Left sulcal list with 3 lobes……*O. magnificus*
2. Left sulcal list with more than 3 lobes:
3. All ribs ending at lobes……..*O. steinii*
3. All ribs not ending at lobes……*O. thumii*

***Ornithocercus quadratus* Schütt (Figure 2a)**

References: Taylor et al. (2008, pp. 410-411), Figure 2d; Okolodkov (2010, p. 38, pl.4 Figure 9).
Description: Cells bodies are large, suboval, slightly deeper than long, with the epitheca markedly displaced to the ventral side. Cingulum is dorsally excavated and distinctly wider than ventrally.
Size: 45 x 37 µm (Station 2).
Distribution: Oceanic; warm temperate to tropical waters; worldwide distribution.

***Ornithocerus magnificus* Stein (Figure 2b)**

References: Okolodkov (2010), p. 46, pl.5 (Figures 1 to 3).
Description: Cells bodies are relatively small, subcircular in lateral view, slightly asymmetrical in relation to the longitudinal axis, directed from the posterior dorsal end to anterior ventral end. The girdle list is very large with a spreading anterior skirt-like wing. The sulcal list is supported by radial ribs. The girdle list characterizes a convex and concave outline compared to other *Ornithocercus* species. Well known as a tropical planktonic species indicator.
Size: Length 88-100 µm (Station 2).
Distribution: Oceanic; cosmopolitan in warm temperate to tropical waters.

***Ornithocercus steinii* Schütt (Figure 2c)**

References: Okolodkov (2010, p 46, pl.5 Figure 4).
Description: Girdle list is supported by rigid ribs. Sulcal list has several radial ribs with round outline.
Size: Length 116-166 µm, width 111-123 µm. Stations 2, 10
Distribution: Oceanic; cosmopolitan in warm temperate to tropical waters.

***Ornithocercus thumii* (Schmidt) Kofoid and Skogsberg (Figure 2d and e)**

References: Okolodkov (2010, p. 46, pl.5 Figure 6).
Description: Girdle list spreads anteriorly like a skirt and the sulcus is supported by ribs with regular intervals. The outline of sulcal list is distinctively divided into three parts. The left dorsal hypothecal plate is, on the contrary, much simpler in its structure as illustrated in Figure 2e, in which the anterior ventral hypothecal plate is lost, leaving a corresponding broad but shallow dent at the anteroventral portion of the thecal plate.
Size of cell body: 48 x 40 µm, width 50 µm (Station 2).
Distribution: Neritic/oceanic species; tropical species; worldwide distribution

Genus *Podolampas* Stein

Key to the identified species of genus *Podolampas* Stein
1. Antapicalspines almost equal ----------*P. bipes*
1. Antapical spines not almost equal:
2. Spines with wings and wings connected----------*P. elegans*
2. Spines are winged and not connected ----------

***Podolampas bipes* Stein (Figure 3a)**

References**:** Taylor (1987, pp 58-59), Figure 2.16d; Sadaf and Muhammad (2014), p 95 (Figure 3a).
Description: The genus is characterized by the presence of a distinct apical horn ending in an apical pore and is generally pyriform in shape bearing two antapical spines. Cell looks like a slightly depressed chestnut. Epitheca is triangular, ending in two equal antapical spines. Hypotheca is half spherical form, with two left and right wing-like structures with sharp and strong spines at the antapical end.
Size: Length 100-115 µm, width 95 µm. Station 2.
Distribution: Oceanic; warm temperate to tropical waters; worldwide distribution.

***Podolampas elegans* Schütt (Figure 3b)**

References: Schiller (1937, p. 475, Figure 546).
The species is characterized by a bilaterally bulged midbody, the elongated conical apical horn and a low but uninterrupted antapical wing. This antapical wing consists of two median side-wings of the two antapical appendages which distinctly diverge distally and have rather a greater length as compared to the body length. More divergent, right antapical spine appears shorter than left.

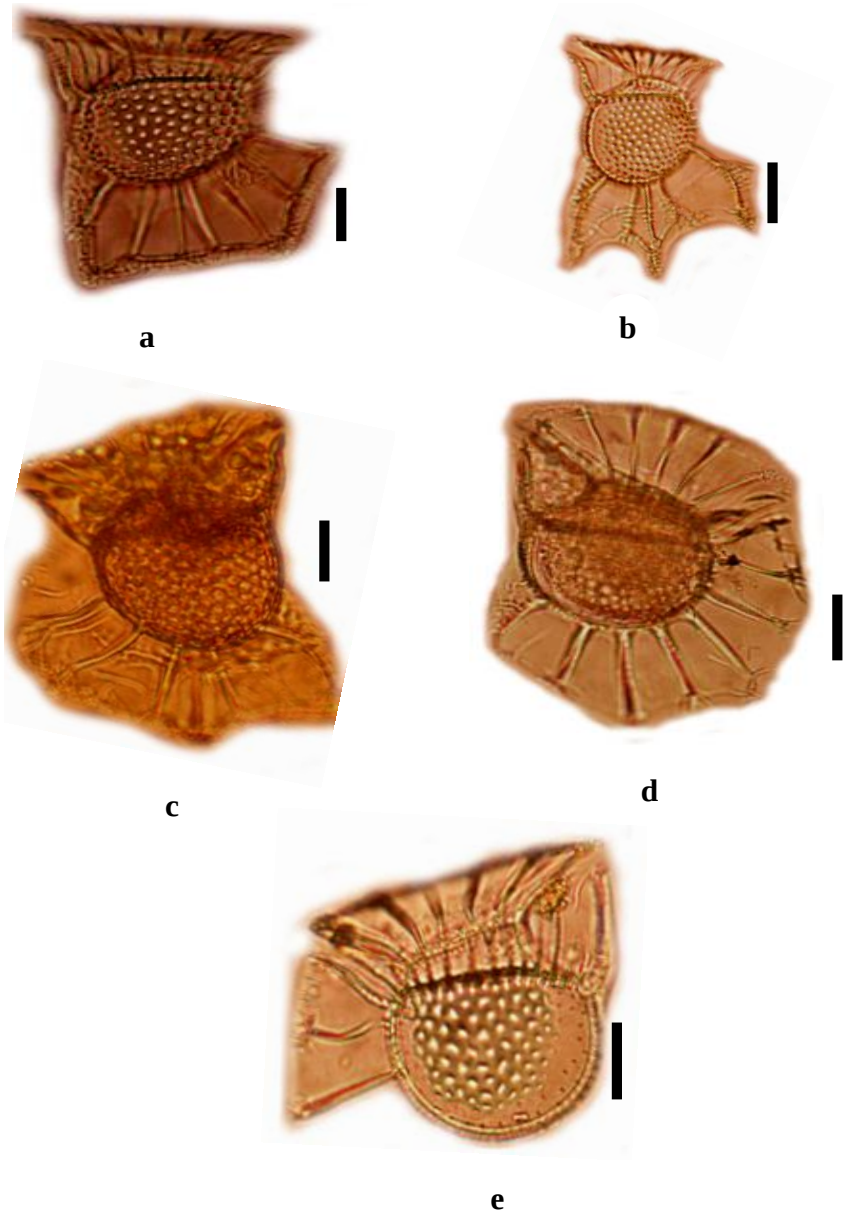

Figure 2. Lateral view of entire body (a) *Ornithocercus quadrates* Schütt (b) *Ornithocerus magnificus* Stein (c) *Ornithocercus steinii* Schütt (d & e) *Ornithocercus thumii* (Schmidt) Kofoid and Skogsberg. Scale bar 20 µm.

Size: Length 80-100 µm, width 55-80 µm (Stations 2 and 10).
Distribution: Oceanic; subtropical to tropical waters; worldwide distribution.

***Podolampas palmipes* Stein (Figure 3c)**

References: Sadaf and Muhammad 2014, p 95, Figure 3C1, C2
Description: Cell pyriform, narrow, ending in two unequal antapical spines. The epitheca is drawn out into a long, slender neck. The right-hand spine is much shorter than the left antapical spine.
Size: Length 60 µm, width 20 µm (Station 2).
Distribution: Oceanic; warm temperate to tropical waters; worldwide distribution.

****Pyrocystis robusta* Kofoid (Figure 3d)**

References: Sadaf and Saifullah (2009), p 3214, Figure 5.

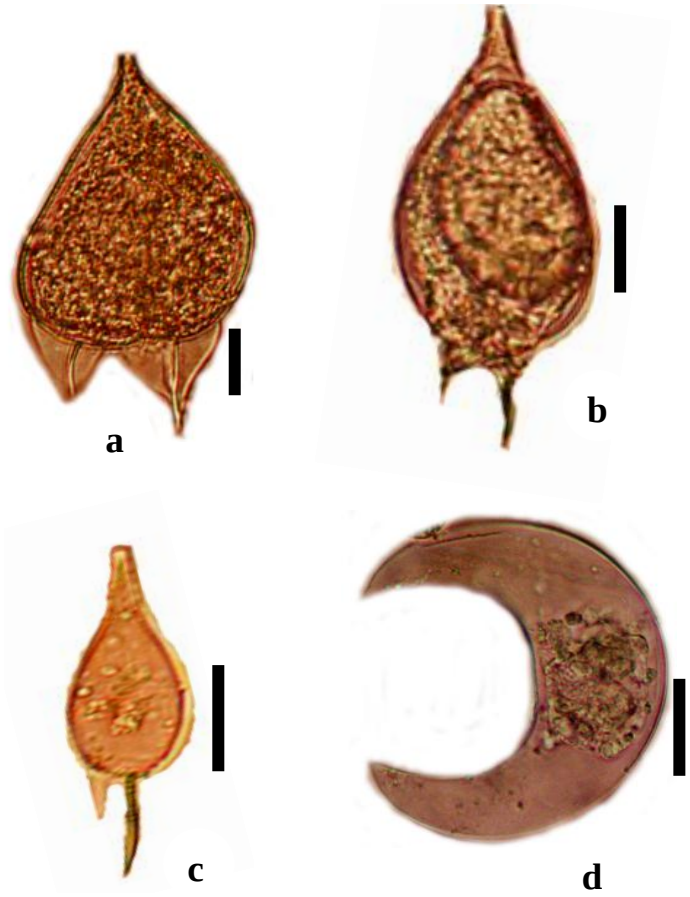

Figure 3. Lateral view of entire body *of* (a) *Podolampas bipes* Stein (b) *Podolampas elegans* Schütt (c) *Podolampas palmipes* Stein (d) *Pyrocystis robusta* Kofoid. Scale bar 20 µm.

Description: This species is lunate in form with jelly-like cyst body. Cytoplasm is located in the center of the cyst. Similar to *P. lunula* but relatively small.
Size: Length 90-125 µm. Station 2.
Distribution: Oceanic; warm temperate to tropical waters; worldwide distribution

DISCUSSION

In addition to the species illustrated in the present study, Reyssac (1970) reported *Ornithocerus magnificus* Stein, *Ornithocercus quadratus* Schütt, *Ornithocercus steinii* Schütt, *Ornithocercus thumii, Podolampas bipes* Stein and *Podolampas palmipes* Stein from the Atlantic Ocean water (in total, 158 species of the order Dinophysiales).

Dandonneau (1971) mentioned 18 Dinophysiales species including *Ornithocerus magnificus* Stein, *Ornithocercus quadratus* Schütt, *Ornithocercus steinii* Schütt and *Podolampas palmipes* Stein. Couté and Iltis (1985) reported *Ornithocerus magnificus* Stein from Ebrié lagoon. It should be noted that systematic studies on the lagoon and marine environments are rare in Côte d'Ivoire.

The genus *Podolampas* is a pear shaped cell with an apical horn and 1 or 2 antapical spines (Burns and Mitchell, 1982). *Podolampas bipes* (Figure 3a) is recognized by relatively strong antapical spines with accessory lists which have smooth margins. *Podolampas palmipes* is relatively more slender than *P. bipes* and *P. elegans*. Dinoflagellates occur preferably in the tropical water (Taylor, 1987), hence a greater proportion of the species in the study area were tropical or subtropical in nature. Most species described in the present study were inventoried during the long dry season (December to March), during which period, the marine waters invade the lagoon waters and during the short dry season (August).

Indeed, August is the period of upwelling in the ocean, so we are witnessing has a nutrient recovery that cause algal blooms. The intrusion of seawater in the lagoon complex would explain the presence of species in the

samples taken.

Most of the works cited in the present study are related to ecological studies except for Couté and Iltis (1985) who conducted systematic studies. The new records (*Podolampas elegans* Schütt and *Pyrocystis robusta* Kofoid) for the Côte d'Ivoire part of the Gulf of Guinea originated mainly from an oceanographic station (Station 2: Grau of Lahou) situated further from the coastline.

Conflict of interest

Authors did not declare any conflict of interest.

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academicJournals

Vol. 7(9), pp. 394-407, September, 2015
DOI: 10.5897/IJBC2015.0837
Article Number: D5BC90D54910
ISSN 2141-243X

http://www.academicjournals.org/IJBC

International Journal of Biodiversity and Conservation

Full Length Research Paper

Will Ngorongoro Conservation Area remain a world heritage site amidst increasing human footprint?

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Received 25 March, 2015; Accepted 11 August, 2015

The Ngorongoro Conservation Area (NCA) is a World's Heritage site and Biosphere Reserve in Tanzania. It is the only protected area with multiple land use where both wildlife conservation and limited human activities are allowed. Despite such an important status, the area is experiencing ecosystem changes resulting from increasing human population, diversified livelihoods and tourism activities. This study was conducted to determine the trends and challenges of livelihood activities of the local Maasai and tourism in NCA and their implications on the ecology of the area. Household questionnaire interviews, key informant interviews, focus group discussions, direct field observations and secondary data reviews were applied. A total of 145 people from Enduleni, Oloirobi villages and the NCA Authority (NCAA) were involved in the study. To complement the socio-economic data, landsat MSS satellite images of 1990, 2000 and 2013 blocks were analysed to assess land use/cover changes occurring in the study area. Results indicate rapid human population growth rate of 5.6% and an increment of 1.1% of livestock population per annum. It is also noted that about 46% of cropland has increased in the studied villages. Furthermore, the Maasai who were historically pastoralists are changing to agro-pastoralists. The grasslands and other natural forests showed a decreasing trend. The decreasing trends in wildlife are being associated with the changing vegetation characteristics among other factors. Despite the ecological changes, the Maasai have remained uncomfortable with the restrictions over land use so far implemented by the NCAA. In addition, there has been an increasing number of tourists and facility development within the NCA. There were also differing views between the Maasai and NCAA, which might put the NCA ecosystem under serious threats questioning its future. Whether or not the NCA will remain a world heritage site depends on management measures taken, otherwise the disappearance of the NCA ecosystem is imminent.

Key words: NCA, NCAA, world heritage site, tourism, ecosystem change, human population, diversified livelihoods.

INTRODUCTION

The contemporary processes of land use change and livelihood diversifications have been a result of local communities abandoning their traditional lives (Mundia and Murayama, 2009). Thus, in the process of improving

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their quality of life local communities are able to choose what they will keep and what they will discard of their traditional ways (Riemer and Kelder, 2008). Expecting indigenous people to retain traditional, low-impact patterns on resource use can be denying them of the right to grow and change in ways compatible with the rest of humanity (Riemer and Kelder, 2008). However, if not well organized, land use changes and livelihood diversification will have detrimental effects on the ecosystem that the community and wild animal depends on (Homewood et al., 2001). For instance, farmers and pastoralists were traditionally perceived as the primary causes of environmental degradation but currently political, institutional and structural factors are recognized as being equally important factors that fuel the problem (Nelson, 2009). The spread of cultivation and establishment of commercial agriculture in formerly subsistence agricultural and pastoralist areas contradict with the national and international society's interests in conservation of biodiversity (Mvungi, 2007). The technologies in use determine the extent to which human activities damage or sustain the environment and the amount of waste associated with any level of consumption (Mlengeya and Lyaruu, 2005). Furthermore, increasing agricultural practices in the protected areas or in areas adjacent to those are likely to have reduced the size of the grazing areas for both wild animals and livestock. The implication of this change is that pastoralists can no longer subsist on pastoralism due to scarcity of pasture and competition for grazing land and water thus resulting in livelihood diversification.

Tanzania is endowed with the richest wildlife areas in East Africa and the world at large (Goldman 2003). It is among the countries in Africa with a large percentage of land under protection. So far, the country has set aside about 43.7% of its land under some form of protection, which is under state control and largely prohibit human settlement (among which 28% is wildlife protected areas including Game Controlled Areas and 15.7% forest reserves; VPO/DE 2009). This is probably one of the highest percentages of land set aside for conservation in the world. Protected areas in Tanzania have been increasing in number and almost 80% of these areas were gazetted after independence (Neumann, 1995) thus reflecting the principles of the Arusha Manifesto that Julius Nyerere, the first president of Tanzania laid out on the importance of wildlife conservation. The increasing number of protected areas in Tanzania further relates to the importance of tourism that is contributing about 17.2% of national GDP by 2014 (World Travel and Tourism Council, 2014). To date, the tourism industry has been relying primarily on wildlife resources as the major attraction, with up to 90% of all tourists taking part in game viewing or hunting safaris (Nelson, 2007). Noteworthy, the increasing protection of the Tanzanian natural resources has not been without some associated challenges. The Ngorongoro Conservation Area was established under the NCA Ordinance No. 413 of 1959 as a multiple land use area, where both wildlife conservation and limited human development are allowed (Olenasha et al., 2001). The principal land uses allowed in the area include conservation of natural resources, traditional Maasai livestock grazing, and tourism (Niboye, 2010). The Ngorongoro Conservation Area (NCA) is recognised globally as a World Heritage Site (WHS).

The convention concerning the protection of the world cultural and natural heritage (the World Heritage Convention) was adopted by the United Nations Education, Scientific and Cultural Organisation (UNESCO) General Conference at its 17th session in Paris on 16 November 1972. UNESCO encourages the identification, protection and preservation of cultural and natural heritage around the world considered to be of outstanding value to humanity. By regarding heritage as both cultural and natural, the convention demonstrates the dynamic relationship between people and with nature and stresses "the fundamental need to preserve the balance between the two" (www.whc.unesco.org). By agreeing to set aside such areas, the State Parties thus agree to take all the necessary measures to preserve the resources for the good of human kind in the world and also agree that world heritage sites belong to all the people of the world irrespective of the territories on which they are located. Besides NCA that was listed in 1979 other world heritage sites in Tanzania include: Ruins of Kilwa Kisiwani and Ruins of Songo Mnara listed in 1982, Serengeti National Park listed in 1981, Selous Game Reserve listed in 1981, Kilimanjaro National Park listed in 1987 and Stone Town of Zanzibar, listed in 2000 (www.whc.unessco.org).

The NCA falls within the vast plains of the Serengeti that comprises of more than 1.5 million ha of savannah. The annual migration to permanent water holes of vast herds of herbivores (wildebeest, gazelles and zebras), followed by their predators, is one of the most impressive natural events in the world (UNESCO World Heritage Centre, 1992). Apart from being a WHS, the NCA is also a Biosphere Reserve under UNESCO's Man and Biosphere Reserve Programme (IUCN 1987). The WHC states that State Parties are duly bound to ensure that development activities do not impact negatively on the resources that have prompted the listing of those sites into WHS.

Data from the Ngorongoro Conservation Area Authority (NCAA) shows an increase of human population from 26,743 in 1988 to 87,851 in 2012, which is about 5.6% increase per annum (NCAA 2013). As a result of the population increase, in April 2009 the government of Tanzania announced the imminent removal of some 30,000 local Maasai from the NCA to a site at Oldonyosambu, some 200 km away from the crater, the reduction of the NCAA staff and facilities from within the NCA to a location outside the NCA and the immediate ban on all forms of cultivation including home gardens

(UNEP/WCMC, 2011). This process was aimed at reducing adverse impacts on NCA while promoting and developing tourism that could be ecologically friendly and environmentally sustainable as described in the Tanzanian National Tourism Policy of 1999. So far the process has been negatively perceived by the local people and somewhat, it could be contributing to the on-going local destruction. So far, human livelihood activities within NCA are increasing, thus threatening the ecosystem at large. Furthermore, there has been a significant increment of tourism facilities and tourist visiting the NCA thus also threatening the area's cultural heritage status. So far since 1969, the number of tourists visiting the NCA has increased from 54,518 in 1969 to 647,733 in 2013 (NCA, 2014). It is also important to note that, the number of vehicles entering this area have increased from 24,164 in 1997 to 129,968 in 2013 (NCA, 2014). The increasing number of tourist has taken place in tandem with the increasing facilities thus expanding the human footprint in the area. There are now four lodges, six camps, four picnic sites and two sites for bush lunch in the crater. Obviously this is good news from revenue perspectives but has far reaching ecological implications. However, both the changing local culture (partly as a result of tourism) and the desire to improve livelihoods and increasing tourism influx into the area are possibly causing significant changes on the ecology of the area thus putting the NCA under serious ecological threats that affect the survival of existing wildlife species in a long run. NCAA has been setting aside portion of the tourism earning to support community development initiatives earmarked by the local people inside the NCA. The NCAA gives about 10% of its total annual revenue to the Pastoral Council (PC), a grass root body that represents the local people in the NCAA. The PC receives the money after submitting a list of community programme they want to implement in the villages inside NCA (Runyoro, 2006). For example, it is reported that since 2004/05 to 2011/12 financial years the NCAA has provided to PC funds for development amounting to about 8.2 billion Tanzanian shillings (NCAA 2013). This is an important source of revenue and has been used to build educational facilities and pastoralists' infrastructure as well as sponsoring students to study outside the NCA. However, whether or not this has stimulated and scaled up local participation in conservation is subject of another research.

The observed increase in human population, tourist development and livelihood diversification in the last two decades have encouraged NCAA to develop land use zoning for settlement, subsistence agriculture and their access to resources. This was assumed could accommodate future population growth at low ecological cost. Whether or not the Maasai were well involved in the process and decisions in the process has remained unclear because these management actions have been reported to limit pastoral mobility thus causing some significant decrease in pastoral production and wildlife conservation (Niboye, 2010). Thus, such complex interaction and contradictions between the conservation and development measures so far ongoing might be contributing to a serious damage of NCA ecosystem as a whole. So far, there have been few attempts to research on the impacts of the increased human activities and their management in the NCA ecosystem including studies by Homewood et al. (2001) and Estes et al. (2006). None of these examples have tried to associate increasing human footprints as possible threat to the NCA status. This study thus attempts to fill that gap by looking at the bigger picture and question on whether this model in NCA is still relevant and stand the test of pressure over time. The knowledge generated from this study will shed more insights into conservation discussions.

Furthermore, based on the World Heritage sites regulations which led to the designation of the NCA to become among its sites, the changing Maasai culture and increasing tourism activity (and population at large) in the area are somewhat putting NCA at a compromising situation especially due to possible ecological and cultural changes so far ongoing.

Initially, the NCA was supposed to support the minimal number of Maasai who largely were typical traditional pastoral communities dependent on small-scale cultivation. With time, the Maasai population has increased and their livelihood options diversified. It is from this background that we see the need to address the impact of pressure caused by the increasing human livelihood diversification and the increasing tourism population and facilities within NCA.

Specifically the study analyzed the ongoing human activities in the NCA, land use/cover change over time and determine the drivers of change and their possible impacts in the long run. Methods and tools such as household questionnaire interviews, key informant interviews, focus group discussions, direct field observations and secondary data reviews as well as the Landsat MSS satellite images of 1990, 2000 and 2013 blocks were applied. A total of 145 people from Enduleni, Oloirobi villages and the NCAA were involved in the study.

METHODOLOGY

The study area

This study was conducted in Ngorongoro Conservation Area (NCA), Tanzania (Figure 1). The NCA has eight wards among which two (namely Ngorongoro and Enduleni) were involved. In each of the wards, one village was purposely selected for the study. The selected wards and villages (Enduleni from Enduleni ward and Oloirobi from Ngorongoro ward) were regarded as good representative of others which have intensive cultivation, livestock keeping and observable changes on land uses and cover.

The NCA is in the North of Tanzania 90 kilometres West of Arusha, adjoining the South-eastern edge of Serengeti National Park between 2°30' to 3°30'S and 34°50' to 35°55'E (UNEP/WCMC

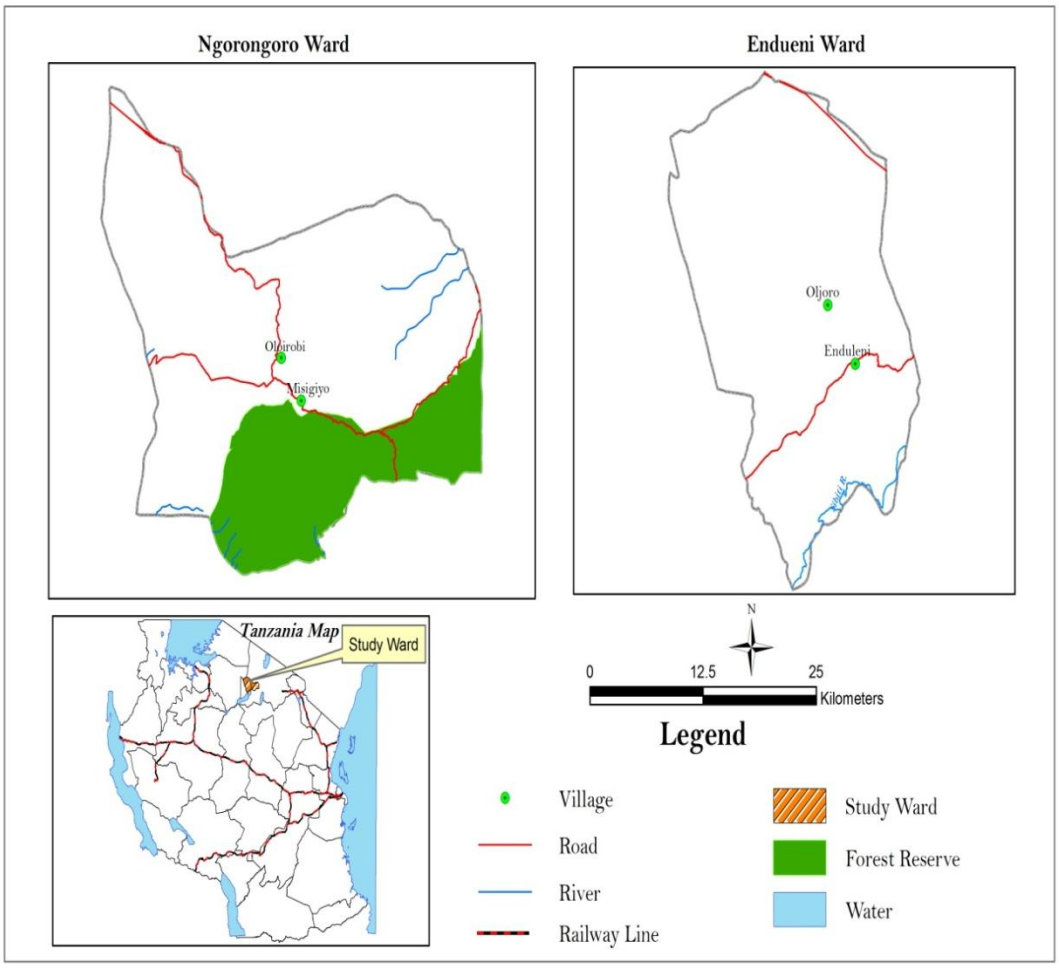

Figure 1. Map indicating the study area.

2011). The NCA also contains the Ngorongoro Crater which is the largest unbroken caldera in the world and one of the best places in Africa to view wildlife descending for pasture, water and mineral salts (*ibid*). The NCA is signified as the home of biodiversity (flora and fauna) where forest cover plays a great role in maintaining the existence of wildlife animals. The extensive grasslands and bush are rich and relatively support large animal populations. The NCA is also in the highlands with moist and misty where temperatures in the semi-arid plains can fall as low as 2°C, and often rise to 35°C (UNEP/WCMC, 2011). The annual precipitation falls between November and April and varies from 500 mm on the arid plains in the West to 1,700 mm on the forested slopes in the East as increasing with altitude (UNEP/WCMC, 2011).

Data collection methods and techniques

A multi-dimensional approach was used in the collection of both qualitative and quantitative data that helped to depict the same magnitude of human activities impact on the ecosystem. Study methods included household questionnaire interviews, focus group discussions, key informant interviews, field observations and remote sensing and GIS data processing techniques. As suggested by Rocco et al. (2003), triangulation of techniques in data collection process helps one to verify or compare results and/or information obtained from one technique to the other thus increasing the reliability of the findings. Information and results in this study were verified and validated through cross cheeking data from all sources to find out if leads to similar conclusions. A random sampling technique was used to select the members of the households that participated in the interviews. Sampling of households for interviews was randomly chosen using a list of heads of households in each village from village records. From that list, names were picked randomly and without any preference or order to get representative sample of people that were involved in the interviews from both villages. Purposive sampling techniques were used to select people that participated in focused group discussions and key informant groups, involving specific categories of individuals. The household interviews were conducted using structured questionnaires. The interviews were conducted such that the respondents were asked questions and provided answers verbally. The method was used to capture general information on the socio-economic conditions of particular household demographic characteristics of the household members and the people's perceptions and implications of human activities on the NCA's ecosystem. This quantitative data were gathered from 117 household heads. Beside the household interviews, focused group discussions were also held. This was an attempt to delve deep into issues and get information from few

people to augment other sources of information. The focused group discussion was also conducted particularly to gain knowledge about the NCA ecosystem change and possible attributes thereof. The number of individuals within each focused group discussions varied between five and seven with men and women forming separate groups also considering age differences. A total of four group discussions were conducted in each village, involving a total of 24 discussants. Of the total 24 group discussants involved in the process, 18 were men and six were females. All individuals involved in the focused group discussions did not take part in the household interviews. Key informant interview were further conducted to get in-depth details about the issues in NCA especially those, which could not be easily explained by a layman or by those who were not so much knowledgeable about the area. A semi-structured checklist of questions with both closed and open questions was used to ensure collection of uniform information from all informants in the study area. This method involved people with firsthand information and experts with particular knowledge and understanding on the NCA ecosystem change and gave recommendations for solutions. A total of four key informants were interviewed during this process. The key informant representatives included one individual from NCAA and three village leaders. Among other issues discussed during key informant interviews were the historical background of human activities and trends in the NCA and their possible implications on the environment and natural resources at large.

The interviewed respondents in focus group discussions and key informants were sufficient because in collection of qualitative data the samples are not meant to represent large populations. Rather, small purposeful samples of articulate respondents with an in-depth and highly contextualised understanding of specific phenomena provide important information that serves the purpose of a study (Given, 2008). Field observations were carried in order to ascertain some of the issues by seeing physically. Field observation involved collecting impressions of the NCA by looking and listening in a systematic and purposeful way to learn about a phenomenon of interest (Given 2008). During field observations, pictures of various areas and scenario that provided tangible evidence of the research site as well as helping to verify the information from the interviewees and other data sources were taken.

Assessment of ecological/land cover change in NCA was obtained through analysing the satellite images using remote sensing and GIS techniques. The maps of 1990, 2000 and 2013 blocks of the studied villages were used for this purpose. Wildlife, tourists' vehicles, human, wildlife and livestock population data were obtained from NCAA census data for the years 1987-2012.

Data analysis

The quantitative data from questionnaire interviews were coded processed and edited using SPSS version 20. The data were computed using the Chi-square statistical test (χ^2-test) to determine any significant variation not exceeding the 5% significant level (p-value) that would work more than expected. Frequency charts and percentages of variables were performed and summarized to determine ecosystem changes with human activities using Microsoft Office Excel, 2007. The qualitative data were derived from direct observation, FGDs and key informants interviews and were analysed using theme-content analysis strategy. Thematic analysis involves reduction of data and analysis strategy by which qualitative data are segmented, categorised, summarised, and reconstructed in a way that captures the important concepts within the data set (Given, 2008). Remote sensing involved conducting unsupervised cluster analysis on vegetation change using ERAD IMAGINE v.9 software. Classified images were analysed using ArcGIS 10 software to produce comparable land cover change statistics. The vegetation change and dynamics were analysed quantitatively to determine the extent of their variation over a study period.

RESULTS AND DISCUSSION

Changing local livelihood activities and population trends

Poor rural communities engage in various livelihood activities to generate income mainly for subsistence needs (Madulu, 2001). The NCA allows settlement, tourism, livestock herding and small-scale cultivation. The increasing drought and human exposure has somewhat increased the possibilities of Maasai communities in Tanzania to access and practice other life forms other than pastoralism. The various discussions with interviewed respondents and group discussants indicated that Maasai culture is changing at quite a high rate. In the past, Maasai were strict pastoralists as they only depended on their livestock for all livelihood needs. With time, the Maasai have been engaging in other livelihood activities including livestock keeping, crop production, petty trade, casual labour and business on forest products (Figure 2).

Although the analysis indicated that the livelihoods of a large (62%) number of the interviewed respondents was still dependent on livestock keeping, quite many (16%) of them were undertaking small to large scale crop production and other livelihoods activities. Generally, there was no significant difference on the activities undertaken in both studied villages but the number of livestock kept by a single household was quite varied (χ^2=221.986; df=186; P = 0.042). The focus group discussions also verified the livelihood activities that were been undertaken at the NCA. According to them it appears that the increasing livelihood diversification had been contributed by the restriction in the utilization of rangelands thus resulting in disrupting the traditional pastoral grazing system of local Maasai leading to resource-use conflicts with the NCAA. Furthermore, according to some group discussants it appeared that the limited grazing area around the villages has reduced the ability of the range lands to sustain Maasai livestock keeping practices, which eventually led to some of them search for other sources of income such crop production and business in forest produce from the areas. The reported increasing crop production from the various interviews is also evident from the analyses of land use/cover change maps (Figures 3 to 8). From the analysis it appears that about 46% of the studied villages' lands have been converted to agricultural land (Figure 2). This is relatively a higher rate compared to that of Homewood et al. (2001) who reported that 3% of five km radius area around each of their study site (that is, Serengeti Masai Mara Ecosystem (SME) that includes NCA) had been converted to agriculture during 1985-1995. However, the almost 46% converted land for agriculture in the study villages is on the high side and somewhat puts the NCA status under threats.

The local people in the study areas like any others adjacent to protected areas indicated a high dependence

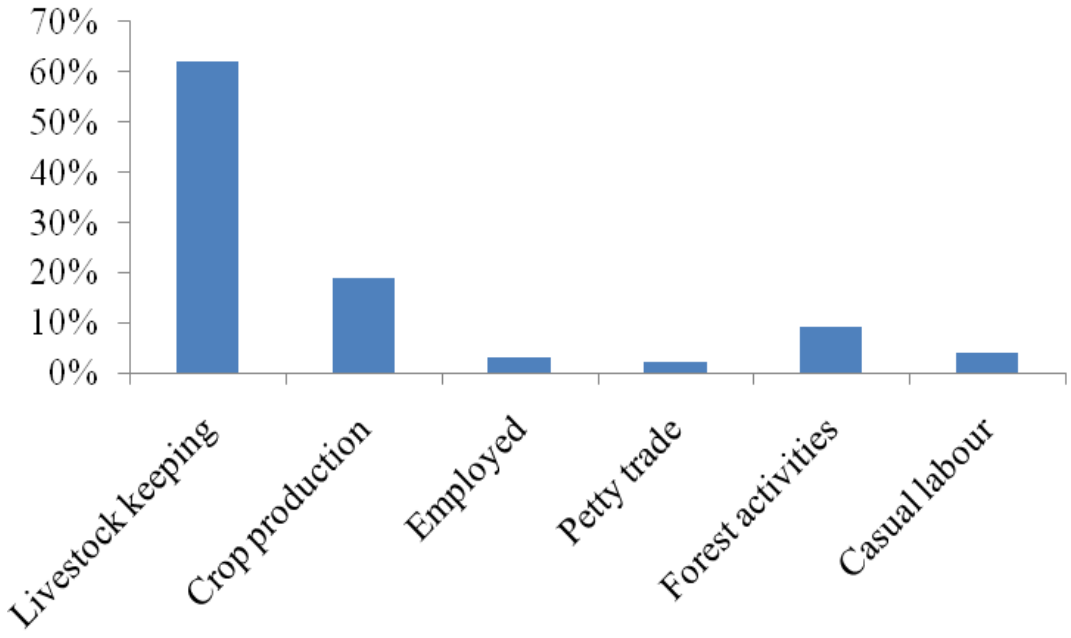

Figure 2. Reported livelihood activities so far undertaken by the interviewed NCA respondents.

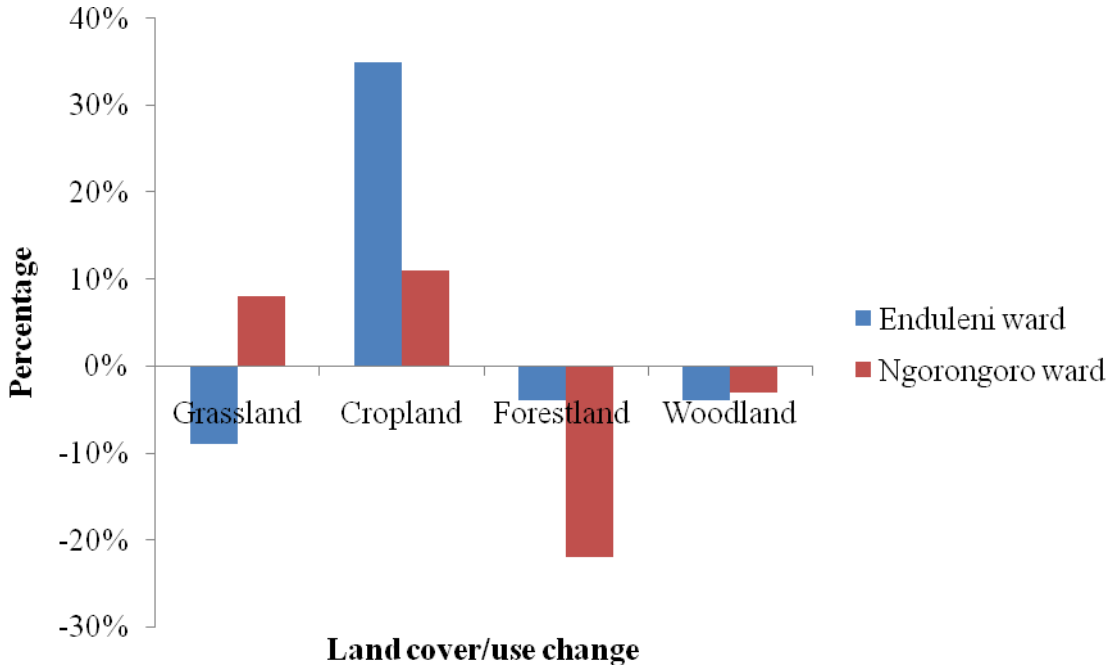

Figure 3. Land use/cover changes in the studied wards.

on natural resources for their livelihoods. For example, during the various interviews, 99% of the respondents acknowledged obtaining natural products such as fuel wood, building poles, honey, timber, medicinal plants, wild vegetables and fruits for their day-to-day life from nearby forests. The main reason provided following this high dependence on forest products was because of their cheap availability. Also it was observed during field visit that women were selling together with fuel wood, some wild vegetables such as *Solanum scrabum* and *Solanum villosum* species (Mnafu pori in Swahili). According to some key informants, this phenomenon was uncommon

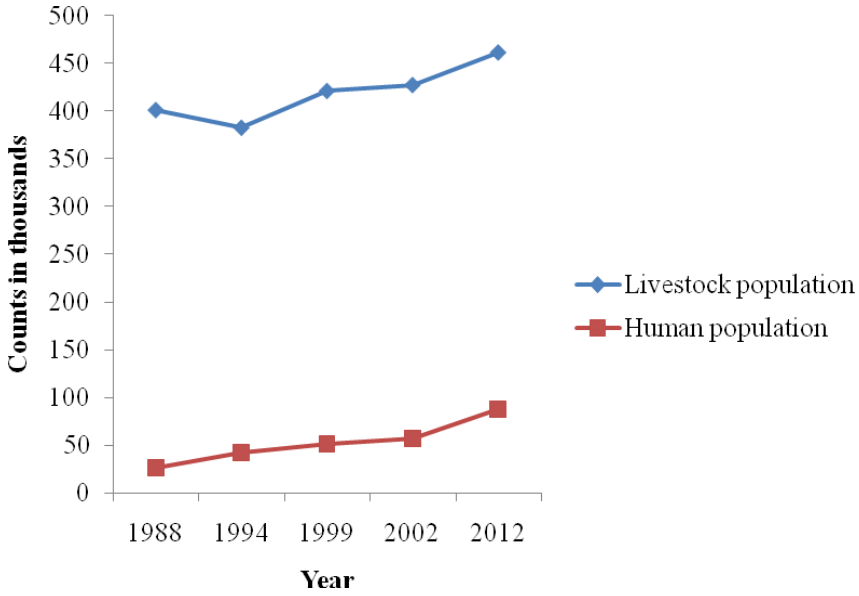

Figure 4. Trends of human and livestock population in NCA.

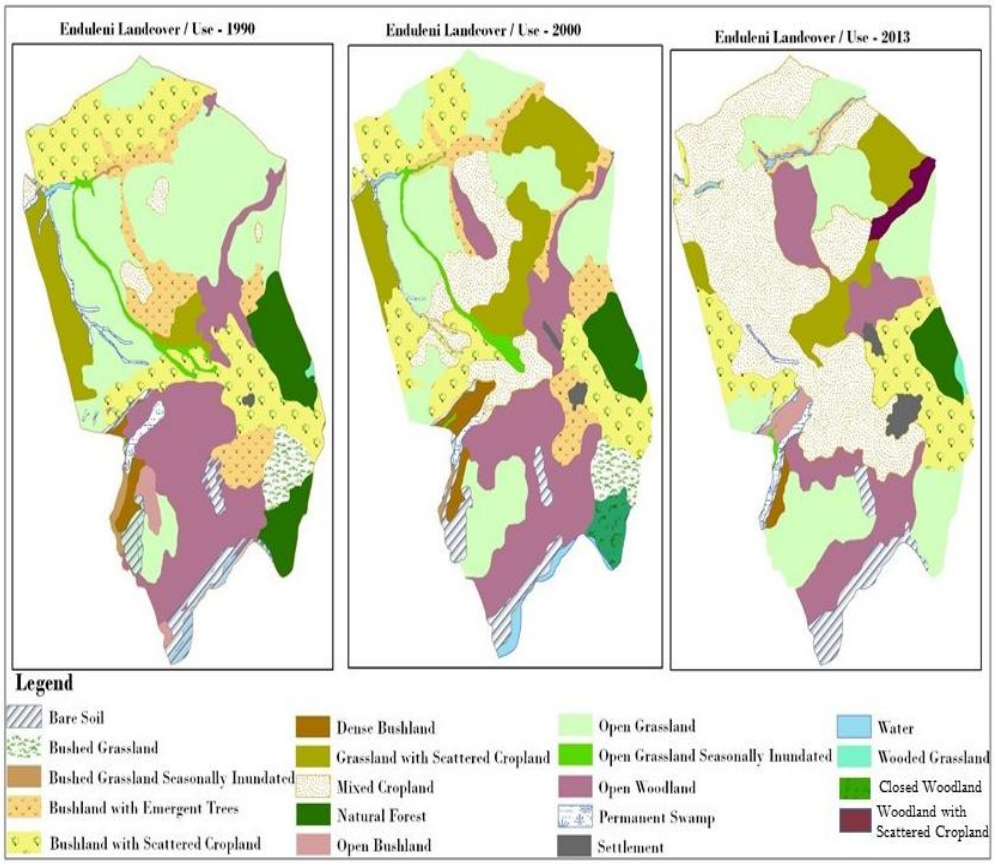

Figure 5. Land cover/use change in Enduleni Ward.

among local Maasai in the past years. Casual labour is another activity which was reported by some 4%

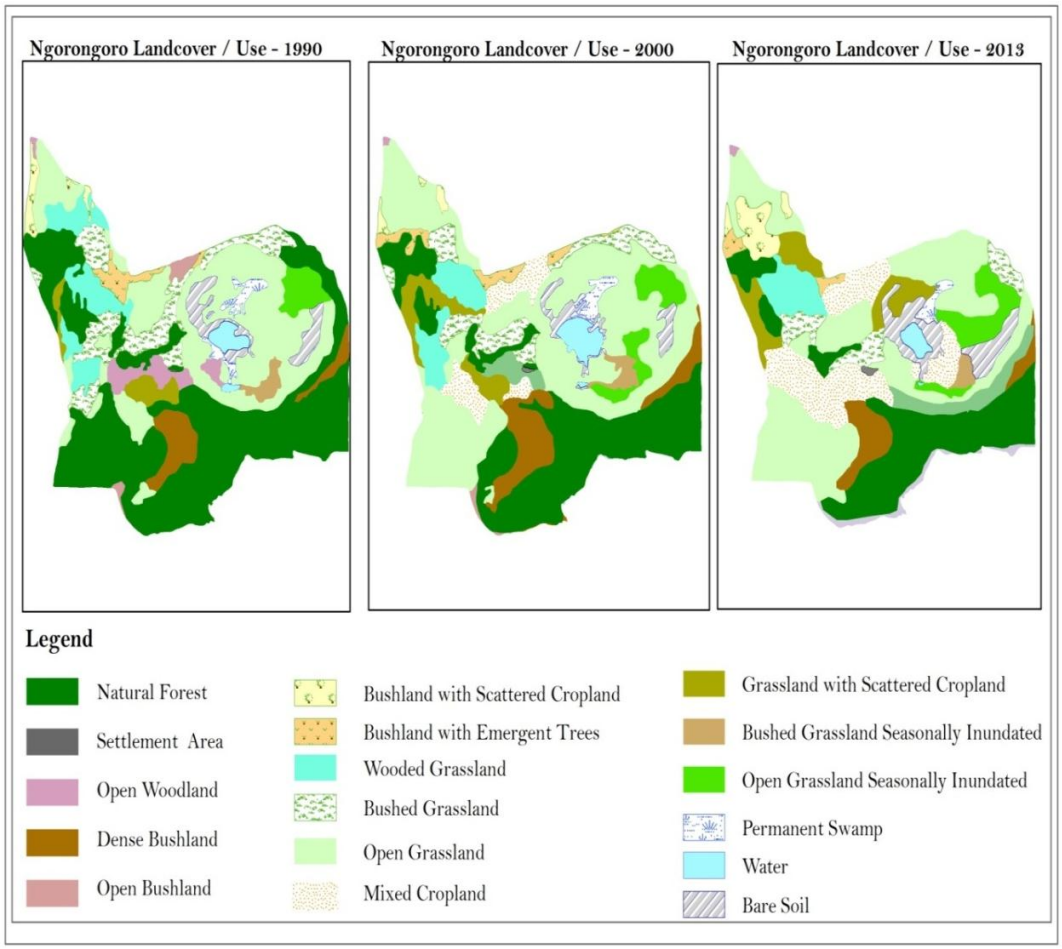

Figure 6. Land cover/use change in Ngorongoro Ward.

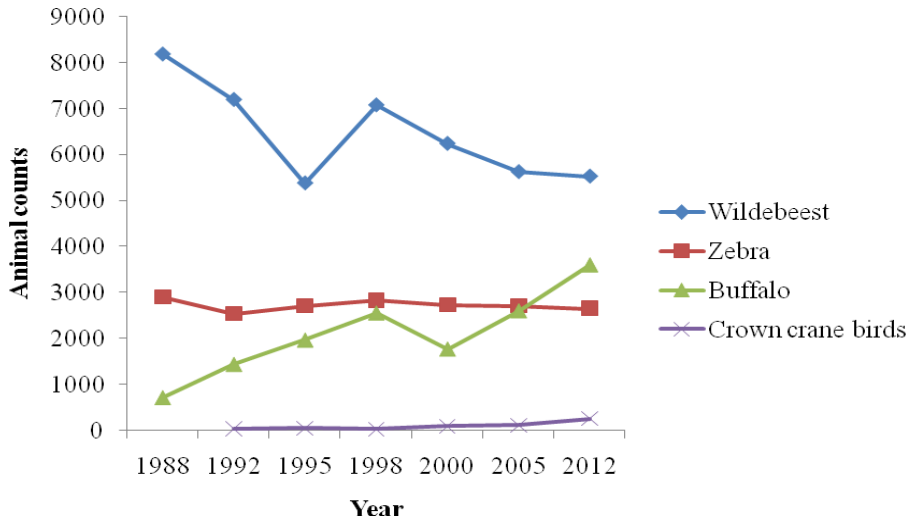

Figure 7. Trends of some wildlife within NCA.

respondents during interview. This activity involves the collection of cow dung and herding livestock to grazing

Figure 8. Some of the encountered exotic/invasive species within the NCA.

area. None of the interviewed respondents reported casual labour as their important or main source of income. This is because casual labour was a temporary occupation in the area and was quite un-common to a Maasai to be employed in the past.

The NCAA population data indicate that, the human population has increased from 26,743 in 1988 to 87,851 in 2013 while livestock population increased from 401,145 in 1988 to 461,586 in 2013 (Figure 4). This increase might be contributing to the high competition on limited grazing land within NCA, Mangewa et al. (2009) reported similar results with reference to the size of the Upper Kiteto-Selela wildlife corridor that was reduced as a result of increased human activities in the area. The analysis of the trends in Figure 3 might also indicate that, despite the restrictive policies in NCA, the humans are still invading the areas thus causing more pressure on the resources. The group discussions indicated that, some Maasai were coming from the outside of NCA including some from Kenya especially during drought or dry seasons. When asked of the reasons of migrations into the area, the migrant Maasai said they came into the area largely for grazing land and other benefits that would be accessed by being a resident into the NCA. Noteworthy, the various discussions indicate that, there is increasing number of Maasai immigrants (16%) coming from outside the NCA.

It has also been reported in the past that the Integrated Conservation with Development Programme (ICDP) development activities may also induce migration into the project area (Wells et al., 1992). It could be noted that the migrant Maasai came into the area largely for grazing land and other benefits that would be accessed by being a resident into the NCA. Similar suggestion had been put forward by Newmark and Hough (2000) who said that many ICDPs may uninten-tionally promote dependency rather than reciprocity and have often treated local communities as recipients of aid rather than partners in development. This scenario has been observed among the local Maasai who largely feel they should receive more help from the NCAA and the visiting tourists. Thus, given the current situation at NCA, there is a need for NCAA and the national at large to explore the effects of factors like markets, land tenure and increasing population

both within and outside the NCA area.

Increasing tourism activities in the NCA and their impacts to the status of NCA

As already mentioned, the number of international and local visitors arriving at NCA has increased from 64,518 in 1969 to 647,733 in 2013 (NCAA, 2014). These numbers show how attractive NCA has become to tourists and this has developed in tandem with the development of infrastructure inside and outside the NCA. It is not the first time that the increasing tourism influx and developments ongoing in NCA has been a worry by scientists. Estes et al. (2006) for example had associated growing tourism in NCA with the reduced water availability for the crater habitats and ecosystem at large. They said that while the rains available were at normal average, the average water inflow to the crater was low both in quantity and quality because of increased water diverted for human use. At that time (in 2006) Maasai population referred to was over 50,000 and now we are talking about hundreds of thousands of people and a significant increment of developments in the area. There are currently four main lodges around the crater rim and several tented camps inside the NCA. In addition, there are several hotels outside the NCA and in particular at Karatu township that accommodate guests whose main interest is to visit the NCA. Such development outside the NCA has both ecological and environmental implications inside the Ngorongoro but there are hardly measures that seek to harmonize development from within and outside the NCA. The increasing number of tourist in the NCA is also reflected in the much-needed revenue both for the NCAA and the country at large. For example, between 2005 and 2013, NCA received over Tanzanian Shillings 16.4 billion or equivalent to US$ 9.6 billion (NCAA 2014). This money has been sued to support numerous development activities inside the NCA as well as communities that lie inside the conservation area and also paying corporate taxes to the government. Alongside increasing number of tourist and visitors, there has also been an increase of vehicles inside the area that has had implications on the environment and the overall quality of the facility. For example, the number of vehicles entering and or passing through the NCA has increased from 24,164 in 1997 to about 129,968 in 2013 (NCA 2014). The road works and all other developments in the area despite the fact that they lead to increased revenues to the government (as indicated) and the responsible management, we have not considered their long-term effects to the NCA ecosystem and tourism at large.

According to Estes, Atwood and Estes (2006), the road works have repeatedly made changes to the crater's ecology, most notably the blockage and diversion of the natural hydrology of the area. The human and car congestion at the crater floor causes soil compaction and other land degradation associated with human presence. This and many other developments will have a lot to do with the ecology of NCA, thus a big question is: will all these changes allow NCA remain a WHS in the long run?

Land cover and wildlife population change over time

The net vegetation cover changes in the study area were determined in terms of absolute areas and percentages from 1990 to 2013 (Figures 5 and 6). The results indicate a shift between grassland, bush, woodland and cropland. From the maps it is noted that forested areas have been cleared for settlement, search for thatching materials and energy sources while open grassland and bush land were converted to cropland. The analysis of remote sensing imagery indicates a decrease in forestland, grasslands, woodlands and an increase in croplands in the study wards. This change appears high than what was reported by Homewood et al. (2001), who found no significant land use changes within Tanzanian SME as compared to the Kenyan side.

During that time, there were more human activities within Kenya where the market accessibility and mechanised agriculture were the assumed drivers of change. However, the results from this study are suggesting that the increasing human population (so far at 5.6% annual growth rate) might have contributed to the observed increase in settlement areas, forest clearances and in all areas with invasive or exotic species invasive/exotic as one word species in the area. However, during various interviews, it was revealed that some areas where human activities were not conducted were still undergoing changes in its vegetation cover. This might indicate that there are other factors causing the observed changes than those caused by human thus indicating the need for detailed long term research in the area. During the study by Homewood et al. 2001, the land-use/cover changes observed (especially for the SME-Tanzania) were more attributed to climate change than to human induced factors. Niboye (2010) also reported that there are natural vegetation succession processes taking place in East African rangelands and other similar savannah ecosystems from grasslands towards woody vegetation. Despite that the changes might be caused by a wide range of factors of ecological succession but within savannah ecosystems both overgrazing and under grazing may result into regeneration of woody vegetation (Niboye, 2010).

The maps further indicate some differences in open grassland coverage within the studied wards. While Ngorongoro ward indicates an increase on the open grassland coverage, the status in Enduleni is decreasing. Furthermore, the study indicated that in both wards, the forestland was decreasing although at different levels while cropland had increased in both cases. Niboye (2010) who got almost similar trends associated the their

vegetation changes to human driven factors such as high livestock grazing pressure, land clearing for cultivation and settlement development. The decreasing woodland, grassland, bush land and forest in our case is therefore associated with increased human activities especially commercial agriculture and intensive livestock keeping so far ongoing in the area. Although the NCAA indicated that about 30,000 people had been shifted from the area, discussions in the FGDs indicated that many people were still coming to NCA without being captured by the responsible authorities. Among the interviewed respondents, Enduleni village had high number (13 respondents) of immigrants compared to Oloirobi village who were six. The FGDs insisted that there was increasing number of immigrants in the area. The reported increment in the number of immigrants might be a reason to the observed increase in cropland and the decreasing grassland in the study villages. However, detail research is required to monitor the situation in general.

Further analysis of existing long-term data on wildlife from NCAA shows a varied migration patterns in the ecosystem in both wet and dry seasons. The study explored both migratory and non-migratory wildlife animals such as wildebeest, zebra, buffalo and crown crane birds (Figure 7). The data shows a general decrease of wildebeest and zebra populations during the 1988-2012 periods. The wildebeests indicate a decreasing from 8,179 to 5,526 while zebras decreased from 2,900 to 2,655. Specifically, the decrease in wildebeest is quite high (32%) compared to that of zebras which is about 8%. This trend is so much striking especially due to the fact that a very intensive study by Homewood et al. (2001) found only minor fluctuations of wildebeest in the SME Tanzania as compared to the 75% decrease on the SME-Kenya indicating that the existing conservation policies on the Tanzanian side were quite practical during old days than now. The decreased wildlife population in the Kenyan side were associated with the increased commercialised agriculture. Similar situations can be taking place in the NCA at the moment. Local people inside the NCA are increasingly advancing in their ways of living and thinking. Many Maasai are now found in the urban areas in Tanzania thus making them exposed to various lifestyles and technologies. Once they earn money they do go back to their villages. On the other hand, their population in NCA is increasing.

Despite the observed decrease rate, wildebeest and zebra population have remained the most dominant species in NCA. The decrease in some of the species in the NCA might be attributed to increased human settlements, crop cultivation, livestock keeping and other human activities, thus indicating a need for improved measures for conservation around this area. Various focus discussions indicated that, despite the existing bylaws and procedures to manage the area local people within NCA are constantly moving in search of pasture. Logan and Moseley (2002) argued that a shift to marginal lands for subsistence agriculture in order to survive might have implications on conservation efforts.

Contrary to the decreasing wildebeest and zebra populations, an analysis of buffaloes and crown crane birds population data showed significant increase (χ^2=41.432; df=28; *P*=0.02 and χ^2=25.143; df=15; *P*=0.008 respectively) between 1988 and 2012. Specifically, the increase in buffaloes was twice (24%) that of crown crane population which was about 12%. Our results on the four selected species are in line with a study by Estes, Atwood and Estes (2006) who reported that, during the 1964 to 2005 wildebeest counts had declined and counts of zebra were approximately stable but the numbers of buffalo dramatically increased. The reason for increase can be associated to the shift of grassland composition and condition from medium and short grassland, which were predominant to long grasslands that are more favourable to buffaloes. The decreasing wildebeest and zebra populations can thus be associated to pasture availability, but also to human impacts.

During the field visits and from the focus group discussions it was observed that apart from increasing land use/cover changes already on-going in the NCA, the area is as well affected by a number of invasive species. During field visits in different areas, about 21 exotic species were identified growing in disturbed areas in studied villages. Among these include *Datura stramonium* L., *Argemone mexicana* L., *Tagetes minuta* L. and *Eleusine jaegeria* (Figure 8). In this study, we observed less exotic species compared to that of Henderson (2002), which identified about 39 of invasive species. This slight lower number could be contributed by the fact that only a small area of the two surveyed villages was covered to establish possible exotic/invasive species within NCA. It was reported that these species are being accidentally introduced through people, winds, animals and vehicles passing entering the NCA. Other possible means of exotic species introductions so far reported include the importation of construction materials from Karatu and elsewhere especially because most of the species were around construction sites (Foxcroft et al., 2006). Some intentional introductions have been observed around the lodges, staff offices and other residential houses. A study by Elisante et al. (2013) in NCA noted that about 69.6% of the Lerai area used for grazing has been invaded by *D. stramonium* species despite its known effects when ingested by animals.

Local people's perception towards conservation in NCA

In the previous section, it has been observed that increased land use/cover change has resulted in vegetation changes that could be in favour of some wildlife species and excluding others. It has also been observed

that, increasing tourism might have contributed to the increasing number of exotic species in the NCA. The long term impacts of such changes have not yet been considered in the various conservation initiatives so far ongoing in the NCA. During various interviews and group discussions the respondents were of varied views on the availability of land resources such as forage, fuel wood, thatching materials and wild vegetables. Almost half of respondents had the view that availability of natural resources were decreasing while others (39%) thought resources were increasing. Only a few (12%) of the respondents did not notice any changing trends (most probably the immigrants in the area).

To cope with the ongoing changes in the NCA, the NCAA reported that they had instituted various developmental projects, programs and policies. The NCAA said that, the measures taken were aiming at protecting further destruction of the environment and improving socio-economic conditions of the people in NCA. Although such programs and projects were designed to stimulate changes in the environment and socio-economic conditions of the people, most of them were reported to have failed due to poor participation of local Maasai. For example, the NCAA has instituted a program of providing mineral salts to pastoralists' livestock aiming at reducing congestion and soil erosion in the crater. The program was not in good progress due to disagreement among local Maasai that the quality of salt provided was poor in mineral compositions compared to natural salts from the crater.

However, there is no scientific proof on mineral salt composition provided as true or a myth from local Maasai. Therefore, in order for management interventions to be successful over the long-term there should be a strategic plan of awareness creation and sustainable use of these resources (Foxcroft et al., 2006).

Furthermore, the management actions taken by NCAA have been perceived as limiting the Maasai access and enjoyment of resources. Such negative views towards NCAA were noted during focus group discussions and key informant interviews undertaken in the study area. For example, in one of the groups a member said that "*For every step of development a local Maasai wants to make we have to ask permission from NCAA despite the fact that we do have village title deed*". He added "*Moreover, there is no free grazing in the reserve without special permit from NCAA"*. These statements indicate that Maasai felt denied of their user rights of the NCA and to them permit process was unfair and limiting. Worthy-noting, during the legislation council session in 1958 it was agreed that any conservation initiative in NCA would not exclude the local and would be developed following the interests of the Maasai themselves. This therefore indicates the need for the NCAA to sit and discuss issues with the local Maasai thus to avoid the ongoing misunderstanding that might be contributing to the NCA destruction.

Thus, from various discussions, interviews and other documentary review, it was observed that some promises had not fully kept and somehow most conservation initiatives are being implemented without clear and open participation of the local Maasai. This might have therefore caused the observed failure. The respondents said that all NCA management plans, projects and programs are centrally managed thus contributing to current negative perceptions by local Maasai. Other studies elsewhere have indicated that conservation planning in Tanzania has remained a top-down endeavour where claims of local communities and their knowledge remain relegated to the margins (Goldman, 2003). Similar observations were found in Costa Rica where communities benefit little from the conservation projects and have not been encouraged to participate in the original designation of the protected area (Campbell and Vainio-Mattila, 2003). However, Ololosokwan village in Tanzania appears to be an example of community-based ecotourism where villagers generate income from tourism activities. The village land of about 80% is set aside as livestock pasture while the other is left for wildlife, tourism activities and hunting safaris (Nelson, 2009).

The ecological changes in NCA and the world heritage criteria

The NCA is experiencing increased tourism development, increased human and livestock populations and associated anthropogenic consequences including deterioration of environmental and cultural conditions that were critical for the inclusion of the NCA in the prestigious world heritage sites. Therefore, looking at the current situation in the NCA, it is obvious that the area is slowly losing both its pristine cultural resources and natural conditions that have distinguished it as a world heritage site. The increasing tourism development in the areas and other human activities as discussed above, together with the inability to take decisive steps to reverse the trends are spearheading this loss casting doubts as to whether the existing NCA model is valid or need to be re-examined. Indeed, according to the WHC, any development in a world heritage site must be subjected to environmental assessments; development activities that involve individuals are not addressed in any organised ways. The NCAA has a General Management Plan but to what extent it has been respected and enforced is yet to be known given the increasing changes taking place in the area.

Conclusion

Neither humans nor their cultures are static. This is also true for the Maasai community in the NCA. The increasing drought and human exposure has somewhat increased the possibilities of Maasai communities in

Tanzania to access and practice other life forms than pastoralism. Given the ongoing changes so far observed, the area appears highly vulnerable and it is facing significant changes that are affecting the natural and cultural aspects that are the foundations of the area being recognized as a WHS. Improved technology and exposure are related to the increased development and changes in land use types. The GIS and remote sensing data indicate an increased cropland area of about 46%, while the grasslands and forested lands had indicated a decreasing trend. The changes observed on the land cover and uses are associated with current human activities ongoing in the area. So far there has been a decreasing trend in wildebeests (32%) and zebra (8%) populations while the populations of buffaloes and crown crane birds showed an increasing trend. Both the natural and cultural changes so far observed in the areas threaten the future status of the NCA. On the other hand, the increasing tourism population is causing negative impacts on the NCA ecosystem, although this trend and its implications are yet to be quantified and are rarely being considered as a threat compared to the local poor Maasai. A majority of the interviewed respondents acknowledged the decreasing pastures and other natural resource availability in the NCA. This decrease has caused an increase in time spent to obtain fuel, wild vegetables and those ching materials while women have suffered significantly as a result of such changes. Despite the implementation of different programs by NCAA to bring about household income relief, many local stakeholders are still complaining about the lack of benefits accrued from conservation of this area. We think that there is still room for changes but this will require bold policy decisions and consensus building with the local people who depend on the available resources in the NCA for their livelihoods. Debates on whether the NCA model, which is multiple land use is relevant or it needs to be changed or need to be improved must be taken up further by involving all stakeholders (such as: researchers, policy makers and conservation organizations), whilst taking into account local, national and international ecological, social and economic significance of the NCA.

Conflict of interest

Authors did not declare any conflict of interest.

ACKNOWLEDGEMENTS

We would like to thank the Institute of Resource Assessment for all the support during data collection process for this study. We also thank all the people who participated in providing the necessary information for this research including Mr. Patrice, Manager for Ecology Management in Ngorongoro Conservation Area (NCA) and all the villagers in the study areas, for providing full support and necessary information as required for this study. Last but not least are the anonymous reviewers who gave us constructive comments to improve this article.

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